THE GEOLOGY

OF

NEW HAMPSHIRE.

A REPORT COMPRISING THE RESULTS OF EXPLORATIONS ORDERED BY THE LEGISLATURE.

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PART III. SURFACE GEOLOGY.
PART IV. MINERALOGY AND LITHOLOGY.
PART V. ECONOMIC GEOLOGY.

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SURFACE GEOLOGY.

CHAPTER I.

MODIFIED DRIFT IN NEW HAMPSHIRE.

BY WARREN UPHAM.

THE portion of geological history of which we have our principal record in the *Modified Drift*, begins with the departure of the great northern ice-sheet, and extends from that time to the present. The deposits included under this title are the water-worn and stratified gravel, sand, and clay or silt, which occur abundantly in almost every valley in the state. These river-lands comprise the intervals, which are annually overflowed at the high water of spring, and successive terraces which rise in steps upon the side of the valley, the highest often forming extensive plains.

The origin and distribution of these materials present many interesting questions. When the term was first employed, it was the prevailing opinion that modified drift was gradually formed from the unmodified glacial drift by the ordinary action of rain and streams; and similar materials in small amount have been added by these causes, which are still at work. The boulder that is separated from the ledge by frost, and carried forward by the heaviest floods of a mountain torrent, is on its way to form a part successively of the coarse rounded gravel, sand, and silt, over which the river flows on its journey to the sea. It is evident, however, that the high terraces and wide plains bordering our rivers were formed by much greater floods than those of the present time, laden with vast quantities of alluvium. Both the materials and the water for sweeping them into the valleys appear to have been supplied by the melting of an immense sheet of ice. These deposits thus had the same origin with the glacial *drift;* but they have been *modified*, being separated from the coarser portions, and further pulverized or rounded, and assorted in layers, by water.

The Glacial Period.

The indications of a glacial period abound in all northern countries whose geology has been explored; and in New Hampshire they are probably as well shown as in any part of the world. Underlying the modified drift we often find masses of earth and rocks mingled confusedly together, without stratification or any appearance of having been deposited in water. These are the glacial drift or *till.* Unlike the modified drift, till is distributed with no reference to lines of drainage, and frequently covers the slopes or lies at the summits of our highest hills and mountains. The boulders which it contains, or which lie upon its surface, are of all sizes up to ten feet, or rarely even twenty or thirty feet, in diameter; and in this state they have nearly all been transported southward from their native ledges. Where an outcrop of rock is so peculiar that its boulders cannot be confounded with those from other ledges, we may trace them southward or south-eastward, but not in other directions. They are abundant near their source, and diminish in numbers and size as we advance. The till of New Hampshire contains boulders which are thus known to have travelled a hundred miles. Wherever till occurs, it is also found that the ledges have been commonly worn to a rounded form; and, if the rock is sufficiently durable, it is covered with long parallel scratches or *striæ*, which have the same direction with the dispersal of rocks in the till. The same areas are also characterized by extensive deposits of modified drift.

To explain these related facts was a most difficult task, which remained after nearly all other great questions in geology had been settled. The theory which has now been received by most who have studied this subject was first brought out prominently by Agassiz in 1840, and was based upon his studies of the glaciers in the Alps. There fields and rivers of ice several hundred feet in depth are found descending from the regions of perpetual snow, their rate of motion being from one to five hundred feet, or even more in their steepest portions, in a year. Many angular blocks and fragments which fall from the bordering cliffs are carried along on the surface of the ice, or are contained in its mass with others torn from the rocks over which it moves, and under its vast weight these act as graving tools to round and striate the ledges beneath. The similar striation of all northern countries, and the formation of the till, are probably due to a similar cause, namely, a moving ice-sheet which overspread the continents from the north.

This continental glacier had accumulated sufficiently deep to cover every mountain summit in New Hampshire. That it overtopped Mount Washington is fully proved by recent discoveries of the state geologist.* Its thickness farther to the north was so much greater than in this latitude that its immense weight caused the ice to flow slowly outward. The direction of its current in New England was between south and south-east. Its terminal front in the United States coincided nearly with the course of the Missouri and Ohio rivers, passing into the ocean south of Long Island. Its greater extent east of the Missouri resulted from the increased snow-fall of this side of the continent. The termination of this ice-sheet in the Atlantic, south-east of New England, was probably like the great ice-wall bordering the Antarctic continent, along which Sir J. C. Ross sailed four hundred and fifty miles, finding only one point low enough to allow the upper surface of the ice to be seen from the masthead. Here it was a smooth plain of snowy whiteness, extending as far as the eye could see. The Humboldt glacier, in Greenland, discovered by Dr. Kane, is sixty miles wide where it enters the sea, above which it rises in cliffs three hundred feet high. All icebergs have their origin from glaciers which thus extend into the ocean, being broken off, because of their lower specific gravity, by the uplifting power of the water.

Cause of the Arctic Climate. The conditions which brought on the severe climate of this epoch have been the subject of much speculation and discussion. A theory which, with much probability, refers the ice-sheet to an astronomical cause, and claims to determine the date and duration of the glacial period, was proposed by James Croll in 1864, and has been advocated by James Geikie in his recent work on the *Great Ice Age.* The earth's path about the sun is not exactly a circle, but is a

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* See Chapter II of this volume.

nearly circular ellipse, so that at one point of its orbit it is somewhat farther from the sun than at the opposite point. This eccentricity of the earth's orbit is not constant, but increases and diminishes through long periods. During the past fifty thousand years it has been comparatively small, and will continue so for the same time to come. The last period of great eccentricity began about 240,000 years ago, and lasted 160,000 years. During this time the winters which occurred farthest from the sun, or in aphelion, would be longer and colder than now. The summer's heat would be increased in the same proportion, but it is argued that its length would not suffice to melt the annual accumulation of snow. This would gain slowly in depth, and become solidified, till a large part of this hemisphere would be enveloped in ice. At the same time the opposite side of the globe would have a short, mild winter, and a long, cool summer. Owing to other astronomical causes, known as the precession of the equinoxes and motion of the line of apsides, these different climates would not be permanent for each hemisphere during the whole of this long period, but they would be several times changed, prevailing by turns on each side of the equator. In 21,000 years the hemisphere which at first had its winter at aphelion would have passed through a cycle, in which its place in winter would have traversed the entire orbit,—falling after half this time at perihelion, and finally arriving at its first position. This theory accordingly supposes that an ice-sheet was produced several times about each pole, alternating with long intervals of genial temperature, in which it disappeared. Stratified deposits of sand or clay containing organic remains have been found in Europe, underlaid and overlaid by till, proving the existence of mild inter-glacial epochs. Equally certain proofs of these are rarely found in America. Thick beds of modified drift in the midst of till occur in New Hampshire, but they do not appear to prove a disappearance and return of the ice-sheet.

If glacial epochs are produced by a great eccentricity of the earth's orbit, we should also expect indications of ice-action in the older rocks, and probably many coarse conglomerates have been formed in this way. The remote date to which this theory assigns the last glacial period is not improbable, as the amount of erosion effected by Niagara river since the ice age, and other facts bearing on this question, indicate a similar lapse of time. This, however, seems but as yesterday when it is compared with the distant Eozoic and Paleozoic past, in which the rocky strata of New Hampshire were deposited beneath the sea and upheaved in crumpled folds to form our hills and mountains.

The theory of Mr. Croll,* which supposes that during the long period of great eccentricity glacial and warm inter-glacial epochs succeeded each other in cycles of 21,000 years, does not seem to be sustained so fully as we should expect by evidence of such warm intervals, which he thinks even in arctic latitudes would be nearly free from ice and snow. A consideration of what we have to explain by the agency of ice, and of the mode in which these results are likely to have been produced, seems to point to a very long, continuous period of glacial action, with times of retreat and advance, but not apparently of complete departure and return of a continental ice-sheet. By other writers the glacial climate is believed to have been principally caused by a different distribution and elevation of the land, attended with changes in the direction of oceanic currents. Even if a supposed combination of such conditions could be shown to be adequate to produce the ice-sheet, it seems more reasonable to attribute its origin to an astronomical cause, which we know to have existed, with a tendency to bring about these results. As very intense cold is not required for the accumulation and preservation of snow and ice, may not the continually cool climate, when winter occurred in perihelion during the period of great eccentricity, have kept the ice-sheet which was already formed from being melted? The rare testimony of any retreat and subsequent advance of the ice during the glacial period in America, with the vast results which were accomplished in this time, favor this view.

The motion of the ice, being produced by the pressure of its own weight, and extending immense distances over a comparatively level but very irregular surface, must have been exceedingly slow. The average yearly progress of the glaciers of the Alps is about three hundred feet. The continental glacier, which striated the northern United States and Canada, must have had a much less slope. If its upper surface descended only one foot in two hundred, which in this state is considered a very moderate railroad grade, the ice would increase one mile in

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* Croll's *Climate and Time*, Amer. ed., pp. 76–78, etc.

thickness for every two hundred miles that we advance towards the head of its outflow at the north. Over the highlands between the St. Lawrence valley and Hudson bay it would have been three or four miles in depth, and at the same time probably much deeper over Greenland. Even with this vast accumulation of ice we have so gentle a slope to produce its motion that we can scarcely suppose this progress, at least in its lower portion, which passed over the very uneven surface of the land, to have exceeded one twelfth that of the glaciers in the Alps. This would give us an advance of twenty-five feet yearly, requiring 21,000 years to move one hundred miles. If these conclusions are any approximation to the truth, the highest rate of motion which could be attained by the ice-sheet at its greatest depth, continuing through half of this time, would seem quite inadequate to plough up and remove the extensive and thick deposits of stratified gravel, sand, and clay which we now find in New Hampshire, so that scarcely any traces of them would remain. Similar deposits of modified drift would have been formed at each melting away of the ice; and their almost complete removal in the epochs during which this theory supposes the ice-sheet to prevail seems improbable, when we consider the slowness of its motion.

The accumulation of the vast thickness of ice which must have existed at the north, probably amounting to twenty thousand feet, seems also to require a longer time than Mr. Croll's theory allows. The average rainfall of New England is about three and a half feet, three fifths of which are evaporated from the surface, while two fifths flow to the sea. This rain-fall exceeds that of the continent northward and westward. Probably it was from a precipitation of snow and rain of no greater amount that the ice-sheet increased in thickness from year to year. Melting and evaporation must have removed a large portion of this; and an annual addition of two feet of ice seems to be too high an estimate. The formation of the ice-sheet would thus occupy all the time through which it is supposed to act in any single glacial epoch.

Another consideration which adds to the probability that the ice-sheet continued through the whole period of great eccentricity, being principally formed in the successive epochs when the winters occurred near aphelion, but not disappearing when winters fell at perihelion, is found in the great elevation of these ice-fields which over the White Mountains reached nearly or perhaps quite to the line of perpetual snow, while farther northward they rose far above this line. The very low temperature which this must cause would seem to make it improbable that the changed proportions of heat received from the sun, such as to produce, if no ice existed, a mild winter and a cool summer, could melt this vast mass of ice and bring a temperate climate in its place. It is certain that this or some other cause partially melted this ice at times, and that it afterwards advanced, covering the territory from which it had retreated; but the work which the ice-sheet accomplished, the length of time requisite for its formation, and the low temperature of the altitude to which it reached, render it improbable that it was several times wholly melted away, alternating with warm inter-glacial periods. The view here taken is, that the glacial period was principally produced by the last great eccentricity of the earth's orbit, the changed proportions of heat received from the sun in the different seasons of the year favoring the accumulation and preservation of vast sheets of ice, which existed in the northern and southern hemispheres at the same time.

Formation and Distribution of Till. The till or coarse glacial drift was produced by the long-continued wearing and grinding of the ice-sheet. As this slowly advanced, fragments were torn from the ledges, and a large part of these were sooner or later held in the bottom of the ice, and worn to small size by friction upon the surface over which it moved. The resulting mixture formed beneath the ice is variously called the ground moraine, boulder-clay, or *Lower Till.* It consists of smoothed and striated stones, with fine detritus, which is usually a gravelly clay of dark bluish color, being always clayey, dark, and very hard and compact. The characteristics of the lower till are due to the mode of its formation. Most of its pebbles and boulders are glaciated, having rounded edges and smoothly-worn sides, which often retain striæ. These show that the finer material in which they occur has been produced by the slow grinding up of these stones under the ice. The dark and usually bluish color is due to seclusion from air and water during its formation, as pointed out by Torell, leaving its iron principally in the form of ferrous silicates or carbonates. Its compactness and hardness are due to compression under the great weight of ice. Because of this quality, the lower till is commonly known as "hardpan."

While this deposit was thus accumulating beneath the ice, great amounts of material, coarse and fine, were swept away from hill-slopes and mountain sides, and afterwards carried forward in the ice. When this melted, a large portion of the material which it contained fell loosely upon the surface, forming an unstratified deposit of gravelly earth and boulders, which may be called the *Upper Till.* There is almost always a definite line of separation, at a depth varying from two or three to fifteen or twenty feet, between the upper and lower till. It will be seen that the upper member is the one usually exposed at the surface, and it is often the only one present where only a thin covering of till is found. Its characteristics are the larger size of its boulders, which are mostly angular and unworn, and commonly derived from less remote localities than the glaciated stones in the lower till; the yellowish or reddish color of its fine detritus, produced by the hydrated ferric oxide to which its iron has been changed by exposure to air and water; and the comparative looseness of its whole mass. This division of the till into two members, which is very well marked throughout New Hampshire, is also conspicuous in Sweden and other parts of Europe; and the peculiar features of each have been recently pointed out by Dr. Otto Torell, of Sweden,* in nearly the same terms here used.

The distribution of the till in this state and in eastern Massachusetts is quite irregular. Sometimes no considerable accumulations of it are seen for several miles, and the ledges lie at or near the surface. Elsewhere the till occurs in large amount, covering the ledges which are scarcely exposed over some whole townships near the coast. Wherever it is found plentifully, it is to a large extent massed in peculiar oblong or sometimes nearly round hills, which usually have quite steep sides and gently sloping, rounded tops, presenting a very smooth and regular contour. These hills are of all sizes up to one third or one half mile long, with two thirds as great width; and their longest axis is most frequently north-west to south-east, coinciding nearly with the current of the ice-sheet. Their height varies from forty or fifty to two hundred feet. These accumulations of till are most abundant near the coast, where they sometimes occupy nearly the whole territory for many miles, while adjoining

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* *Proceedings of American Association for the Advancement of Science*, vol. 25, 1876.

areas on each side may be nearly destitute of surface deposits, showing only naked, striated ledges. The peculiar distribution of the till, the dispersal of boulders, the course of striæ, and other topics connected with the unmodified glacial drift, will form the subject of the next chapter of this report. Having taken this brief view of the glacial period, we are now prepared to understand the origin of the modified drift.

The Champlain Period.

The departure of the ice-sheet was attended with a comparatively rapid deposition of the abundant materials which it contained. It is probable that its final melting took place mostly upon the surface, so that at the last great amounts of detritus were exposed to the washing of its innumerable streams. The finer portions of these materials would be commonly carried away; and the strong current of the rivers which would be formed near the terminal front of the ice-sheet could transport coarse gravel, or even boulders of considerable size. When the glacial river entered the open valley from which the ice had retreated, or in the lower part of its channel while still walled on both sides by ice, its current was slackened by the less rapid descent, causing the deposition, first, of its coarsest gravel, and afterwards, in succession, of its finer gravel, sand, and fine silt or clay. The valleys were thus filled with extensive and thick deposits of modified drift, which increased in depth in the same way that additions are now made to the bottom-land or interval of our large rivers by the annual floods of spring. The portion of the material contained in the ice-sheet which escaped this erosion of its streams formed the upper till. The abundant deposition of drift, both stratified and unstratified, during the final melting of the ice-sheet, has been brought into due prominence by Prof. James D. Dana,* who denominates this the *Champlain period*, deriving the name from marine beds of this era, which occur on the borders of Lake Champlain.

The retreat of the ice-sheet was towards the north-west and north; and wherever the natural drainage was in the same direction, it would be for a time obstructed by the ice, forming lakes in which the deposition of modified drift would be much different from that which took place where the

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* *American Journal of Science*, Third Series, vol. v, p. 198, and various papers in vol. x.

slope was to the south. In New Hampshire, the portion of the Contoocook valley which extends through Hillsborough county was thus occupied by a lake during a large part of the Champlain period.

Kames. The oldest of our deposits of modified drift are long ridges or intermixed short ridges and mounds, composed of very coarse water-worn gravel, or of alternate layers of gravel and sand irregularly bedded, a section of which shows an arched or anticlinal stratification. Wherever the ordinary fine alluvium also occurs, it overlies, or in part covers, these deposits. Similar ridges of gravel have been often described by European geologists, under the various names of *Kames* in Scotland, *Eskers* in Ireland, and *Åsar* in Sweden. The first of these names will be adopted in this report. They have also been described by geologists in many portions of the northern United States. In New Hampshire, kames are of frequent occurrence, sometimes a single one extending in a very steep, narrow ridge for miles along the lowest portion of a valley, or elsewhere short and several parallel to each other, or in very irregular mounds and ridges, with hollows enclosing small ponds. Their position is generally along the middle or lowest part of the valleys, which are bordered by high ranges of hills; but in the south-east part of the state, in some parts of Maine, and in eastern Massachusetts, where there are only scattered hills with the valleys not much below the general level of the country, these ridges, of smaller size than in the great valleys, are found extending usually north and south, without special regard to the present water-courses. In the valleys of our two largest rivers, the Connecticut and Merrimack, they extend long distances, but had heretofore escaped notice, owing to the large amount of levelly stratified alluvium, forming the conspicuous terraces and plains by which the underlying kames are often nearly concealed. Before this later alluvium was deposited, a kame had been formed in the Connecticut valley, which extended for many miles in a single continuous ridge, from one hundred to two hundred and fifty feet high, with steep sides; and in the Merrimack valley a continuous series of kames had been formed, consisting sometimes of a single ridge, and again of several parallel to each other. Another interesting series of kames extends from Saco river to Six-mile pond, and from Ossipee lake south-easterly along Pine river, and by Pine River and Balch ponds into Maine. The first description of any of these ridges in America appears to have been given by Dr. Edward Hitchcock in 1842,* respecting a series which is well shown in Lawrence and Andover, Mass. Short kames, and small areas occupied by a confusion of gravel ridges and mounds, but not connected with any extended series, are also frequently found.

The origin of the kames has been a question much discussed by European geologists, and the theory commonly accepted on both sides of the Atlantic was, that they were heaped up in these peculiar ridges and mounds through the agency of marine currents during a submergence of the land. Even if such ridges could be formed by this cause under any circumstances, it seemed impossible to account thus for the kames in the Connecticut and Merrimack valleys, which, being bordered on both sides by high hills, would have been long estuaries open to the sea only at their mouths, and therefore not affected by oceanic currents. From the position of these peculiar accumulations of gravel, which are overlaid by the horizontally stratified drift, the date of their formation is known to be between the period when the ice-sheet moved over the land and that closely following, in which this more recent modified drift was deposited in the open valley from the floods that were supplied by the melting ice. We are thus led to an explanation of the kames, which seems to be supported by all the facts observed in New Hampshire, and which appears to apply, also, to the similar deposits which have been described in other parts of the United States and in Europe. During the melting of the ice-sheet it became moulded upon the surface, by this process of destruction, into great basins and valleys; and at the last the avenues by which its melting waters escaped came gradually to coincide with the depressions of our present surface. These lowest and warmest portions of the land were first uncovered from the ice; and as the melted area slowly extended into the continental glacier, its vast floods found their outlet at the head of the advancing valley. This often took place by a single channel, bordered by ice-walls, as was the case along the whole Connecticut kame; but in the Merrimack valley, and in eastern New Hampshire and Massachusetts, these glacial rivers also frequently had their mouth by numerous channels, which were separated by ridges of ice. In these

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Transactions of the Association of American Geologists and Naturalists.

channels were deposited materials gathered by the streams from the melting glacier. By the low water of winter layers of sand would be formed, and by the strong currents of summer layers of gravel, often very coarse, which would be very irregularly bedded, here sand and there gravel accumulating, and without much order interstratified with each other. Sometimes the melting may have been so rapid that the entire section of a kame may show only the deposition of a single summer, which would then be very coarse gravel without layers of sand. When the bordering and separating ice-walls disappeared, these deposits remained in the long ridges of the kames, with steep slopes and irregularly arched stratification. Very irregular short ridges, mounds, and enclosed hollows resulted from deposition among irregular masses of ice.

The glacial rivers which we have described appear to have flowed in channels upon the surface of the ice, and the formation of the kames took place at or near their mouths, extending along the valleys as fast as the ice-front retreated. Large angular boulders are sometimes, but not frequently, found in the kames, or upon their surface. They appear to have been transported by floating ice. Their rare occurrence forbids the supposition that these deposits were formed in channels beneath the ice-sheet, from which many such blocks would have fallen upon the kames.

The necessity of referring the formation of the gravel ridges to glacial rivers became apparent during the exploration and study of our modified drift in 1875; and in August, 1876, this was announced in a paper "On the Origin of Kames or Eskers in New Hampshire."* In the revised edition of Geikie's *Great Ice Age*, published in London in the winter of 1876–77, this distinguished glacialist retracts his former opinion that the kames were heaped up by marine currents, and attributes their formation to sub-glacial rivers.† This may be the true explanation in some cases, for such rivers probably existed through the glacial period; but more commonly it would appear, as already shown, that the kames were deposited at the final melting of the ice-sheet in channels formed upon the surface of the ice.

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* *Proceedings of American Association for the Advancement of Science*, vol. 25.

† *Great Ice Age*, second edition, revised, pp. 217, 239, 243, 469, 478, etc. By page 414 it appears that this theory was first proposed by Mr. D. Hummel of the geological survey of Sweden, in 1874; and on page 415 allusion is made to a recent paper by Dr. N. O. Holst, also of Sweden, in which the kames have been explained in the same manner as in this chapter.

Plains and Terraces. The extensive level plains and high terraces which border our rivers, constituting the most conspicuous and by far the largest portion of our modified drift, were also deposited in the Champlain period. The open valleys became gradually filled with great depths of horizontally stratified gravel, sand, and clay, which were brought down by the glacial rivers from the melting ice-sheet, or washed from the till after the ice had retreated, and which were deposited in the same way as by high floods at the present time. The departing ice-sheet was the principal source both of the vast amount of material and of water for transporting it into the valleys, which appear in most cases to have been filled to the level of the highest terraces or plains. The prevailing horizontal stratification of these deposits shows that they were spread over large areas by the current of the floods which held them in suspension. The modified drift thus increased in depth in the principal valleys through a long period, which may have continued until the last of the ice at the head of the valley and of its tributaries had disappeared.

The Terrace Period.

During the *recent or terrace period* the rivers have been at work excavating deep and wide channels in this alluvium. The terraces mark heights at which in this work of erosion they have left portions of their successive flood-plains. As soon as the supply of material became insufficient to fill the place of that excavated by the river, a deep channel was gradually formed in the broad flood-plain. The process was very slow, allowing the river to continue for a long time at nearly the same level, undermining and wearing away its bank on one side, and depositing the material on the opposite side, till a wide and nearly level lower flood-plain would be formed, bordered on both sides by steep terraces. When the current became turned to wear away the bank in the opposite direction, a large portion of this new flood-plain would be undermined and re-deposited at a lower level; but the direction of the current's wear might be again reversed in season to leave a narrow strip, which would then form a lower terrace. In this way the Connecticut river, along the greater part of its course on the west border of New Hampshire, has excavated its ancient high flood-plain of the Champlain period to a depth of from one hundred and fifty to two hundred feet for a width varying from one eighth mile to one mile, leaving numerous terraces at each side. The Merrimack and Saco valleys show similar erosion, and it may be seen upon a small scale on every river in the state. On our largest rivers we see the highest plain in some places, and the lower terraces very frequently, being now undermined by the wear of the current, forming steep bluffs and banks. It seems impossible to explain in any different way the cause of the slope, often nearly as steep as is possible for loose materials, which forms the abrupt face or escarpment of level-topped and horizontally stratified terraces. The finer character of the materials which compose the lowest terraces and the interval, or present flood-plain, is due to this wearing away and re-deposition by the river, which have been many times repeated, till what may have been at first gravel becomes very fine sand or silt. By each removal it is made one degree finer, and is deposited at a lower level and farther down the stream. The end of its slow journey is the sea, where it will help to make the sedimentary rocks of this epoch. It has completed a great cycle of changes, ending where the upheaved and contorted ledges from which it was derived had their remote beginning.

Deltas of Tributaries. Upon entering the large valleys, tributary streams of comparatively narrow channel and rapid descent frequently formed extensive deposits in the Champlain period, similar in material to the flood-plain of the main valley, but having a greater height. Sometimes these *deltas*, being partially undermined, form conspicuous terraces a hundred feet above the *highest normal terrace*, which is the remnant of the river's continuous flood-plain. The deposition of the modified drift of the main river was usually but not always to the same level across the valley. The increased supply from tributaries was sometimes a temporary barrier, damming up the waters of the main valley above; and the current could then deposit its sediment principally upon one side, making the highest normal terraces quite different in elevation.

Dunes. Wind-blown banks of sand or *dunes*, apparently isolated on the hillsides, are occasionally found along the east side of Connecticut and Merrimack valleys and south-east of Ossipee lake, at heights varying from the level of the highest terrace or plain to two hundred feet above it. These patches of sand are very conspicuous, because they are often destitute of vegetation, being blown in drifts by the wind. They vary in size, the largest sometimes covering an acre or more, with their thickest portions from ten to fifteen feet in depth. These dunes appear to have been swept up from the broad plains of the Champlain period, before forests had fully covered the land, by the strong north-west winds, which we may suppose prevailed the same then as now. That this is a true explanation of these high banks of sand appears to be proved by the fineness of their material, which contains only particles such as could be carried by the wind; by their frequent occurrence on the east side of the valleys, where they would be formed by the prevailing strong north-west winds, while they are not found on the opposite side; and by the train of sand-drifts usually grassed over, which may be traced down in a north-west direction from the banks of sand now blown by the wind to the normal modified drift. Since the clearing away of the forest, the upper portion of these trains of sand has sometimes been carried several hundred feet onward, and from thirty to fifty feet higher. The excavation of the old drifts has been six or seven feet in depth, as shown by great stumps, beneath which the sand has been swept away. These dunes are ridged, channelled, and heaped up by the wind in the same manner as the more extensive dunes of a sea-coast.

Modified Drift overlaid by Till. About Winnipiseogee lake beds of stratified clay are often found underlaid and overlaid by till. The clay is free from pebbles, and well suited for brick-making. It varies from five or ten to thirty feet in thickness, and occurs at various heights from the level of the lake to three hundred feet above it. The overlying till is from two or three to ten or fifteen feet in thickness, wholly unstratified, and very coarse, containing numerous boulders, which may be five or six feet in diameter. These remarkable clay-beds probably accumulated during the departure of the ice-sheet, in spaces melted under the ice, between it and the lower till.

Modified Drift near the Coast. About Dover, and southward near the sea-coast, thick deposits of modified drift, sometimes forming extensive plains, are found occupying areas of water-shed from one hundred to two hundred feet above the streams, which often flow in wide valleys that are nearly destitute of modified drift. Some of these, as the high plains of coarse gravel and sand about Willand and Barbadoes ponds, near Dover, seem to have been produced by the rapid deposition of materials brought down from the ice-sheet by glacial rivers. At the time of their formation the adjoining valleys were probably still occupied by the unmelted ice. Nearer to the coast we find in this situation beds of fine gravel, sand, or clay, sometimes enclosing marine shells and pine cones, and in several instances overlaid on their north-west side by coarse glacial drift or upper till a few feet in depth, giving evidence of a retreat and subsequent advance of the ice sheet.

Submergence by the Sea. These marine deposits, which reach to about one hundred and fifty feet above the sea, afford the only certain proof found in our exploration of the modified drift in New Hampshire of any change in the relative heights of land and ocean. With the exception of the trunks, branches, and leaves of trees, which have been rarely found, all the rest of our modified drift is, so far as known, destitute of organic remains; and we have seen that the explanation of the thick deposits of the Champlain period, and of their present excavated and terraced condition, requires no submergence by the sea, nor change in the height and slope of the land. It seems quite probable that the submergence in the glacial period, of which we have proof, amounting to fifty feet in southern New England, two hundred feet on the coast of Maine, and about five hundred feet in the valley of the St. Lawrence, was not caused by any downward and upward movement of the earth's surface, but by the attraction of the immense masses of ice, which, as pointed out by Adhémar, would draw the ocean away from the equator towards the poles. The whole amount of water in the sea was diminished, but the accumulation of vast sheets of ice, several miles in thickness, would be sufficient to retain the ocean at its present height near their lower limits, while it would rise much higher than now about the poles, and at the equator would sink far below its present level. Such a rise of the sea, increasing in amount at high latitudes, is attested by the modified drift of both America and Europe; and coral islands afford proof of the corresponding depression of the ocean, succeeded by a gradual elevation to its present height, over large areas within the tropics.

The two great continents appear to have existed, with somewhat the same outlines as now, from a very remote geological epoch. From the Silurian age to the glacial period we have no record that any part of New Hampshire was submerged beneath the ocean; and nearly all that we can say of its history through this vast extent of time is, that it probably had for the most part a temperate climate, and witnessed the same slow succession in its forms of vegetable and animal life of which the coal measures and later rocks in other parts of the United States bear witness. This comparative stability through long ages makes it more probable that these recent changes in the relative heights of land and sea are due to the cause which we have explained rather than to movements of the land.

The exploration of the modified drift in New Hampshire, under direction of the state geologist, was principally made in 1875. In this work on the Connecticut and Merrimack rivers the author had the valuable assistance of William F. Flint, being thus enabled to map all the terraces of these rivers, and measure their heights by an engineers' level. On the Connecticut, this was more conveniently done, and the expense lessened, by employing a boat, which was built by Mr. Flint, for the journey between McIndoe's Falls and Massachusetts line. The particular description of the modified drift of the state will be taken up in the following order: Connecticut river, followed by such of its tributaries as have been examined; Merrimack river, followed by Contoocook river and Winnipiseogee and Squam lakes; Androscoggin river; Saco river and basin of Ossipee lake; basin of Piscataqua river; and the sea-coast.

Modified Drift along Connecticut River.

The sources of Connecticut river, its hydrographic basin, its course and descent on the west side of New Hampshire, and its tributaries from this state, have been described in the first volume of this report.* The territory of Vermont extends to the west shore of this river, but in exploring its modified drift equal attention has been given to both sides. Only by this study of the whole valley could the history of these deposits be discovered, and the portion in this state be understood. A series of maps occupying three plates accompanies the following descriptions. The various terraces which border the river are there delineated, and their heights stated in feet above the sea. The extent and contour of the modified drift is thus shown along the whole valley. Throughout this distance the alluvial area is bounded on each side by high hills, which are only interrupted by the entrance of tributaries.

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* Vol. i, pp. 222-224, 299, 302-305, and 318.

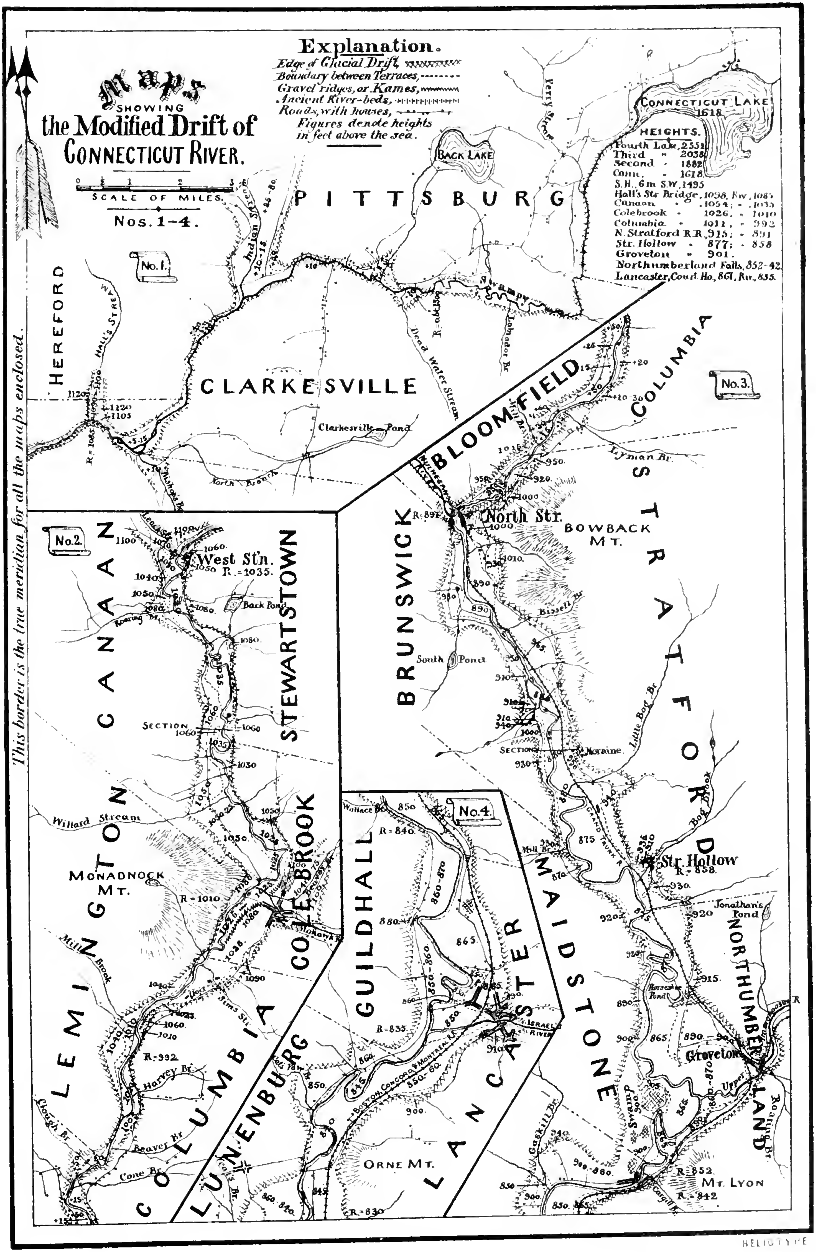
Connecticut Lake to West Stewartstown. For the first four miles below Connecticut lake the river has a rapid descent, with a southerly course. It then bends to the west, and winds with a sluggish current through a narrow swamp three miles in length, which is the first alluvium seen on the river. Its lower end is at the mouth of Deadwater stream. One half mile farther down, at the outlet from Back lake, the road passes over a sand and gravel plain 30 feet above the river. This is material deposited in the Champlain period by the tributary stream. Much of it has been excavated during the terrace period; and till extends to the river on the opposite side in a very gentle, regular slope.

On Indian stream there is a large extent of low alluvial land, comprising several valuable farms. This consists mainly of a wide interval, from 10 to 15 feet high, which is bordered on the east by a narrow lateral terrace from 30 to 40 feet above the river. In the next four miles scarcely anything but glacial drift and ledges is found. The scanty portions which may be called modified drift consist of very coarse, somewhat water-worn gravel, in terraces from 10 to 40 feet above the river, which has probably in many places cut its channel to this depth through the till. About the mouth of Bishop's brook considerable low alluvium occurs, partly brought by the main river and partly by its tributary. Thence we have a narrow width of modified drift on the north side of the river to Hall's stream, which is bordered by an interval from 5 to 10 feet, and two terraces, 20 and 35 feet, above the river. On the south side here, and on both sides for nearly two miles below, the river is closely bordered by hills, and no modified drift is seen.

The portion of the river which we have now described extends southwesterly about eighteen miles from the mouth of Connecticut lake. The descent in this distance is 583 feet. High wooded hills border the valley, which is destitute of modified drift for half of the way. The largest alluvial area is on Indian stream; and the highest terraces are from 30 to 40 feet above the river.

Upper Connecticut Valley. Below West Stewartstown the course of the river is southerly, having a descent in nearly fifty miles, to the head of Fifteen-miles falls in Dalton, of only 205 feet, one half of which takes place in nine miles between Columbia bridge and North Stratford. Along this whole distance the modified drift is continuous, and, including both

Plate I.



HELIOTYPE

sides, is usually a half to a mile and a half wide. It is very simple, having two heights, and consists of the present flood-plain, bordered by remnants of that which filled the valley in the Champlain period. The former is about ten feet above low water, being annually overflowed by the floods of spring. This would be called *bottom-land* in the western United States. In New England it is commonly termed *interval;* but along Connecticut river it is frequently known as *meadow.* On all our large rivers this lowest terrace has a firm and well-drained surface, much different from the marshy areas bordering small streams to which the name *meadow* is restricted in other parts of the state. It is the most valuable portion of these alluvial lands, having a more finely-pulverized and more fertile soil than that of the higher terraces. The ancient flood-plain is here represented by a lateral terrace, from 40 to 120 feet above the river, usually remaining at both sides, and in many places forming considerable plains.

From West Stewartstown to Colebrook the only alluvium of importance on the New Hampshire side is the interval; but small remnants of the upper terrace are found, especially where there is a tributary stream. On the Vermont side the upper terrace, composed of sand or fine gravel, is usually well shown, having a nearly constant but small elevation of 40 to 60 feet above the river, with which it slopes. It appears that this formerly had possession of the whole valley, and that the channelling of the river has swept it away from the area now occupied by the interval or meadows. Portions of it still remain, entirely surrounded by the low flood-plain. Such a plateau may be seen in Canaan, nearly opposite the south line of Stewartstown. The upper terrace and its isolated remnant have both a height of 40 feet above the river, while the lower level is only 15 feet in height. North-east from this in Stewartstown a rivulet has effected a like result on a small scale in the meadow, cutting a channel wholly around a small area which still preserves the height of the rest of the meadow.

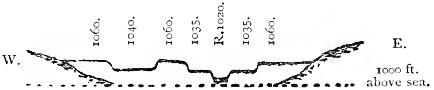


Fig. 1.—Section in Canaan and Stewartstown.
Length, $\frac{2}{3}$ of a mile.

Kames. At Colebrook we find an interesting gravel ridge or kame, portions of which remain north of the junction of Beaver brook and

Mohawk river, but most noticeably west of the village, extending nearly a mile parallel with the river. Its height is about 70 feet above the river, and 50 above the low alluvium on each side. Its material is the same as that of the long kame farther south in this valley, being principally coarse, water-worn gravel, with abundant pebbles six inches to one foot in diameter. This ridge was deposited in the glacial channel of the river which flowed from the ice-sheet at its final melting.

We must refer to a similar cause the slightly modified drift in Lemington, just north-west from Colebrook bridge; in Columbia, the high gravel terrace north of Sims stream; thence for a mile southward the moraine-like, level-topped or irregular drift, slightly modified, at about 100 feet above the river; and the coarse drift ridge on the east side of the river a half mile above Columbia bridge. The last is a distinct ridge, one third of a mile long, parallel with the river, and from 50 to 75 feet above it, being from 25 to 50 feet above the adjoining lowland. This may have been a medial moraine. It contains many angular rock-fragments from two to three feet in size, and seems scarcely modified, appearing like portions of the kames along Merrimack river.

Between Columbia bridge and North Stratford the descent is rapid and the terraces are irregular. At Columbia bridge the highest alluvial banks are 48 feet above the river; at North Stratford, 119. Where the river now descends 101 feet the stratified drift of the valley shows a slope of only 30 feet, or about three feet to a mile. After we pass this steep and narrow portion, and enter a wide valley again where the river is comparatively level, we find the upper terrace falling much more rapidly, or nine feet to a mile. At Groveton it has again descended to a height 50 feet above the river. As we approach Fifteen-miles falls, the upper terrace slopes very slowly down to the lower, and they can scarcely be distinguished as separate heights below South Lancaster. The wide river-plain here rises gradually from 5 or 10 to perhaps 20 or 30 feet above the river.

In Stratford and Brunswick both heights of the alluvium are well shown, the highway being on the upper terrace and the railroad on the meadow. The former is about 100 feet above the river, and at Brunswick Springs, and for much of the way through Stratford, is from one fourth to one third of a mile wide. At Stratford Hollow depot the railroad has cut through a narrow spur of this terrace, which escaped erosion by water. Here the alluvium of the main valley has been excavated into secondary terraces by Bog brook. In the south part of Stratford, and in Northumberland, the meadow or interval occupies more space than the terrace, which has its greatest extent in the level, swampy plain west of Groveton Junction. In Maidstone, for two miles north from Guildhall, low hills on the west side of the valley hem in extensive swamps, which have been scantily filled with alluvium of nearly the same height with the river terrace.

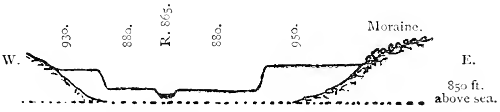


Fig. 2.—SECTION IN BRUNSWICK AND STRATFORD.
Length, ¾ of a mile.

Deltas. At Lancaster the upper terrace of Connecticut river is only 15 or 20 feet above the interval. The only higher modified drift has been brought down by tributaries. Part of Lancaster village is built on one of these deltas, formed by Israel's river on its south side, 50 feet above the terrace of the main valley. This delta sloped rapidly westward, and formerly occupied the whole area of the village; a portion of it, 20 feet lower than the former, remains at the cemetery opposite the court-house. Similar deposits also occur two miles south-west from Lancaster, and on John's river.

Between South Lancaster and Fifteen-miles falls the broad river-plain is unterraced. It seems probable that a lake existed here while the original high plain northward was being deposited. When this was channelled out by the river, so as to leave only terraces as we now see them, the materials excavated were sufficient to fill up the lake. It would be interesting to know the depth of the stratified drift in this basin; it is probably deeper than the height of the highest modified drift northward above the river.

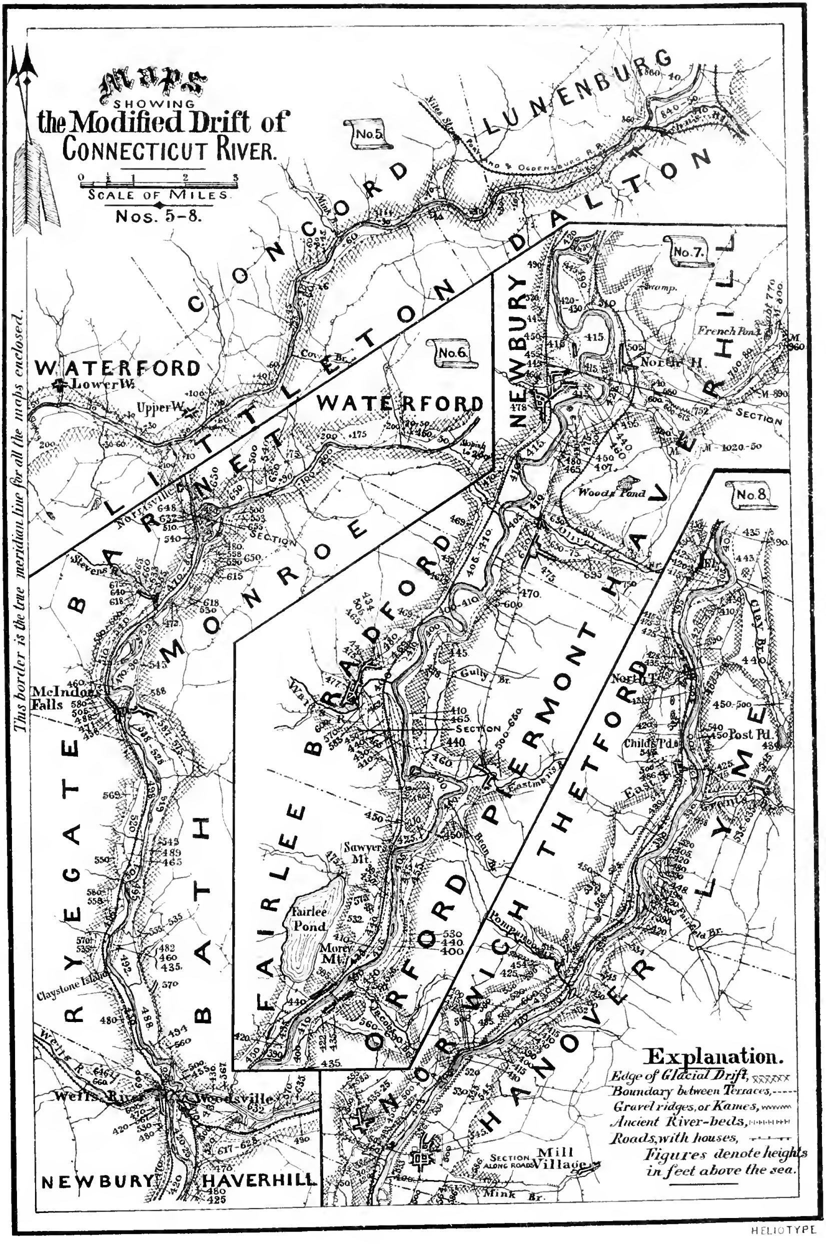
Kame-like materials of small extent were noticed at North Stratford, forming the high bank on the east side of the railroad, one fourth mile south-east from the depot, and in Guildhall, about two miles north from Lancaster bridge. A remarkable moraine of granite boulders occurs in Stratford, covering a large area of hillside just above the upper terrace, one mile south from Beattie's station. Two miles north-west from

Groveton a ridge of till, from 60 to 100 feet above the river, projects half a mile westerly into the valley, or half way across it, appearing like a terminal moraine. Horse-shoe pond, on the north-west side of this ridge, occupies a portion of a deserted river-channel. These ancient river-beds are frequently shown by such ponds, commonly called *sloughs* or *moats*, of which Baker's pond, near Lancaster, is another example. We see the river now slowly changing its position by wearing away one or the other of its banks, and it has thus swept many times from side to side in excavating its valley between the bordering terraces.

Fifteen-miles Falls. From the mouth of John's river the Connecticut has a rapid descent for twenty miles, amounting to 370 feet, falling from 830 to 460 feet above the sea. The bed of the river is a nearly continuous slope of coarse till, showing abundant boulders, but with scarcely any exposure of solid ledges. The only place where these were noticed in our exploration was at the "lower pitch," or foot of these rapids, about a mile above the mouth of Passumpsic river. Here there is a precipitous fall of a few feet, and this is said to be the only point of abrupt descent. In other parts of its course the falls of the Connecticut are produced by ledges, and the channel, except at such falls, is composed of gravel, sand, or silt. Nowhere else below West Stewartstown, except at the falls of Northumberland and Columbia, and rarely, if at all, southward, does the river flow over the glacial drift or till.

The noticeable features of the valley in this distance are, that it is deep and narrow, with sloping sides of till, and destitute of the level alluvial terraces and intervals which occupy a large width everywhere else along the river. Where any modified drift does occur, it is coarser than usual, being generally gravel, sometimes imperfectly rounded or water-worn, and its surface has commonly an irregular slope. The upper portion of these rapids is especially destitute even of such alluvial deposits, the highest that occur being from 60 to 75 feet above the stream. It is frequently evident that the source of these deposits is not the main river, but a tributary, as in the case of Niles stream in Concord, Vt., and on both sides at Upper Waterford. These deltas are greater in height, as well as in amount, than the scanty remnants of the alluvium of the main valley.

On the lower portion of these rapids the modified drift appears in greater quantity and at a much increased height. Opposite Lower


Maps
showing
the Modified Drift of
CONNECTICUT RIVER.
SCALE OF MILES
0 ½ 1 2 3
Nos. 5–8.
This border is the true meridian line for all the maps enclosed.
No. 5
No. 6
No. 7.
No. 8
LUNENBURG
CONCORD
DALTON
LITTLETON
WATERFORD
Lower W.
Upper W.
WATERFORD
BARNET
MONROE
NEWBURY
HAVERHILL
BATH
RYEGATE
BRADFORD
FAIRLEE
ORFORD
PIERMONT
THETFORD
NORWICH
HANOVER
LYME
Portland & Ogdensburg R.R.
Niles Str.
Mink Br.
Cow Br.
Norrisville
Stevens R.
McIndoes Falls
Claystone Island
Wells R.
Wells River
Woodsville
Waits R.
Gully Br.
Sawyers Mt.
Fairlee Pond
Morey Mt.
Jacobs Br.
Eastmans Br.
Bean Br.
Pompanoosuc R.
North T.
Childs Pd.
East T.
Post Pd.
Clay Br.
Grants Br.
Fairfield Br.
Ely
Oliverian Br.
Woods Pond
Swamp.
French Pond
North H.
Section
SECTION ALONG ROADS
Mill Village
Mink Br.
Explanation.
Edge of Glacial Drift,
Boundary between Terraces,
Gravel ridges, or Kames,
Ancient River-beds,
Roads, with houses,
Figures denote heights in feet above the sea.

HELIOTYPE

Waterford we find irregular hillocks of sand, barren of vegetation, and drifted by the wind, the highest of which are about 200 feet above the river. Below this point the modified drift rises in irregular slopes to a height of 200 feet in several places, and its position shows it to have been principally deposited from currents of the main valley. As we approach the foot of the falls its coarse character is changed, and sand predominates in the place of gravel. These deposits probably once filled this part of the valley nearly 200 feet above the present river, sloping in six miles between Lower Waterford and Passumpsic river from about 800 to 650 feet above the sea.

The course of the river along Fifteen-miles falls is S. 70° W., being turned much to the west from its general direction. This course is at right angles to the line of motion of the great ice-sheet; consequently this valley was sheltered from the direct grooving and rasping of the ice, and must be supposed to have furnished a lodgment for much of the ground-moraine or till that accumulated in its track. We have mentioned that this material forms the river channel, nearly everywhere concealing the underlying rocks. It also forms the sides of the valley for most of the way, rising quite steeply from the river, and sometimes presenting a terraced appearance at a height much above the present channel. These considerations lead to the conclusion that the river has excavated much of its present deep, narrow channel through this till since the disappearance of the ice, and since the deposition of its highest modified drift.

The facts observed point to an order of events somewhat as follows: In the ice-age a great amount of till was caught by the transverse valley. At the melting of the ice modified drift was swept into the valley, massing in the largest quantity at its lower end, and deltas were deposited by tributary streams. In some places the wind seems to have blown up sand-drifts to a position on the hillside above the normal height of modified drift. As soon as the melting had receded to a few miles above the head of these falls, further deposition ceased, all the material supplied being retained in the upper valley. The river next began the work of excavation. Most of the modified drift was carried away, and considerable depths channelled out in the till. It does not appear certain that a great amount of till was removed from the head of the falls; at least, nothing seen in the surface geology of the valley above would require such a barrier. The depth of till thus removed must have been variable, sometimes probably amounting to 100 feet; and more or less of this excavation seems to have taken place along the entire extent of these falls. The irregular surface left by the ice has been thus reduced to a channel of nearly regular slope with no abrupt falls, cut through the till, which still covers the ancient bed in which the river flowed before the glacial period.

Lower Connecticut Valley. The early pioneers retained the Indian name *Coös*, which they found applied to the fertile intervals of Lancaster and Haverhill. These were the Upper and Lower Coös, separated by the Fifteen-miles falls. By a similar division, the whole extent below these falls is here called the lower valley. This is comparatively level and straight, with a southerly course nearly the same as that of the upper valley. In a direct distance of 118 miles from the mouth of Passumpsic river to Massachusetts line, the river flows 137 miles, descending from 460 to 180 feet above the sea, or two feet to the mile. The principal falls in this distance are Beard's falls at Barnet, 5 feet; McIndoe's falls, 10 feet; Dodge's falls, three and a half miles south, 5 feet; at Woodsville, about 10 feet; White River falls, 35 feet (see map, vol. i, p. 302); Sumner's or Quechee falls, two miles below the mouth of Quechee river, 5 feet; and Bellows falls, 49 feet,—making a total of 119 feet, and leaving an average descent, excluding falls, of $1\frac{1}{6}$ feet per mile.

The modified drift of this lower valley is everywhere well developed, and occurs in extensive terraces of various heights, three or four often on each side, the upper one being usually from 150 to 200 feet above the river, while the lowest is the interval or meadow. The largest plains are expanses of the upper terrace, or of still higher tributary deltas. These areas are generally of a clayey, moist, productive soil, quite in contrast with the dry sandy plains of Merrimack river, Ossipee lake, and other parts of the state. The nearest resemblance to these barren "pine-plains" is found at Woodsville, in the high delta of Lower Ammonosuc river, on the north side of Black river in Springfield, Vt., and in the high, broad plain of Hinsdale. The latter is the only one of these areas which can be compared in size with the extensive plains of central and eastern New Hampshire.

The most extensive intervals or meadows are between Woodsville and Bradford, Vt., 12 miles long and one half to one mile wide, including the Lower Coös intervals of Newbury, Vt., Haverhill, and Piermont; and in Charlestown and Rockingham, Vt., 6 miles long and half a mile wide. But, in addition to these, smaller areas, up to a mile or more in length and a few rods to a half mile wide, are of common occurrence along the entire valley. These bottom-lands are very fertile, being composed of the finest silt, and enriched every year by a coating of mud from the turbid freshets of spring. Many of the lower terraces which are not overflowed are of the same material; but the higher terraces usually show some intermixed sand or fine gravel.

These lateral terraces are less plainly continuous in extent and height than the intervals or the upper terrace. They are sometimes numerous, again wanting; seldom agreeing in height on opposite sides; usually showing a slight slope with the river, but not often more than one or two miles, and generally less than one mile in length, and succeeded by others higher or lower. An examination of them over long distances, however, sometimes shows a well-marked series, descending with the river, and recording a height at which, during the process of erosion, it remained nearly stationary for an unusual length of time, forming a broad and continuous flood-plain, now interrupted and mainly swept away by the further deepening of the channel. These terraces are almost always level-topped, and bounded at the face by a steep escarpment; and their appearance is sometimes very striking, and even grand, as they rise in gigantic steps on the side of the valley, shaped with a smoothness, order, and beauty which could not be surpassed by art.

The greatest widths of modified drift that can be measured in this valley, on the west side of New Hampshire, are in Haverhill and Newbury, two miles, and in Hinsdale and Vernon, two and a half miles wide. The average width is fully one mile. The narrowest places are at Shaw's mountain, near the south line of Bradford, Vt., and at Barber's mountain, in Claremont, both of which occupy the middle of the valley, with narrow belts of alluvium on each side; at the west side of Rattlesnake hill, Charlestown; and at the south end of Wantastiquit mountain, below Brattleborough, Vt. We do not discover, however, at these places, or elsewhere, any evidence of former barriers, which could have made the valley a series of lakes. The vast amounts of modified drift which accumulated in this valley do not appear to have filled ancient lake-basins, but to have been rapidly deposited from the immense floods supplied by the melting of the ice-sheet. These great deposits of modified drift, for which there appears no other adequate cause, should rank with the till, striæ, and embossed ledges, as proof of a former continental glacier.

The Passumpsic river must be considered as occupying the continuation of the lower Connecticut valley, but at its mouth it flows through a rocky gorge, which separates its numerous and high terraces from those of the Connecticut. Four or five terraces are shown here on the Monroe side, the highest 190 feet, and the lowest from 15 to 20 feet above the river. The latter forms the Nine Islands, of which only one is above the reach of high water. This is a wooded island close to the Vermont side, and forms a north and south ridge 50 feet above the river, composed in part of kame-like gravel. Delta terraces from 50 to 60 feet above the highest in the main valley have been brought down by Stevens river, which falls 100 feet in Barnet village. Gleason's islands, one mile below, like nearly all those found in the river southward, are alluvial interval. Several terraces appear at McIndoe's falls, on the widest of which the village is situated, 50 feet above the river. The high terraces do not present a broad level top till we come to Monroe village, where we find two, 100 and 150 feet above the river, both of which are continuous a mile and a half, with regular southward slopes of ten and twelve feet. Occasional remnants of the highest of these are found on both sides through Bath and Ryegate; and the lower is well shown through these towns, agreeing closely in height on opposite sides of the river. On the east side it is continuous for eight miles, from one mile north of Monroe to the Narrows near Woodsville, sloping from 545 to 488 feet above the sea.

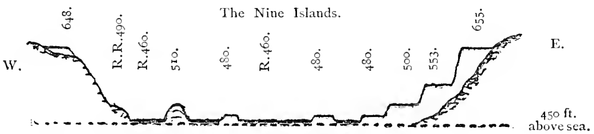


Fig. 3.—SECTION IN BARNET AND MONROE, AT MOUTH OF PASSUMPSIC RIVER. Length, 1 mile.

At Woodsville a great depth of material was brought into the valley by the Lower Ammonoosuc and Wells rivers. The former stream has cut its channel 200 feet deep through its delta, wide areas of which still remain on both sides. An old outlet of Wells river may be seen on its north side, one mile above its mouth, occupied at the close of the ice period until it cleared away a hundred feet or more of modified drift from the pre-glacial rocky bed in which it now flows. A well-marked kame occurs here, commencing in Bath half a mile north-west from the Narrows. It has been cut through by the river, and appears on the east side of the railroad at and above the junction, and again at the south-west side of Wells River depot, being more than a mile long. It is composed of coarse gravel and sand, anticlinally stratified, with varying height from 80 to 150 feet above the river. It is well shown by cuttings, but otherwise might escape notice, as most of it is partially or wholly concealed by the ordinary alluvium. In position, material, and stratification, this is like the long kame which extends in this valley from Lyme to Windsor; but in the twenty-four miles from Wells River to Lyme no similar ridge is found.

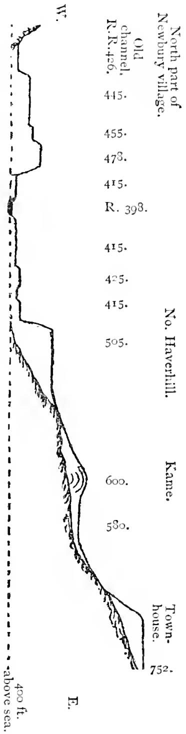


Fig. 4.—Section in Newbury and North Haverhill. Length, 4 miles.

From Wells river to Wait's river, at Bradford, the lowest terrace or interval is one half mile to one mile in width; and the river sweeps in broad curves from side to side between its bordering upper terraces. By the largest of these bends, called the Ox-bow, the river traverses two and a half miles to make one half mile of advance, by which a beautiful expanse of interval is added to Newbury. An old channel formerly left this and as much more on its east side. This ancient course extended from the north-west end of the Ox-bow south-west to the railroad, which it followed to the brook that flows through Newbury village, by which it passed east to its present channel. North Haverhill is situated on the highest normal terrace, 107 feet above the river and 27 feet higher than the corresponding terrace opposite, on which Newbury is built. This difference may be partly due to the fact that here was one of the principal outlets of the melting ice-sheet that continued to cover Moosilauke and the high water-shed after it had withdrawn from the Connecticut valley. East from North Haverhill, where there are now only insignificant brooks, we find an abundance of sand and coarse gravel which came from this source. It is disposed in irregular slopes, in some portions mounded or ridged, and rising in about one mile 250 feet, beyond which the same materials extend nearly level to French pond. Taking the road to Haverhill town-house, we pass a ridge of coarse gravel or slightly modified drift, which rises from 40 to 100 feet above the village. North-east from this there is a nearly level plain of fine alluvium, with beds of clay. A short distance farther east we come to a sand ridge, which extends about a half mile along the road, rising 80 feet by a gentle slope, and then abruptly 75 feet more, like the face of a terrace, to a level plain on which the town-house stands, 247 feet above North Haverhill and 752 feet above the sea. This plain, its western steep slope, and the first ridge below are all of sand, with none of the coarse gravel characteristic of kames. Similar deposits of fine material reach for a half mile on each side of this road, sometimes in level plains of small extent, but generally in varying slopes, by which they are continuous from the town-house to the upper terrace of the river.

The remainder of the way to French pond is comparatively level, being at first a plain of stratified, coarse-grained sand, which extends north one half mile to the brook; thence, for a mile and a half farther, sand or coarse rounded gravel extends along the road and on its east side as far north as to French pond. Immediately about this pond the modifying action of water is not apparent, but the surface is composed of heaped and ridged morainic drift, over which the road passes. This material is, however, in the main, level; with irregular hollows and depressions of only ten to twenty feet. Its rock-fragments are angular, but small in size, seldom exceeding two feet. A coarse morainic ridge extends more than a mile on the east side of this level alluvial valley, with a height about 125 feet above it, while on the west rises the precipitous face of Brier hill. Three miles south-east are the serrated mountains which extend north from Owl's Head; and nine miles south-east is the high, massive ridge of Moosilauke.

By estimate, French pond is about 770 feet above the sea, and the water-shed on the road northward is from 40 to 50 feet higher. This hollow, bounded on both sides by high hills, seems to have been for a time the outlet of the melting ice at the north, before the way was opened westward for the Lower Ammonoosuc river. The glacier which covered the mountains at the south-east also contributed to these deposits of modified drift, as is shown by the high moraine mentioned, and by others three fourths of a mile south from the town-house, at the mouth of a gap in the first high range of hills. The highest of these last has been modified by a current of water. It presents on the west side a steep escarpment of clear sand, reaching from 980 to 1020 feet above the sea. At the top this changes to gravel, which becomes coarse as we recede from the edge of the steep slope; next are large glaciated boulders, heaped together with no earth among them, which again present a steep face and somewhat level top 1050 feet above the sea. These rest at the east against the hillside. On the north-west nothing intervenes to the town-house and North Haverhill, 300 and 550 feet below, where we find the sand and clay which were brought down by these glacial streams.

At Haverhill there are only scanty remains of modified drift above the interval, which is nearly a mile wide. The highest terrace, best shown on the Vermont side, is 80 feet above the river; enough of it is left on the east side to indicate that it was once continuous across the valley. Hall's brook and Oliverian brook, which have their mouths here opposite to each other, have brought down large amounts of modified drift, which is deposited along the lower portion of their course. On the former this slopes in one mile to 125 feet above the upper terrace of the Connecticut. On the east side only slight vestiges of this terrace are found, and we have a direct rise of 220 feet from the interval to the modified drift of Oliverian brook, which thus commences at a greater height than is reached in the first mile on Hall's brook. In two miles this slopes upward 100 feet, or to 340 feet above the river, being well shown all the way, and at one place nearly a mile wide. These streams are both of large size, but the deposits along their course cannot be attributed to their ordinary action, any more than the modified drift east of North Haverhill is due to the brooks there. All these deposits are plainly of the same date and from one cause,—the melting of the ice-sheet.

The village of Haverhill is situated on a high, smoothly rounded, terrace-like area of till. This slopes steeply towards the river, but very slightly to the north and north-east, and extends nearly level for half a mile south-east to the foot of Catamount hill, and for two miles southward along the Piermont road. A large proportion of the boulders in this till are glaciated, sometimes preserving distinct striæ. The prevailing size is less than three feet; but rocks of five or six feet diameter, or even larger, also occur. These are found most rarely over the south part of this area in Piermont, where the abundant rounded or glaciated pebbles exposed by the channels of streams present the appearance of coarse kame-like gravel. At about one fourth mile south-west from Haverhill village a gully recently made on a previously smooth slope, at a height about 175 feet above the river, and consequently much above its highest terrace, and 75 feet below the village, showed 15 feet of modified drift resting on till. The surface was 3 feet of coarse gravel, which was succeeded by 12 feet of interstratified fine gravel and sand, obliquely bedded. The stratification here sloped with the present surface, about 10 feet in 100, with the obliquely bedded portions steeper in the same direction. Similar sections of overlying modified drift are shown in many places west and south from Haverhill, but the north and east parts of this area consist only of till. This is the ground-moraine of the ice-sheet, peculiarly massed here in very large amount, resembling the massive rounded hills of the same material, which are abundant near the coast. On the opposite side of the river we find the extensive slope, which rises south from Hall's brook, also composed of till with no outcropping ledges.

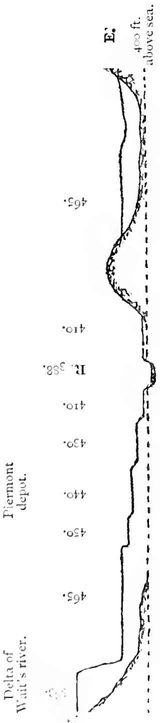


Fig. 5.—Section in Bradford and Piermont. Length, 1¾ miles.

In Piermont, opposite Bradford village, the modified drift is divided by ledgy hills close to the river into two belts, the eastern of which has a height of 478 feet above the sea, or about 90 above the river, where it departs from the main valley. This extends along Gully brook, sloping in two miles to 460 feet, nearly representing in height the normal upper terrace of Connecticut river. We find this normal line shown on the Vermont side by a nearly constant height of this terrace, varying between 470 and 460 feet for more than seven miles, from above Hall's brook to the south line of Bradford.

Delta of Wait's River. We thus exclude, on the north from Bradford village, the principal plain, which is from 10 to 15 feet above this upper terrace, being highest at its south end, and the still higher terrace of the fair-ground, and on the south the conspicuous remnants of the ancient delta of Wait's river, which are more than 100 feet above the Connecticut normal line. These terraces have all been deposited by Wait's river, which seems to have first thrust its high delta into the main valley, whose strong currents undermined and removed a large portion, leaving the rest with a steep escarpment; afterwards most of this delta was channelled out by its parent stream and carried down into the main valley, by which the terraces north of Bradford were formed; and, lastly, it has also swept out a large amount of the upper Connecticut terrace east of the village.

For a mile from the mouth of Wait's river southward, the number of terraces is multiplied to five or six in ascending 75 feet from the river to the wide upper plain. These furnish the best examples seen on the Connecticut of *glacis terraces*, sloping steeply towards the river and gently away from it in a wave-like series, with from 5 to 10 feet difference in the height of successive crests.

Eastman's brook is the source of the modified drift on which Piermont village is built. This delta rises in two thirds of a mile nearly 200 feet above our normal line.

Delta of Jacob's Brook. We now encounter in Fairlee and Orford one of the most difficult problems presented on this river, in the abundant deposit of alluvial sand, which, between Sawyer's mountain and Morey's mountain, forms a high plateau, whose eastern edge overlooks the river, while its western slope descends towards Fairlee pond. The highest portion of this alluvium is 190 feet above the river and 155 feet above the pond. The highest normal terrace is well shown through these towns, varying from 75 to 55 feet above the river, or from 455 to 435 feet above the sea. This terrace appears in Fairlee, at its north line, south-west of

Shaw's mountain; next east below the plateau; southward from Fairlee village and pond; and at Ely station. In Orford it is wide north-west of Soapstone mountain, and the river road runs upon it south to Jacob's brook; in the village it is the terrace at the east side of the street; and from near the mouth of Sawyer's brook it averages one half mile wide for three miles south, leaving the river at the north line of Lyme, and extending along Clay brook nearly level to within one mile of Post pond. All the modified drift above this regular terrace, embracing the plateau east of Fairlee pond, the high terrace in Orford, which begins at the south foot of Soapstone mountain, and the high remnants at each side of Jacob's brook, must be referred to a common origin, being portions of an immense deposit brought down in the Champlain period by Jacob's brook.

This stream drains a large area west and north-west from Cuba and Smart's mountains, flowing through Orfordville into the Connecticut by a north-west course. An uncommon abundance of fine material was supplied from the melting glacier over this area, and the northward flood which transported it was turned up the valley by the vertical wall of Morey's mountain. For a time the accumulation was too great to be cleared away by the current of the main valley, which was filled by this deposit north to Soapstone and Sawyer's mountains. A wide avenue was next cut through this barrier by the Connecticut, which did not complete till a later date the deposition of its own flood-plain, the remains of which we have called its highest normal terrace.

A few measurements of this remarkable tributary deposit will indicate its extent and depth. It filled the valley for more than two miles north from Orford, averaging a mile in width. The ordinary height of the river here is 383 feet above the sea. The highest point of the plateau in Fairlee, a mile and a half north from the mouth of Jacob's brook, is 575; the lowest point where the current swept west across this plateau, one third of a mile south of the former, is 532; on the east side, a mile and a half north from the mouth of the brook, it is 530; and close at its north side, 565. Along its course we also find a large amount of modified drift, rising in a mile and a half to 690, or more than 100 feet above the comparatively level barrier which it had thrown across the Connecticut valley.

A peculiarly contorted band of clay (Fig. 6), in a layer of clayey sand, with regular strata of sand exposed for several feet both above and below, was seen on the north side of a cart-road which ascends the east bluff of the Fairlee plateau, opposite the house of William Childs.

The shores of Fairlee pond are mostly rugged ledgy hills, and scarcely any alluvium has reached them, either from the plateau of Jacob's brook or from inflowing streams. This pond is 35 feet above the river, and is from 40 to 45 feet in its greatest depth, the bottom being principally sand. It seems not to have been filled with alluvium, simply because it was not in the path of the current; and the steep escarpment of the plain bordering its south end is probably due to its undermining waves. Several glacis terraces were noted south-west of Ely station.

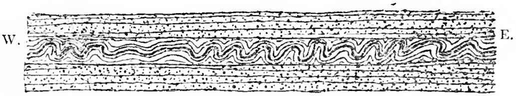


Fig. 6.—FOLDED LAYER OF CLAY IN HORIZONTALLY STRATIFIED SAND, FAIRLEE, VT. Scale, 1 inch=10 feet.

In Thetford and Lyme we come to an abrupt change in the height of the upper terrace-plain. We have seen this line descend, in 33 miles between the mouth of Passumpsic river and the south line of Orford, from 650 to 440 feet above the sea, gradually declining from 190 to only 60 feet above the river. At North Thetford this line of the highest terrace suddenly rises to 525, and in a mile and a half farther south to 545 feet. This formation is well shown through Thetford, with remnants in Lyme, and continues well developed and nearly level for twenty-five miles to Windsor, varying from 560 to 500 feet above the sea, and from 150 to 220 feet above the river. It forms extensive terraces or plains on one or both sides along this whole distance, and is clearly the original flood-plain of the river. Frequent delta-terraces rise above it, sometimes 100 feet higher, being more than 300 feet above the present river channel. It is a notable coincidence, that along this same distance we have a continuous kame, occupying the centre of the valley, commonly rising somewhat above the highest plain, but not seldom entirely covered by it. Superposition and conformable stratification show the fine material of the terrace-plain to have been deposited upon this kame or gravel ridge, which beforehand extended like a windrow along the empty valley. To the south from Windsor the highest terrace shows a somewhat regular slope, descending with the river, and preserving a height about 150 feet above it.

This high and continuous flood-plain, extending from Thetford to Massachusetts line, seems to have been formed during a gradual and slow melting of the ice along this distance. It would appear that the greater part of the depth of ice, as far northward as to the Passumpsic river, had been melted in the last part of this time, sending down its floods laden with gravel to form the kame. A comparatively shallow mantle of ice remained, and when the melting advanced to the north from Thetford and Lyme this disappeared too rapidly to give time for the formation of a kame, or the deposition of a high flood-plain.

At the north line of Thetford, near Ely station, the highest terrace is 435 feet above the sea, or 55 feet above the river. This is the south end of the continuous descending slope from the mouth of Passumpsic river. The first intimation of change is a high terrace, which rises from 475 to 545 feet in going from one mile north to one mile and a half south of North Thetford. Opposite to this place in Lyme the alluvium does not appear as usual in distinct terraces, but lies in a slope rising from 400 to 450, and at one mile north to 490 feet. South from North Thetford the high plain averages one half mile wide for eight miles, extending half way through the town of Norwich. Along this distance in Lyme and Hanover only narrow terraces of corresponding height remain.

Child's pond, situated on the high plain one third of a mile north of East Thetford, is worthy of notice. No terrace occurs here below the plain, which has been so undermined as to slope from its top to the river at an angle of 45°, excepting only the width of the railroad bed built on its side near the bottom. Eighty-five feet back from the edge of this plain, with a road between, is the pond, occupying some two acres, 142 feet above the river, and by our soundings 40 feet deep. Its range from high to low water is said to be one foot and a half, with outlet to the west, but no inlet; and its surface is only from two to five feet below the plain on its east and south-east sides against the river. The clayey character of this alluvium is shown by the impervious bank which holds in the pond. The circumstance that only so narrow a width intervenes between the pond and its edge is not specially remarkable, as this plain was originally continuous across the valley, all its east portion having been excavated by the river. The question which we see no satisfactory way to answer is, How came the hollow which contains the pond to be formed or left vacant, when the material of the otherwise nearly level plain was deposited? Probably it marks the site of a mass of ice, broken from the glacier, brought down by the flood, and finally stranded at this spot. The principal objection to this hypothesis is the rapidity of deposition required.

A large amount of modified drift has been brought down by Grant's brook, forming the plain on which Lyme village is built. The common has a slope of fifteen feet, and in a short distance farther east the same deposit rises eighty feet more, to 635 feet above the sea, or 90 feet higher than the water-shed between the village and Post pond.

Ancient River-bed. In Norwich occurs the most interesting example seen by us of a well-marked ancient river-bed high above its present level. This extends two miles from Pompanoosuc river, one third mile above its mouth, to the bend of Connecticut river a half mile south of Tilden pond, which lies in a depression of this old channel. Its highest point, from which there is a gradual descent both ways, is 520 feet above the sea, or 145 feet above the river. West and south-west from this point is a plain, from 30 to 40 feet higher; at the north-west the alluvium forms a delta-like slope with no level top. South-west from Tilden pond the original high plain has been excavated by springs and small streams to a very irregular surface of hillocks and ridges. On the east side of this ancient channel is the steep gravel kame, which for a while turned the Pompanoosuc river in this course, till a direct passage was cut through its ridge.

Norwich village, 525 feet above the sea, is situated on a terrace-plain of Bloody brook, which extends three fourths of a mile above the village, rising 30 feet. At one mile south the modified drift on the Vermont side is interrupted by a ledgy hill.

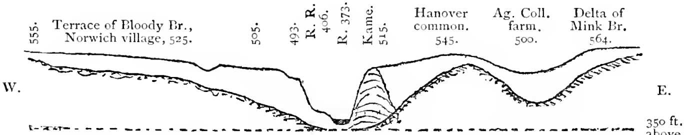


Fig. 7.—SECTION IN NORWICH AND HANOVER. Length, 3 miles.

Two miles north of Hanover the Connecticut river has cut through the kame, and thence flows close on its west side to White River falls. Along this distance of four miles we find the high plain well developed in New Hampshire, averaging three fourths of a mile wide. Hanover common, 545 feet above the sea and 172 above the river, represents its greatest altitude. Westward, a gradual slope descends 30 feet in one third mile to the kame; one third mile east the farm of the agricultural college is 45 feet lower than the common; and we have the same height one mile south, at the highest portion of the road to West Lebanon. Observatory hill, and others in Norwich and Lebanon, are examples of outcropping ledges and till, surrounded by alluvium. Half a mile south-east from Hanover, a delta 20 to 40 feet higher than the common has been brought down by Mink brook, which, west from this point, has also excavated a large amount from the plain. On the roads to Lyme and West Lebanon such erosion as this exposes a *clayey stratum*, noticeable in the spring by remaining muddy after all the rest of the road has become settled and dry. Two miles north of Hanover this stratum appears from 488 to 503 feet above the sea, most notably at the height of 495; a mile and a half south, at the north side of the Vale of Tempe, its height is 482; on the south side, 479 to 482; a mile farther south, on the north side of Mink brook, it appears from 503 to 480, being most marked at 485; on its south side it occurs at two points, with heights 470 and 478 to 483, the last being most prominent; and about a mile farther south, at the descent just before the turn-off to the falls, it is very noticeable, with about the same height. It also occurs in Vermont at a corresponding height, just below the top of the ascent between the depot and Norwich village. This extensive and nearly level stratum shows that deposition took place gradually and at the same time over this whole area.

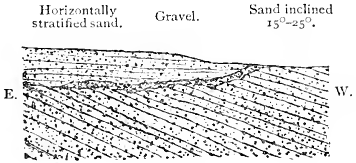


Fig. 8.—Section in Delta of Mink Brook, Hanover. Scale, 1 inch=20 feet.

The lower sand shows the usual stratification of the outer part of a delta, dipping towards the open valley. A current of water has eroded a portion of this, bringing a bed of gravel, upon which rests a later deposit of sand.

In digging the first well at Hanover (near the residence of Prof. H. E. Parker) a large log was found in this alluvium 40 feet below the surface, but no prospect of water, which caused this site, selected for the buildings of Dartmouth college, to be abandoned, and led to their location farther east, upon coarse glacial drift. This log was at nearly the same level with the clayey stratum described, and adds to our knowledge of the conditions which prevailed at the time of its deposition. The glacial age had here been succeeded by a temperate climate, under which forests grew again upon the land; and floods, sent out freighted from the melting ice-sheet, which still remained farther north and on the highlands, brought down drift-wood to be buried with this alluvium. It was not till long after this that the river ceased its work of accumulation and began to cut its present channel.

Veins of segregation in sand, attended in some instances by a slight displacement or fault, are well displayed at the present time by the fresh washing away of the bank, a portion of the high plain, on the south side of the road between Hanover and the depot. These veins abound for 200 feet or so east from the kame, a good section of which is also shown here; they are in somewhat obliquely stratified sand, which inclines conformably where it overlies the side of the kame.

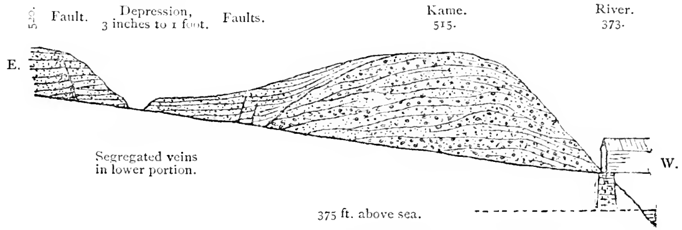


Fig. 9.—Section on south side of road, east from Ledyard Bridge, Hanover. Length, about 700 feet.

Between Hanover and White River Junction the Connecticut descends 40 feet, principally at White River falls (vol. i, pp. 302* and 319), situated two miles above the mouth of White river, and three miles above that of Mascomy river. An illustration of the terraces on the west side of these falls, as seen from Colburn hill in Lebanon, appears in Dana's *Manual of Geology*.† The upper terrace is wide, with a height 525 feet

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* The survey for this map was made when the river was above its ordinary height, which is at Hanover 373 and at White River Junction 333 feet above the sea.

† First edition, p. 548; second edition, p. 544.

above the sea, or 190 feet above the river at the foot of the falls. The middle terrace here rises in going south from 435 to 455 feet; and its material, well shown by a long railroad cut a sixth of a mile west of the upper falls, is mainly fine and coarse gravel, quite in contrast with the more common sand and clay. This difference in material is clearly explained, however, by a gap in the kame, which has been cut through and swept away by the river above the falls and on the north-west side of this terrace, which has been formed from it. Tributary streams have also often brought down coarse gravel deposits, forming deltas or contributing to the normal high terrace-plain, which on this account is often difficult to be precisely distinguished. Mascomy river, in Lebanon, and Little Sugar river, at North Charlestown, especially, have brought in these coarse deposits in large amount, changing the character of all the modified drift to a mile below their mouths.

A quarter of a mile south-west from White River Junction we find an ancient bed of White river, similar in position and height, and formed and deserted under the same causes with that of Pompanoosuc river (p. 37). This is a nearly level depression, 300 to 400 feet wide, 25 feet below the alluvial plain on the west, and 60 feet below the gravel ridge or kame on the east. Its height is 154 feet above the river on the north, or 487 feet above the sea. It descends only three feet in going 1,000 feet to the south, where the high plain in which it was formed, and the ridge which was its eastern barrier, have both been washed away.

Through Hartford and Hartland the upper terrace is well exhibited, of a normal height 525 to 500 feet above the sea, or nearly 200 feet above the river, and reaching one third to one mile back from it; but in several places this is broken by hills of ledge or till, isolated or extending across it nearly to the river. Its normal height is increased 40 to 80 feet by

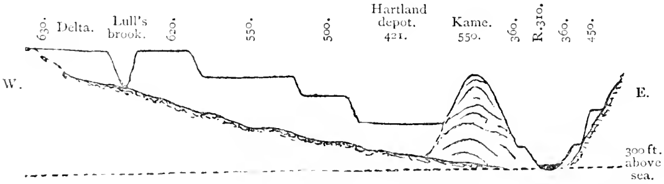
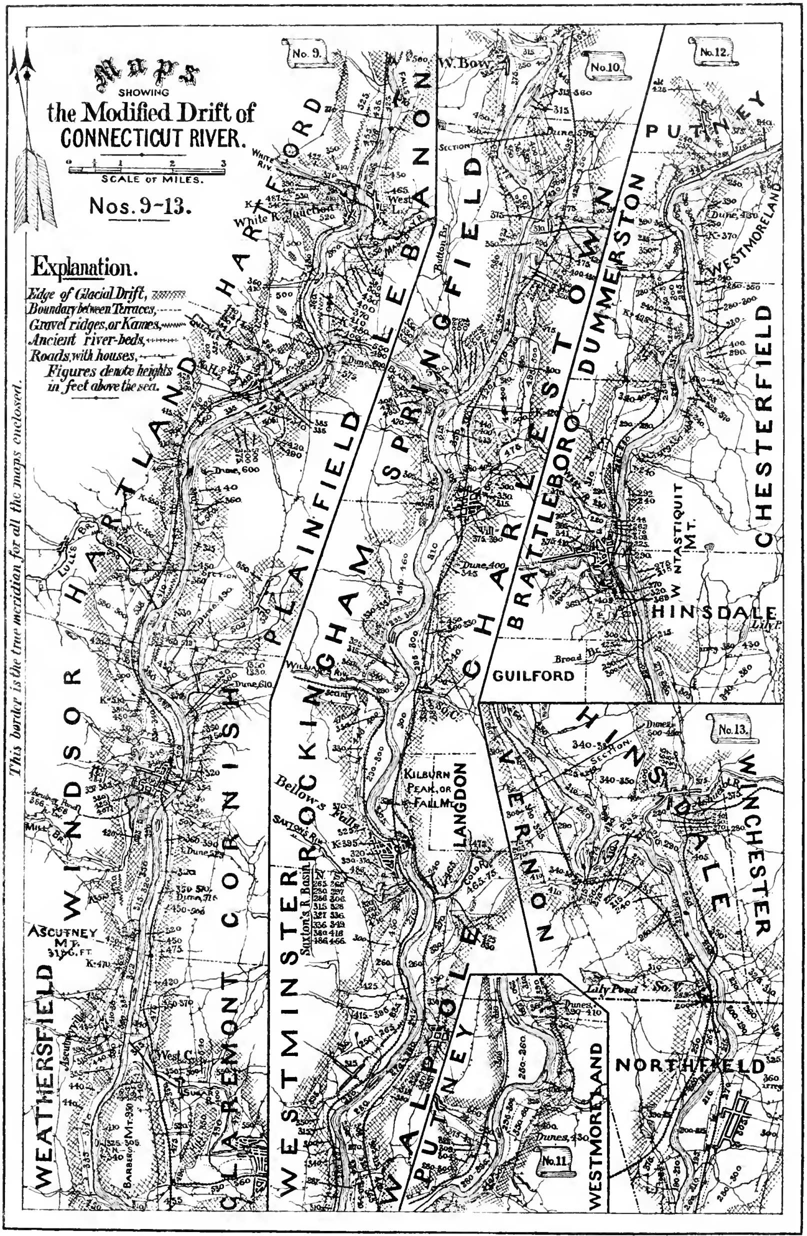


Fig. 10.—SECTION IN HARTLAND AND PLAINFIELD. Length, 1½ miles.

Plate III.



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tributary alluvium for two miles south from Quechee river, and for one mile south from Lull's brook. A level-topped delta, on both sides of the latter at its opening into the main valley just south of Hartland village, is 320 feet above the river, which is less than a mile distant. This high delta is terminated by a steep slope of from 25 to 40 feet, below which, at the south, there is no line of separation between the additions from this brook and the ordinary highest terrace; but the whole shows an irregular surface of smoothly rounded hills and hollows, formed by small streams. Similar erosion has taken place west of North Hartland. This cause has frequently destroyed the true shape of these high plains, originally level, and bounded by a steep escarpment; instead of which we now find sloping buttresses, ravines, and scattered knolls and ridges, in a confusion quite opposite to the beautiful system and regular form of the terraces.

In Lebanon and Cornish steep hills of till or ledge come quite to the river at the lower descent of White River falls and opposite Windsor village; in Plainfield the hill comes near the river at Sumner's falls, and opposite Hartland village the alluvium is thus reduced to a very narrow strip for a mile. No very broad development of modified drift occurs in either of these towns. Of the original high plain we find only scanty remnants; the intermediate terraces are present, but as usual of small width; of the lowest terrace we have at the mouth of Mascomy river the largest expanse that occurs in the twenty-four miles along which the kame remains, but this comprises only about half a square mile, and it is mostly above the reach of high water.

The readiness with which the fine, loose modified drift may be channelled out by rivulets or springs is often shown by long, deep gullies extending from the edge of a terrace directly across some field, whose level surface was never before marked by any water-course or hollow. Such a gully, fifteen rods long, two to four rods wide, and fifty feet deep, has recently been made in a terrace 100 feet above the river, at a point two miles south of West Lebanon, on the east side of the river road, which was undermined and turned aside by it.

Dunes. Near the south line of Lebanon, east of Sumner's falls in Plainfield, and at several places in Cornish, we find banks of sand, or dunes, destitute of vegetation, and blown in drifts by the wind. These vary in height from a few feet to 100 feet above the highest terrace, from which they appear to have been carried up by the prevailing north-west winds. Southward they are found in many places on the east side of this valley, but none were seen in Vermont.

Deltas. A large amount of modified drift occurs on Blow-me-down brook. Three miles from its highest source, where the road crosses Croydon mountain, it has formed the plain of Cornish Flat, 855 feet above the sea, and six miles lower that of Plainfield village, 520 feet above the sea, with an older deposit 30 feet higher, at the north end of the village. Two miles farther down, where this stream opens into the broad valley, it has formed a delta of irregular slope from 512 to 420 feet. These tributary deposits often throw light on the history of the modified drift of the main river. We have seen that the deltas north of the continuous kame, as of Wait's river at Bradford, and Jacob's brook at Orford, were deposited before the completion of the original flood-plain of the Connecticut; but the deltas of Quechee river and Lull's brook appear to have been brought down at about the same time with this upper terrace, which is notably increased in height by them for a considerable distance; while the long sloping delta of Blow-me-down brook, covering a square mile and descending to nearly 100 feet below the normal highest plain, seems to be of a date subsequent to its formation and partial removal by the river. A conspicuous dune at the east side of this delta, derived from it and from the original high plain, is 610 feet above the sea, or 100 feet higher than the deposits from which it was blown.

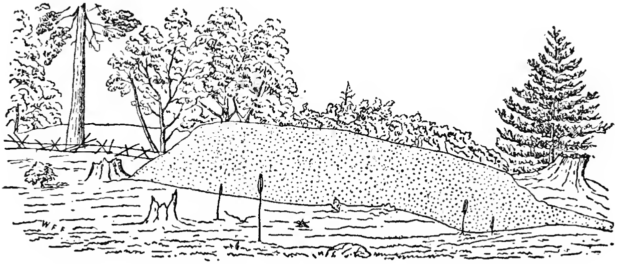

Fig. 11.—Sand Dune, near the South Line of Lebanon.

The Kame of Connecticut Valley.

From Lyme to Windsor we find a continuous gravel ridge or kame, extending twenty-four miles along the middle and lowest portion of this valley, with its top from 100 to 250 feet above the river, or from 500 to 600 feet above the sea. Its material is gravel and sand, in irregular, obliquely-bedded layers, always showing an inclined, and in most cases a distinctly anticlinal or arched, stratification. The sand is usually coarse and sharp, well suited for masons' use. It occurs in layers of varying thickness up to one or two feet, but sometimes it is wholly wanting. The gravel, which always forms the principal part of the ridge, varies in coarseness, from layers with pebbles only one or two inches in diameter, to portions where the largest measure one and a half or two feet. The finer kinds prevail; and the channels of brooks cutting through the ridge frequently show no pebbles exceeding one foot in size. All the materials of this kame, and of its remnants along this valley, are plainly water-worn and stratified.

Large and unworn boulders, which could not have been brought in the same way with the gravel and sand, occur very rarely upon or in the Connecticut kame. Except at its south termination, the only instance of this discovered was three fourths of a mile south of Pompanoosuc river, at the point where the kame reaches its greatest height above the sea. Two angular boulders, each of five feet dimension, were found here at the top of the ridge, one lying on the surface, and the other partly imbedded. This place was covered with a thick growth of sapling white pines. Several miles at least of journey on foot along the top of this ridge, and the examination of many sections where the river or its tributaries have cut through it, failed to reveal other boulders of this kind.

One or both sides of this kame are generally covered by the alluvium of the upper terrace, which plainly was of later deposition; but the top usually projects in a long, rounded ridge, 10 to 30 feet above the adjoining highest plain. At one place, east of Hartland depot, this plain has been swept away from both sides, and the kame forms a conspicuous, steep ridge 125 feet in height. Wherever it is exposed, it is readily recognized by the pebbles which strew its surface, and which are very rarely found in the ordinary modified drift of the valley.

The most important feature of this kame, if we compare it with others in New Hampshire, is, that along its entire extent it constitutes a single continuous ridge, which runs by a very direct course nearly in the middle of the valley, having no outlying spurs, branches, parallel ridges, or scattered hillocks of the same material associated with it. The kames in the Merrimack valley and in eastern New Hampshire also average much coarser, and more frequently contain angular boulders, while in some places they show a gradual transition from sand and water-worn gravel to unmodified moraines.

This remarkable ridge shows the course of the glacial river by which the floods from the melting ice, laden with gravel, sand, and clay, found their way between ice-walls to the open valley below. All the material which was thus brought down was probably gathered from the melting surface of the ice-sheet; and the pebbles were rounded in being carried along by its streams. Near the mouth of the channel in which these waters flowed, a portion of their gravel and sand was deposited with the alternation of summer and winter. Elsewhere, kames may have been formed by rivers beneath the ice-sheet; and when many boulders are contained in them, or found on their surface, they seem to be most readily explained by supposing them dropped from a melting roof of ice. It is at least plain, that if any kames have been formed under the ice, they must contain many boulders derived from this source. In nearly all the kames of New Hampshire it seems more probable that the angular materials and large boulders, which we find associated with these water-worn deposits, were brought by the same currents, frequently in floating masses of ice. Their infrequency here puts it beyond doubt that the kame of Connecticut valley was formed in an open ice-channel. It is probable that this did not extend at one time over the whole distance where we find the kame, but that it was gradually formed as the melting advanced northward, which was at so slow a pace that for a long time walls of ice enclosed the deposits of the glacial river. After these walls melted, the gravel and sand remained in a long, high ridge, which became nearly covered by the subsequent slow deposition of the high alluvial plain.

When the river entered upon the work of excavating its present channel in the alluvium, the kame was a barrier which confined erosion to the area on one of its sides and protected its opposite side; so that this ridge of gravel often forms the escarpment of a high plain, with the river flowing at its base. On this account we find the upper terrace occupying a greater width along the course of the kame than it averages elsewhere in this valley.

In calling this kame continuous from Lyme to Windsor, it is not meant to imply that it is now entire, since it has been frequently cut through and considerable portions swept away by the main river and by tributary streams; but that so much of it remains as to make it certain that it originally formed an unbroken ridge. The portions now separated by gaps always lie in a continuous line.

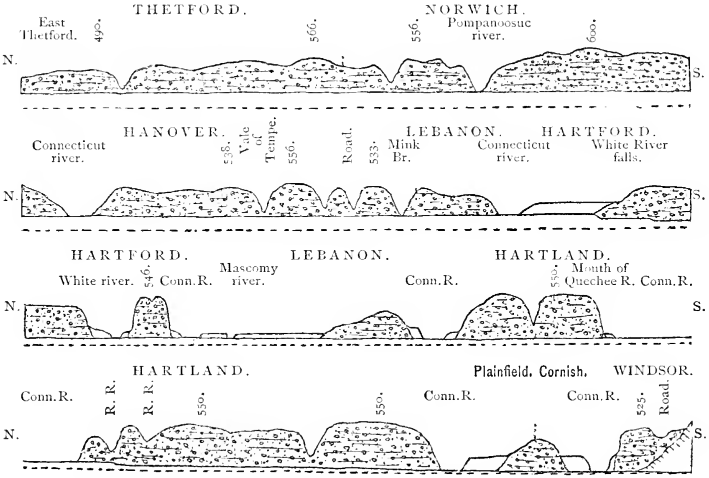

Fig. 12.—Profile of the Kame of Connecticut Valley (24 miles; vertical scale, 1 inch=800 feet).

The dotted line marks a height 300 feet above the sea, and the line next above represents the river.

The first evidence that we find of this ridge is a coarse gravel deposit on the south side of a hill in Lyme, one mile north of the mouth of Grant's brook. For about one mile south from this point it has been carried away by the river. It then commences about one third of a mile south-west of the railroad station in Thetford, and thence extends southward with the profile shown in Fig. 12. It is nearly straight four miles to the mouth of Pompanoosuc river, which has cut through it, but was at first turned south by it, as shown by an ancient river-bed (p. 37). There is a slight bend in the kame at this point, but it continues with very nearly the same course eleven and a half miles farther to the south line of Lebanon, where it bends with the valley. It has no long gaps in the first half of this distance above White River falls. The Connecticut has formed for itself a more irregular course than this of the old glacial river, first flowing with the kame at a considerable but varying distance on its west side; then, about two miles south of Pompanoosuc river, it cuts through this ridge, which thence through Hanover and Lebanon forms its high east bank to these falls. Gaps have been made in Hanover at the Vale of Tempe, at Webster's vale, at the road to the bridge, and by Mink brook. The second and third places are outlets of long gullies, which now have no running streams.

At White River falls one mile of the kame has been removed by the river, giving coarse materials for terraces below (p. 40). It appears next in Hartford, where it is cut through by White river, south of which a good section of it is shown only a stone's throw from the Junction depot. Next, about a mile and a half has been swept away by the Connecticut, across the area now occupied by the low terrace at the mouth of Mascomy river. A remnant is found in the south part of Lebanon, but it is soon crossed again by the river, and then continues a mile on the west side from the north line of Hartland to the mouth of the Quechee river. From this point, for two miles to Sumner's falls, it has been washed away by the Connecticut, which probably occupies nearly the former place of the kame. Thence it forms a high ridge close upon the west side of the river for nearly three miles to the mouth of Lull's brook. Next a remnant appears on the east side, at the line between Plainfield and Cornish, south of which it is cut through by the Connecticut for the seventh and last time. A section of it is exposed here on the south-west side of the river and railroad, where the largest pebbles seen were a foot in diameter. Thence it is well shown for a third of a mile south, reaching somewhat above the highest terrace, but with a natural gap 40 feet below its general level where it is crossed by the road. It terminates a short distance farther south-west, resting upon the side of a ledgy hill, about one mile north-west from Windsor village. The portion south of the road has a few boulders on its surface, which takes the form of a terrace.

Probably a similar gravel ridge once existed along the valley southward, though now shown by only a few fragments; and it seems proper to add here whatever facts we have on this subject. Gravel, which is unmistakably that of the kame, was seen in the west part of Windsor village, exposed by excavation at a street corner some 500 to 600 feet north-west from the dam of Ascutney pond. Here all of the kame that was above the street has suffered erosion, and all else seen was fine alluvium. On the east side of Ascutney pond we find a high, nearly level-topped area of kame-like gravel. This extends from north to south about three fourths of a mile, being one eighth of a mile wide, with a steep escarpment on each side. This seems to be a kame deposit, wider than usual, and resembling the high plains or broad ridges of the same origin about Dover and southward near the coast. The south end of this deposit rests upon the north end of a ledgy hill. A mile and a half farther south we find distinct remains of the kame close upon the west side of the river road, extending about one mile with equal portions in Windsor and Weathersfield. This forms the east border of a high terrace, both kame and terrace being 150 to 170 feet above the river. The material of this kame is plainly shown by excavations made for repair of the road, and it is like that which uniformly prevails in the long range from Lyme to Windsor. Thus we find frequent gravel deposits which are probably remnants of a former kame along the first five miles south from the end of the undoubtedly continuous range. It is noticeable that here the kame was near the west side of the valley, with its continuity broken by hills.

In the next eleven miles no indications of the kame were seen. It is then quite well shown for one mile in Charlestown, first appearing where the railroad cuts the high terrace south of Beaver meadow. This exposes a section of the underlying kame, and between Springfield station and the Cheshire bridge it forms a gravel hill, with a height in both places 130 feet above the river, or 420 feet above the sea. Eight miles intervene before we find its next remnant, which is a pine-covered plateau, used as a picnic ground, in the north part of Bellows Falls village. This is 75 feet above the streets that surround it, 112 feet above the river at the head of the falls, and 395 feet above the sea. At its north end a section is exposed, which shows this to be a portion of a kame by its material, which is the characteristic coarse gravel, and by its anticlinal stratification. The next fifteen miles afforded no evidence of the kame. We then find three remnants of it in six miles, and below these nothing in the following fifteen miles, or to the end of our journey, which extended through Northfield, Mass. The first of these remnants was near the south-west corner of Westmoreland, 158 feet above the river and 370 feet above the sea. The second was a short distance south-west from Dummerston station, 215 feet above the river and 425 above the sea. The river has swept this away at its south end, and the railroad is here built across its terminal slope, which shows a fine anticlinal stratification. The most southern portion of the kame found remaining in this valley is at the north side of West river, lying on ledges between the railroad and the highway, where we have a well-defined gravel ridge 160 feet above the river and 360 feet above the sea.

These peculiar deposits, similar in material and stratification with the kame that extends from Lyme to Windsor, were plainly once more extensive than now, and probably are portions of an originally continuous ridge. Long gaps have been washed away in the southern half of the range, from Lyme to Windsor; and farther south the river has left only scanty remnants of this oldest modified drift of its valley.

Returning now to the later deposits, which have been shaped by the river into terraces, we will begin where we left them, at Cornish and Windsor. The original highest flood-plain of the river in these towns and through Claremont and Weathersfield seems to have sloped from 500 to 450 feet above the sea. The river from Windsor to Bellows Falls, 26 miles, has a very gentle descent from 304 to 283 feet above the sea. Hence it will be sufficient in this distance to state only heights above the sea, from which that above the river may be easily determined.

The terraces of Windsor village are very interesting. That at the depot and railroad is 330 feet above the sea; of the post-office, 354; of the street leading west past the state prison, 382 to 397, rising 15 feet in going a half mile away from the river. The last remains now in the form of an isthmus, having been channelled out by the river on the north side of this street to a depth of 60 feet, and to the same amount on the south side by Mill brook. The highest terrace, increased by a tributary, is shown farther west.

The railroad in Cornish and to within one mile of West Claremont, or for a distance of four miles, is built on one continuous terrace, from one sixth to one third of a mile wide, and sloping in this width some twenty feet towards the river. The west side of this terrace has a height of from 360 to 350 feet. A terrace of corresponding height extends nearly the whole distance opposite to this on the Vermont side. A narrow belt of interval is found much of the way between these terraces and the river, but for the last mile, at the north corners of Claremont and Weathersfield, they are separated only by the channel. These are plainly the remains of a former flood-plain, intermediate between those of the Champlain period and of the present time.

Several hills of ledge and till, entirely surrounded by modified drift, occur in this part of the valley. One of these, in Windsor, turns Mill brook north into Ascutney pond. Another occurs in Weathersfield, about one mile south of Ascutneyville. The largest of them is Barber's mountain in Claremont, which occupies an area more than two miles long by one mile wide, and reaches an altitude of 950 feet above the sea. This has smooth slopes of till on the north and east, but presents abrupt ledges on the west and south. It stands directly in the line of the river's course, so that as it is approached it seems at first to form a barrier across the valley. The Connecticut has always flowed by its present detour on the west side of this mountain. At its north end a remnant of the original high flood-plain is preserved, being 440 feet above the sea; and in Vermont this upper terrace is well shown for half a mile farther south. It is then wanting on the west side of the mountain and for more than a mile in Vermont, but reäppears at its south end on both sides of the river, being continuous on the west side to the north line of Springfield. Scarcely any alluvium remains at the west foot of the mountain. A very narrow strip, however, extends for a mile along the river's edge, notable for its slope of twenty feet in this distance from 325 to 305 feet above the sea. The opposite terrace in Weathersfield, about 340 feet in height, extends more than two miles, with a nearly uniform width of one sixth of a mile, west of which rises a high steep hill.

The high alluvium on the east side of Barber's mountain is the product of Sugar river, and while it was being deposited the Connecticut flowed in its present course. This is shown by the height and configuration of its surface, which tell its origin and mode of deposit. The railroad passes by this route, and the portion in which we are interested is from Sugar river to Claremont junction. East of the railroad Trisback hill rises 850 feet above the sea. This obstacle turns back the course of Sugar river at a sharp angle, whence it flows by a long bend on the north side of the hill. The channel of Sugar river is cut 150 feet deep in its original plain, over which its highest floods at the end of glacial time poured into the Connecticut valley by two routes, one as now north of Trisback hill and Barber's mountain, the other south of these towards Ashley's ferry. The highest portion of this plain in Claremont village is 565 feet above the sea, or 40 feet higher than the river above the upper dam. It thence slopes to 530 feet at one third of a mile east of the junction, and is shown on the east and north sides of the river to West Claremont, sloping to 540 feet. The deposits of modified drift which are cut by the railroad at Ellis's bridge, a mile south of Sugar river, and again just north of the junction, being respectively 515 and 500 feet above the sea, are remnants of these plains. They were both brought down at this time by the floods of Sugar river, the former on the north side, the latter on the south side of Trisback hill. The space between these deposits is a swamp, from 30 to 40 feet lower, showing that the supply was not sufficient for filling the whole area west of this hill.

The descent of Sugar river at Claremont village is 125 feet, of which about 100 feet is used for water-power. Below the foot of these falls it descends 100 feet more before it joins the Connecticut at 300 feet above the sea.

In Charlestown and Springfield the normal high flood-plain of Connecticut river was probably about 450 feet above the sea, or 150 above the river; but it is here more obscured by higher tributary deposits and the terracing process of erosion than in any other portion of the valley. It appears to be shown in the broad, uneven terrace west of Calavant hill; probably in that over which the railroad passes south from North Charlestown station; in the first terrace east and south from Beaver meadow, but not in that of the fair-ground and road northward, which is the delta of Beaver brook; in the terrace east of the cemetery at the village of Charlestown; and in the highest terrace, two miles long, above South Charlestown.

An interesting dune was noted on the north-west slope of Calavant hill, near the north line of Charlestown. Its height is 598 feet above the sea, or about 150 feet above the original plain from which it was blown by the north-west winds, as indicated by the sand-drifts, now principally covered by grass, that were left in its path.

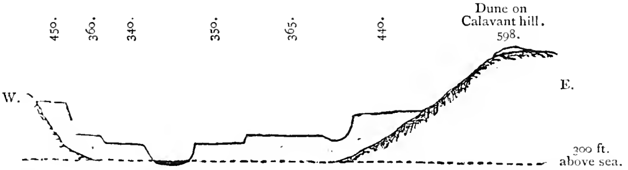

Fig. 13.—Section in Springfield and Charlestown near their north lines. Length, 1¼ miles.

South from Little Sugar river a high terrace of till, on which the road is built, extends a mile and a half to the east side of Rattlesnake hill. It is nearly level-topped, and of about the same height in its whole length, being 550 feet, sloping to 540 feet above the sea. This terrace is composed of till, apparently unstratified and scarcely modified, except so far as its terraced form may be due to water. This is the upper till, distinguished by its comparatively loose and sandy character. The underlying member is exposed by the gully of a brook near the school-house, being a blue, very compact, stony clay.

In Springfield the whole or a part of the modified drift, lying between 320 and 350 feet above the sea, presents an irregularly sloping contour for four miles, from the north line of the town nearly to Skitchawaug mountain.

In Rockingham, opposite the south part of Charlestown, we find two considerable areas, which appear to be remnants of the river's highest plain. One of these, more than a mile long by two thirds of a mile wide, is in the north part of the town, bordering the river. The second is as long, but only one fourth mile wide, extending to the south from near the mouth of Williams river.

Deltas. Three prominent deltas occur in these towns, the products of Little Sugar, Black, and Williams rivers, with heights respectively 530, 520, and 500 feet above the sea. The greatest extent of these deposits now remaining is in each case on the north side of the stream. Only the upper portion of the delta of Little Sugar river is of the height mentioned. Its principal mass is 50 feet lower, being the terrace cut by the railroad one third mile north of the river. It is almost wholly composed of gravel, in which the largest pebbles are one foot in diameter. In the midst of this gravel a stratum $1\frac{1}{2}$ to 3 feet thick, consisting of clay in layers a third of an inch thick, interstratified with a clayey sand, was exposed for 75 feet on the west side of this cut. Along half this distance it was levelly stratified, but beyond was irregularly crumpled, as shown in Fig. 14, apparently by lateral pressure.

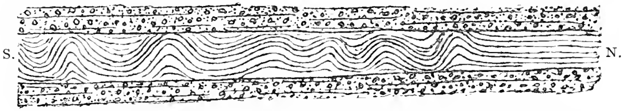

Fig. 14.—Folded Clayey Layer in horizontally stratified Gravel, North Charlestown. Scale, 1 inch=10 feet.

The wide, high delta of Black river has been cut through by Button brook, and has been variously terraced both by this brook and by Black river. A considerable portion of its plain between these streams is covered by heavy white pine woods. This delta increases the height of the upper terrace for more than two miles southward. The delta of Williams river is less extensive than the preceding, and at the same time has less thickness, as it has been partly protected from erosion by ledges, which in some places form its border.

Two miles north from Williams river the west bank of the Connecticut exhibits an interesting section (Fig. 15) of synclinal strata of clay and sand eroded to a level top, and overlaid by levelly stratified sand. The synclinal deposit appears to be the lower part of that which once filled the valley. After its upper portion had been carried away, the overlying sand was brought in by a tributary, and subsequently terraced by the river. The most noticeable feature of the modified drift north and south from here is the wide interval or meadow, which extends from Charlestown village to Bellows Falls, and lies partly on each side, being several times crossed by the river.

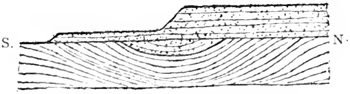

Fig. 15.—Section of River-Bank, Rockingham, Vt. Scale 1 inch=100 feet.

From South Charlestown to Cold river the precipitous face of Kilburn peak or Fall mountain forms the eastern boundary of the modified drift. Opposite Bellows Falls this leaves scarcely room for the railroad and the highway between it and the river. The height of this mountain is about 1,200 feet above the sea. The water-shed on its north-east side in Langdon, between the brook which flows into the Connecticut at South Charlestown and one of the branches of Cold river, is a swamp one sixth of a mile wide, 458 feet above the sea, or 175 feet above the river. Modified drift, mainly coarse, extends south from this water-shed to Cold river. It was formerly supposed that the modified drift was deposited at a time when the valleys were made a series of lakes by the existence of barriers since swept away, and the narrowest space at Bellows Falls was regarded as the probable site of such an obstruction. No evidence pointing to this was seen by us here or in any other portion of the valley, except so far as deltas, the ridge of the kame, or other unusually high deposits of modified drift may have acted in this way for a short time. It is obvious that with any high barrier here the river would have found passage over the low water-shed north-east of the mountain.

At Bellows Falls the river descends 49 feet (from 283 to 234 feet above the sea), through a narrow, water-worn channel of rock. Distinct glacial striæ are seen upon these ledges at the head of the falls. The original highest plain seems to be shown by the upper terrace, 425 feet above the sea, which extends one mile north from the falls on the east side. This is about 30 feet higher than the remnant of the kame (p. 47), around which the high plain has been wholly swept away and the principal terrace of the village formed, from 325 to 320 feet above the sea. This area of fine alluvium extends a third of a mile west from the falls, and it is almost certain that somewhere beneath it is a rocky channel lower than the head of the falls, in which the river flowed before the glacial period. In excavating the modified drift which was afterwards deposited, the river has formed its present channel close upon the east side of its valley, passing over ledges which are probably much higher than its preglacial bed.

Cold and Saxton's rivers have brought down large amounts of modified drift 75 feet above the normal high plain. The proper delta of the former has been eroded so far as it occupied the main valley, but the escarpments thus formed remain at the mouth of the valley of Cold river, from 100 to 200 feet high. Thence a wide plain is found on the south side of Cold river for one mile, and again one half mile farther east at Drewsville. The west part of this deposit is sand or fine gravel, but in the east portion coarse gravel prevails.

On the south side of Saxton's river a considerable part of its delta remains, and the upper terrace is increased in height by this cause for two miles south. The excavation of this delta by Saxton's river has formed a most interestingly terraced basin, situated less than a mile south from Bellows Falls junction. On both sides of this river, and crossed by a road, is an interval about one fourth of a mile in diameter. Around this on all sides are ranged terraces, which rise in succession like the seats of an amphitheatre, the highest on the north-west being 220, and on the south 200 feet above the arena below. They do not, however, show a perfect regularity either in correspondence of height or in continuous extent, and no single section would embrace all of the eight distinct and separate terraces which we noted on each side of the river.

At Walpole village the limits between alluvium and till are not so distinct as usual. The highest terrace of the Connecticut appears to be shown here 395 feet above the sea, and it is nearly continuous southward through this town, descending to 360 feet at its south line, where numerous dunes occur 30 to 50 feet higher. Irregular terraces intervene between this highest level and the river.

In Westminster, opposite Walpole village and for one or two miles north and south, the modified drift is wide, and lies in beautiful, broad terraces. That of the village is 90 feet above the river, or 315 above the sea; another, 50 feet lower, extends one mile northward to the bridge.

Through Westmoreland and Chesterfield the upper terrace varies between 400 and 350 feet above the sea, the former height being reached by deltas three fourths of a mile south-west from Westmoreland depot and at and below the mouth of Catsbane brook. The modified drift in these towns is generally very narrow; but bends in the river give it a width of two thirds of a mile at two places in Westmoreland, one of which is a mile and a half south-west from the depot, and the other the same distance north from the south line of the town. At both these points dunes occur on the hillsides just above the terraces.

In Putney, Dummerston, and Brattleborough, opposite the foregoing, we find nearly the same normal limit of the modified drift, and increased height of that brought in by tributaries. A bend of the river at the north-east corner of Putney gives to that town a notable expanse of low terrace, covering three fourths of a square mile. Many of the terraces in Dummerston, especially for two miles north from the depot, slope more than is common towards the river, and are less distinctly separated by the usual steep escarpment. An interesting remnant of the kame occurs a third of a mile south-west from the depot (p. 48). At the west side of this ridge is a hollow of 100 feet, beyond which is an extensive deposit of kame-like gravel, which has been protected from erosion by a border of ledges on its south-east side. This has about the same height with the top of the kame, and appears to be of similar origin.

Two large streams—West river and Whetstone brook—join the Connecticut in Brattleborough. The latter flows through the centre of the village, supplying valuable water-power. A large part of its delta remains in the high plain at the south and south-west. The height of this a mile west of the river is 425 feet above the sea; at the Catholic cemetery, 409; at the fair-ground, about 400. Above the west part of this plain, however, a still higher delta, at 490 feet, has been formed by a small tributary of this brook. This is the highest deposit of modified drift found in this valley south of Bellows Falls. The height of Connecticut river here is 200 feet above the sea. In the north-west part of Brattleborough village there rises a ledgy hill, about 525 feet above the sea, below which on the west is a belt of alluvium, extending north from the delta of Whetstone brook to the valley of West river. Its northward slope shows it to be a part of the delta deposit of this brook. In the village erosion has removed the delta, giving on the north three principal terraces, 290, 308, and 341, and on the south two, 300 and 369, feet above the sea.

West river is situated one mile farther north, and is larger than Whetstone brook; but it is of less interest, because it forms an exception to a general rule, having apparently brought no delta into the Connecticut valley. It has, however, labored so abundantly in hollowing out its channel, that its course is through a beautiful basin, somewhat like that on Saxton's river, mainly overflowed at high water and bordered by terraces. On the north side of its mouth are the most southern remnants of the kame (p. 48); and on the south side an interesting series of secondary terraces, left as bench-marks of its progress in excavating the basin.

The view of New Hampshire from Brattleborough is similar to that from Bellows Falls. At both these places, the largest towns in Vermont on this river, its eastern shore is an abrupt mountain wall, against which no terraces or only scanty remnants are found. Wantastiquit or West River mountain extends nearly four miles, with about equal portions in Chesterfield and Hinsdale, and rises to an altitude about 1,200 feet above the sea. The lowest point of water-shed at the east, near the head of Catsbane brook, is by estimate 650 feet above the sea, or about 200 feet above the highest portion of the Hinsdale plain.

South-east and south from this mountain is the most extensive plain on this river in New Hampshire or Vermont, being three miles long, with a width decreasing from two miles to two thirds of a mile. The road from Hinsdale to Brattleborough passes over the south end of this plain. Here its height is 350 feet above the sea, or 165 above the Connecticut at the mouth of Ashuelot river. It is mainly composed of sand, nearly level, but with a slight slope to the west and south, being as usual towards the river and in the direction of its course. Its extremity, three fourths of a mile south-west from this road, is twenty feet lower. Northward, its west edge is about 340 and its east side probably as high as 380 feet above the sea. Its northern portion changes to gravel, which becomes coarse on the south-east side of Wantastiquit, containing pebbles one foot or sometimes a foot and a half in diameter. The position and slope of this plain show that it was not deposited wholly from currents of the main valley; evidently a considerable portion was contributed from the melting of the ice-sheet east of Wantastiquit mountain.

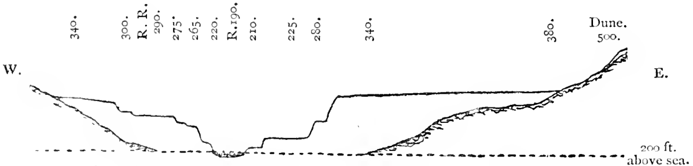

Fig. 16.—SECTION IN VERNON AND HINSDALE. Length, 3 miles.

Extensive sand-drifts or dunes blown from this plain occur on the hills at its east side for a mile and a half north from Hinsdale village. The highest of these at present drifted by the wind are about 100 feet above the east edge of the plain, but large amounts of sand now grassed over extend 50 feet higher.

Ashuelot river at Hinsdale, and for a mile east, is bordered by terraces but little higher than the plain. Slight remains of an older delta, about 400 feet above the sea, appear at its opening into the main valley, especially above the railroad east of its mouth. This stream, like Whetstone brook at Brattleboro', has formed numerous and interesting terraces in the alluvium of the Connecticut during the excavation of its channel to join that river.

In Vernon, a high delta of small extent occurs on the north side of Broad brook. An isolated plateau, 70 feet above the low terrace surrounding it, and plainly a remnant of the principal terraces north and south of this brook, is found on its south side close to the river. It has been cut through for the railroad. Another plateau, similar to this, but only 15 feet in height, is cut through by the Ashuelot Railroad, just north of South Vernon. For two miles north from Vernon village the modified drift averages one mile wide, and is very finely terraced; a half mile west from this village it consists of an extensive delta, 410 feet above the sea. One of the most picturesque portions of this river, as seen in our boat journey, was at this place in the circuit around Cooper's point, where the river is divided by islands, and frequent gneissic ledges are exposed along its shore. These islands, and others along the river, are in nearly all cases alluvial and within the reach of high water. For a half mile east from Vernon the current of the river, by reason of this bend, has been so directed against its south shore that scarcely any alluvium remains, instead of which we have an irregular slope of till and ledge.

Opposite Northfield village we find a prominent delta-plain of gravel, 390 to 375 feet above the sea; and the first brook north of this village has brought down kame-like gravel and irregular delta deposits of similar height. The normal highest plain of the Connecticut seems to be represented by the west portion of the Hinsdale plain; by the irregularly sloping terrace, which extends two miles north from Vernon, with its upper edge 340 feet above the sea; by an extensive terrace one mile east of Vernon, at 330; probably by terraces north and south of South Vernon, at 295 and 290; by irregular remains in the south part of Hinsdale, at 350, expanding into a plain in the south-west corner of Winchester, with a slope from 325 to 310; and by the plains at and south from Northfield village, about 300 feet above the sea, or 120 feet above the river.

An examination of the southern maps of Connecticut river (p. 40) shows a second apparently connected series of terraces, which probably marks one of the principal flood-plains formed by the river during its work of erosion. It exhibits a similar slope with that of the highest plain, or of the present river with its bordering intervals. This series is most clearly continuous below the north line of Brattleboro', but seems to be traceable from White River falls, where it appears in the terrace on the west, from 435 to 455 feet above the sea, formed from the undermined kame. It occurs north and south from West Lebanon, at 430 and 440; one mile south of Mascomy river, at 440; opposite to this, at from 430 to 410; at North Hartland and opposite, from 412 to 400; probably at Hartland depot, from 425 to 410; in the north-west corner of Cornish, from 380 to 375; at Windsor post-office, 354; in the terrace of the railroad for four miles southward, from 360 to 350; in the principal terrace opposite Barber's mountain, from 340 to 335; east of Weathersfield Bow, from 350 to 340; in the north part of Charlestown and Springfield, small terraces, 350; south from Black river, 360; on the road from Cheshire bridge to Charlestown, 350; in several places to South Charlestown, from 345 to 340; in the narrow curved terrace on which the road runs, one to two miles north of Williams river, from 335 to 330; in the principal terrace of Bellows Falls, and that of the Sullivan county railroad for one mile north, from 325 to 320; between Cold river and Walpole, 330; along the railroad, one to two miles south from Walpole, from 315 to 308; at Westminster village, 315; in scanty terraces, for five miles south, from 315 to 300; at East Putney and opposite, from 300 to 280; for eight miles southward, numerous terraces, sometimes irregularly sloping, from 310 to 290; in Brattleboro', from the north line to West river, a broad level terrace, 290; in the village, 290 and 300; at the mouth of Broad brook, the same; in the wide terrace of the railroad north from Vernon, 290; probably at Cooper's point, 274; opposite Ashuelot river, 275; at South Vernon, 270; on the west side of the river in Northfield, from 264 to 260; and on the east in a continuous terrace, varying from 270 to 260, extending from one mile south of Hinsdale to the limit of our map and survey, two miles south of Northfield village.

It will be seen that this list embraces the most conspicuous terraces below the highest plains. The formation of the terraces has taken place by excavation of a vast deposit that filled the valley level with these upper plains; and it might happen that at some period in the deepening of the channel the river would hold nearly the same height for a longer time than usual, after which the deepening might go on rapidly again, leaving the broad flood-plain then formed to be shown only by remnants, as in this series. At the least, it cannot be doubted that this is the true explanation of its most notable portions, as for the eighteen miles through Brattleboro' and southward, and for eight miles south from Windsor.

RECAPITULATION OF MODIFIED DRIFT OF CONNECTICUT RIVER.

PLACES.	Distances in miles from Conn. lake.		HEIGHTS IN FEET ABOVE THE SEA.			
	Direct course (valley).	Course by the river.	Connecticut river.	Highest normal terrace.	Highest tributary deltas.	Altitudes for reference, and remarks.
Labrador brook, . . .	5.4	5.6	About 1300	Above the river. 5		Fourth lake, 2551. Third lake, 2038. Second lake, 1882. Connecticut lake, 1618. Red school-house at the "Hollow," 6 miles from Connecticut lake, 1495. Hall's Stream bridge, 1098. W. Stewartstown bridge, 1053. " dam, 1049. Colebrook bridge, 1025. Columbia bridge, 1011. North Stratford station, 915. Beattie's (flag) station, 880. Stratford Hollow, 877. Groveton junction, 901. Hay scales, Northumberland Falls, 865. Lancaster court-house, 867. " station, 862. Sumner house, Dalton, 898. Upper Waterford bridge, 689. " " hay scales, 752. Railroad near the mouth of Passumpsic river, opposite high wooded island, 490. Barnet station, 467. Stevens River dam, 557. Barnet church, 602. McIndoe's station, 488. " church, 510. Monroe store and P. O., 540. Ryegate station, 471. Wells River station, 443. Railroad bridge, Connecticut river, 455. Woodsville station, 455. School-house, 1 mile S. E., 526. North Haverhill church, 506. " " station, 508. Haverhill town-house, 754. J. N. Morse's house, ½ mile south, 899. Newbury station, 426.
Deadwater stream, . .	7.5	8		10, S.		
Outlet of Back lake, .	8	8.5		10, N.	Above river. 30	
Indian stream, . . .	10.8	11.4		15, N.	30	
1 mile to south-west, .	11.8	12.4		40, W.		
Bishop's brook, . . .	14.3	15.2		15		
Hall's stream, . . .	15.2	16.3	1085	1120, N.	1120	
West Stewartstown and Canaan, ...	17.5	18.7	1049–1035	1100, W.	Leach str., 1100	
2 miles south, ...	19.5	21	1025	1080		
4 "	21.5	24	1017	1060		
Colebrook, ...	24.5	27.5	1010	1050	Beaver br. and Mohawk river, 1100.	
Columbia bridge, . .	28.3	31.7	992	1040, W.	Sims str., 1090	
Rapids 7 miles below Beaver brook, . . .	30–37	33.5–41	990–891	50–60 ab. riv'r		
North Stratford and Bloomfield, ...	37	41	891	1010, E.		
1½ miles south, . . .	38.5	42.6	880	980 W.		
3 " . . .	40	44.2	875	965, E. 950, W.	1000 W.	
5 " . . .	42	46.5	868	950, E. 930, W.		
6 " . . .	43	47.8	865	940, E. 930, W.		
Stratford Hollow, . .	45	51.5	858	935, E.		
1½ miles south, . . .	46.5	54.2	856	920		
Groveton, ...	49	58.5	854	900		

PLACES.	Distances in miles from Conn. lake.		HEIGHTS IN FEET ABOVE THE SEA.			
	Direct course (valley).	Course by the river.	Connecticut river.	Highest normal terrace.	Highest tributary deltas.	Altitudes for reference, and remarks.
Northumberland Falls and Guildhall, . .	51	62	852–842	900, W.		Haverhill sta., C. & P. R., 412. " court-house, 664.
1½ miles west, . . .	52.5	63.5	840	865, E. 900, W.	Gaskill br., 940	Bradford station, 410. Piermont station, 439. " M. E. church, 596.
3 miles north of Lancaster, ...	53.5	65.5	838	865, E. 870, W.		Shaw's mountain, about 750. Water station of railroad near Sawyer's mountain, 449.
Lancaster, ...	56.5	70	835	865	Israel's riv., 910	Fairlee station, 438.
South Lancaster and Lunenburg, ...	60.7	76.2	832	860		Orford bridge, 410. " street, 422. Morey mountain, about 900.
Mouth of John's river,	63.2	79	830	850	John's riv., 870	Fairlee pond, 415–419. Ely station, 433.
First half of Fifteen-miles falls, ...	63.3–74.3	79.1–90.5	830–674	Above the river. 40–60	Ab. r. Niles st., 70	North Thetford station, 402. East Thetford station, 413. Childs pond, 520.
Upper Waterford, . .	74.3	90.5	674	50–60	N. & S., 100	Lyme church, 558. Post pond, 430.
Lower Waterford, . .	77 3	93.5	643	50–200?		Water-shed between do. and Grant's brook, 545.
Fifteen-miles falls, below Lower Waterford,	77.3–82.3	93.5–98.8	643–465	150–200		R. R. bridge, Pomp. river, 409. Norwich station, 406. " church, 530.
Passumpsic river, . .	83.5	100	460	650		Hanover, College church, 552. White River Junction, 369.
Barnet, ...	85.4	102	452	600–618	Stevens riv., 675	R.R. bridge, Quechee riv., 370. North Hartland station, 388.
Monroe and McIndoe's falls, ...	87.6	104.9	440–430	588, E. 580, W.		Railroad summit, 1½ miles north of Hartland, 464. Hartland station, 421.
1½ miles south. . . .	89.1	106.5	427	575, E. 569, W.		B. F. Labaree's house, Hartland village, 620. Plainfield village, 520.
4 " . . .	91.6	109.2	420	555, E. 535, W.		Windsor station, 331.
Woodsville and Wells River, ...	95.4	113.7	407	520–530	L. Am. river, 632,N.; 628,S. Wells river. 600–660.	Railroad bridge, Connecticut river, 352. Vermont state prison, 389. Ascutney Pond dam, 386.
North Haverhill and Newbury, ...	100	120.5	398	505, E. 478, W.	505–752, E.	Balloch's crossing, south edge of Cornish, 368.
Haverhill and So. Newbury, ...	103.3	125.2	392	475, E. 469, W.	Oliverian br., 630–750.	West Claremont station, 404. High bridge (railroad) over the Sugar river, 405.
Bradford, ...	107.5	130.8	389	469–465	Wait's river, 583–600.	Railroad summit, ¼ mile north of Claremont junction, 478.
Piermont, ...	109.5	133.8	387	460, E. 465, W.	East. brook, 500–650.	Claremont junction, 473. Claremont station, 543.
1½ miles north from the mouth of Jacob's br.,	111.8	137	384	440	Jacob's br., 530 E.; 575, W.	Soldiers' monument — foot of shaft, 567. Upper dam, Sugar river, 525.
Orford and Fairlee, . .	113.8	139	383	435, E. 440, W.	Jacob's brook, 560–690.	Foot of falls, " 400. Trisback hill, about 850. Barber's mountain, about 950.
Ely station, ...	116.2	141.8	381	443, E. 435, W.	530, W.	No. Charlestown station, 416.
North Thetford, . . .	118.4	144.5	379	525 W.		Lowest point of railroad, in Beaver meadow, 314.
Lyme and East Thetford, ...	120 3	146.5	378	525–545	Grant's brook, 535–635.	Springfield station, 374. Skitchawaug mt., about 950. Rattlesnake hill, about 650.
North line of Hanover and Norwich, . . .	123.6	150	376	535		Oak hill, 625. Charlestown station, 375. So. Charlestown station, 302.
Pompanoosuc river, . .	125.2	151.6	375	545–552	590	Fall mountain, about 1200. Water-shed N. E. of do., 458. Bellows Falls junction, 304.
Hanover and Norwich,	129.8	156.5	373	500–545	Mink br., 586; 564. Bloody br., 585; and 555–525.	Minard's pond, 592. R. R. br., Saxton's river, 278. " Governor's br., 257.
West Lebanon & White River Junction, . .	133.8	160.6	333	510, W.	Mascomy r., 550.	Cold River station, 259. Walpole station, 277.
North Hartland, . . .	138.3	165.6	323	500	Quechee river, 550–650.	Westmoreland station, 512. Westminster station, 264.

PLACES.	Distances in miles from Conn. lake.		HEIGHTS IN FEET ABOVE THE SEA.		
	Direct course (valley).	Course by the river.	Connecticut river.	Highest normal terrace.	Highest tributary deltas.
Hartland,	142	169.5	311	500	Lull's brook, 630–620, etc.
Windsor,	146.3	174.1	304	500	Mill br., 540.
West Claremont and Ascutneyville,	151.3	179.1	300	475, E. 455, W.	Sugar r., 540, N.; 520, S.
Claremont (on the Sugar river),			Sug.r. 525–400	Sugar r. 560–500	
Weathersfield Bow,	155	183.8	296	455, E. 450, W.	
North Charlestown,	158	187.5	293	450	Lit. Sugar r., 475–530.
Springfield station,	162	191.5	289	450	Black r., 520. Beav'r br., 500.
Charlestown,	163.7	193.4	287	450	
South Charlestown,	167.4	197 5	284	450, E.	Williams riv., 500.
Bellows Falls,	170.5	201	283–234	425, E.	
1 mile south,	171.5	202	230	416, W.	Saxton's riv., 486, N.; 466, S. Cold river. 465–475.
Walpole,	174	204.8	226	395	
Westminster,	175.2	206.2	225	380, E. 385, W.	
Westmoreland and East Putney,	181	213	218	350–360	Slab-hol'w br., 345–375.
Putney,	184	216.2	215	350	Sackett's br., 365–385. Kame-like, W. 420–440.
Dummerston,	187	219.8	210	350	Catsbane br., 420–440.
Brattleborough,	192	225.2	200	341	Wh'tst'ne br., 409–425. Trib. to do. on S., 490.
North line of Vernon,	193.5	226.7	197	340	Broad br., 425.
Hinsdale and Vernon,	198	232.5	187	340	Hins. plain & N., 380–430. Ashuelot riv., 400; 365. W. of Vernon, 410.
South Vernon,	201.8	236.7	180	325, E. 295, W.	
Northfield,	204	239	177	305, E.	360, E. 375–390, W.

Altitudes for reference, and remarks.

Grout's crossing, 258.
East Putney station, 295.
R. R. bridge, Sackett's br., 262.
Putney station, 257.
R. R. bridge, 1½ miles S., 240.
" " Salmon br., 238.
Dummerston station, 262.
R. R. over road, 1½ miles S., 271.
R. R. bridge, West river, 244.
Brattleborough station, 228.
" Catholic cemetery, 409.
Wantastiquit mt., about 1200.
School-house, ½ mile west of Hinsdale village, 373.
South Vernon junction, 261.
Ash. railroad bridge, 237.
N. L. " " 234.
Northfield village, 305.
Bernardston station, 353.

Slope of the highest normal terrace.

	Miles.	Ft. per mile.
Hall's stream to 3 miles north of Colebrook,	6	10
" N. Stratford,	15½	3
" Groveton,	12	9
" Lancaster,	7½	5
" John's river,	7	2
" Passumpsic r.,	20	10
" Monroe,	4	15
" Woodsville,	8	8
" 2 miles north of Orford,	16½	5
" Ely station,	4½	0
" N. Thetford, in 2 miles h. n. ter. rises 85 ft.		
" Windsor, nearly level,	28	1
" Weath. Bow,	9	5
" S. Charlest'wn,	12	0
" Westmoreland,	14	7
" Hinsdale,	17	1
" Northfield,	6	6
Total distance,	189	4.3

MODIFIED DRIFT ALONG LOWER AMMONOOSUC RIVER.

Interesting deposits of modified drift are found on the Lower Ammonoosuc river. Its course through the wide basin at the south-west foot of Mount Washington, descending more than 1,000 feet in six miles from the base of the mountain railway to the Fabyan house, is almost continuously bordered by large amounts of water-worn gravel, and sand becomes abundant in the last two miles below the Upper falls. These deposits appear to have been formed at the disappearance of the ice-sheet, principally consisting of material contained in its mass and set free at its melting. Their origin was like that of the finer alluvium of the lowland valleys; and their date was at the end of the long period in which nearly all our deposits of this kind were formed.

Modified drift of similar character occurs upon the South Branch. At the Crawford house, where several mountain torrents fall into the valley and form this stream, a great depth of very coarse stratified detritus has been brought down. This superficial deposit forms the water-shed between the Connecticut and the Saco, carrying it a third of a mile north-west from the rocky summit of the pass, which is at the gate of the Notch.

A well marked series of kames, or ridges of very coarse gravel, extends along the South Branch from about a mile north of the Crawford house nearly to its mouth. It appears again on the north-east side of the Ammonoosuc, between the mouth of this branch and the Fabyan house. Here it forms a single steep, narrow ridge, from 30 to 40 feet high, around which the river passes in a long southward bend. This ridge is conspicuously seen from the railroads on the opposite side. The mound known as the "Giant's grave," which was levelled down for the site of the Fabyan house, was a similar ridge about 300 feet long. This was noticed by Sir Charles Lyell, in his journey through the White mountains, who says it presented "the same appearance as those mounds which are termed 'osar' in Sweden."* Other deposits of the same kind lie between this place and the White Mountain house, at the north edge of the alluvial area. This series of kames appears to have been formed by a glacial river, which was fed from the melting ice-fields of the Mt. Washington and Mt. Willey ranges. Similar kames, which were also formed by glacial streams tributary to the Ammonoosuc valley, are seen along the Cherry Mountain road south from its summit.

That the ice of this area, near the end of the glacial period, moved westerly down this valley, is shown by abundant morainic boulders, which have been transported from Mt. Deception to the Twin Mountain house, where the glacier seems to have paused after its retreat from the lowlands and the valley below. The kames which we have described mark its

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* Lyell's *Second Visit to the United States*.

diminishing extent at a later date. At both these dates great amounts of alluvium were brought down by its streams, forming a wide interval between the Fabyan house and the Lower falls, which fills what must at first have been a deep lake basin, and spreading out at and below the Twin Mountain house in an extensive low plain. The height of the former is from 1,560 to 1,550, and of the latter from 1,375 to 1,350 feet above the sea. Considerable deposits of modified drift occur at other points along the upper portion of this valley.

Below Littleton we find the alluvium continuous, and usually in large amount on one or both sides of the river to its mouth. This is a distance of nearly twenty miles, in which the river descends about 400 feet, having its mouth 407 feet above the sea. The highest terraces near Littleton are from 60 to 75 feet above the river, but scarcely any deposits occur for the first five miles above the low terrace, which is partly interval. Below North Lisbon both this and the high terrace, which sometimes widens into plains, are well shown. South-west from North Lisbon the high terrace is about 100 feet above the river; at Lisbon, about 125; at the east line of Bath, 150; at Bath village, 175; and one mile from its mouth, 200 feet, or 220 on its south side and 225 on its north side above Connecticut river. The slope of the ancient high flood-plain of the Lower Ammonoosuc was thus about 12 feet to a mile, descending but little more than half as much as the present river. The only kame observed in this lower part of its valley was a short ridge of gravel between the railroad and highway at the east line of Bath.

Modified Drift and Water-worn Rocks at Orange and Newbury Summits.

The lowest point in New Hampshire, upon the water-shed which divides the Connecticut and Merrimack basins, is at the summit of the Northern Railroad in Orange. Two rock-cuts, each about 30 feet in depth and together a quarter of a mile in length, were here made for the passage of the railroad through ledges of gneiss. Both these excavations were at the lowest points over which water could flow between these valleys. At the south excavation the top of the ledge on the east side shows in a distance of about fifty feet three water-worn cavities, 4, 6, and 12 feet deep, in order from north to south, one half of each of which has been blasted away. Still more remarkable evidences of water action, in the form of cylindrical pot-holes, similar to those at Amoskeag and Bellows falls, formerly existed here, but were destroyed in the work of rock-excavation. The most interesting of these was called "the well;" it was situated on the north ledge, and was described by Jackson as 11 feet deep, 4¼ feet in diameter at the top and 2 feet at the bottom. It was originally filled with earth and round stones.* The height of the railroad here is 990 feet above the sea, being about 30 feet below the natural summits of ledge which were thus water-worn. The south ledge was three or four feet lower than the north ledge; and on both the water-worn portion was at their highest points, and thence extended down their south-east slopes.

When we consider the great amount of erosion which was effected during the ice age, it seems impossible that these pot-holes and evident marks of extensive water-wearing could have been preserved through this period, especially when we take also into account that any barrier, which had before existed to turn a stream across this place, must have been removed by this erosion. It becomes necessary, then, to inquire how such water-wearing could be produced during the melting of the ice-sheet.

The modified drift found on both sides of this summit shows us the probable answer to this question. Our examination extended from Grafton Centre to East Canaan. The stream which we follow northward nearly to Orange summit is the head of Smith's river. The first two miles to near Tewksbury pond show considerable areas of low, levelly stratified alluvium. From the north limit of this material we find no modified drift of any consequence for about two miles, extending over the summit, all the valley being ledge or glacial drift. No kame-like deposits were seen in this distance. On the north side of the north rock-cut a deposit of water-worn gravel lies against the ledge. At one fourth mile farther north-west we find a kame from 500 to 600 feet long and about 35 feet high, the top of which has nearly the same height with the top of the rock-cuts. Similar short kames, sometimes 1,000 feet long, generally single, and nearly in line with each other, extend thence for a mile along the south-west side of the railroad. This material is

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* Jackson's *Final Report on Geology of New Hampshire*, pp. 113 and 114.

mainly coarse, water-worn gravel, with the largest pebbles usually about one foot in diameter, sometimes interstratified with considerable sand. Deposits which are also apparently of kame-like origin, consisting of gravel and sand, border the hills on the south-west side of the valley to East Canaan. This distance of nearly three miles has but little descent, and to the north and west the country is nearly level for considerable widths in the valley, and not much lower than Orange summit. These areas are swampy, or are covered with low deposits of sand, which is also seen in patches on the hillsides from 30 to 40 feet higher. Large areas of low modified drift, often swampy, border the Mascomy river for several miles to the west. The heights of these points, in feet above the sea, are as follows: Grafton Centre, 871; Tewksbury pond, 904; Orange summit, 990; top of railroad cuts, natural surface, 1,020; East Canaan, 956.

The Merrimack valley, lying nearer than the Connecticut valley to the coast and outer limit of the great ice-sheet, and not being sheltered by a continuous belt of highland, was the first to become free from ice. It seems probable that the melting in the Merrimack basin proceeded north-westerly to this summit, which became the outlet from the melting ice-sheet over the nearly level area beyond. A long period appears to have followed before the ice disappeared from the Connecticut valley and along its bordering range of highland, of which Croydon and Moose mountains are the culminating points, so as at length to give the basin of Mascomy river a lower outlet to the west. The kames indicate the north-westerly retreat of the stream that descended from the glacial slopes; and the wide-spread, low alluvial deposits of Canaan mark the extent of the ancient lake, from which a large river nearly destitute of alluvium poured over the ledges of Orange summit into the Merrimack basin.

Newbury summit, on the Concord & Claremont Railroad, was probably in a similar way the outlet from the basin of Sunapee lake during a part of the Champlain period. The ledge beside the highway, 150 feet east from the rock-cut at this summit, shows a pot-hole 2½ feet in diameter, and the same in depth. With the present drainage no stream could exist to perform this work, which tells of a time when the ice-sheet had melted on the south-east and from the basin of Sunapee lake, while it still filled the valley of Sugar river, causing an outflow here to the east over the present water-shed. Along the half mile between this summit and the lake, kame-like banks of gravel and sand are found; but in general the shores of the lake are destitute of modified drift, being composed of till or ledge. The heights of these points, in feet above the sea, are as follows: Sunapee lake, low to high water, 1,090 to 1,103; Newbury summit, 1,130; top of railroad cut, 1,181; pot-hole, about 1,175; lowest point over which water could flow towards the Merrimack river, 400 feet south-west from the rock-cut, 1,161. It seems probable that when this pot-hole was formed, the lower avenue at the south-west was still filled with ice.

Another pot-hole, 10 inches in diameter and 3 feet deep, the origin of which we cannot explain, occurs about 20 rods north of Newbury station, at the shore of Sunapee lake, halfway between high and low water. There is no rivulet or depression leading to the lake at this point.

In Warwick, Mass., two miles north-east from the village, the drainage during part of the Champlain period was also over the present line of water-shed, which separates Ashuelot and Miller's rivers.* The current here was from north to south, as shown by an area 40 feet square of indisputably water-worn ledges, with numerous pot-holes, which are locally known as "Indian kettles." This place is near the lowest point of the water-shed, which is a swamp perhaps 25 feet below these water-worn rocks. While the pot-holes were being formed here, the lowest place over which water could have flowed was probably occupied by an unmelted portion of the ice-sheet, as at Newbury summit.

LITTLE SUNAPEE LAKE, NEW LONDON.

The peculiar form of this lake, as shown on the county map, led to an examination of its surface geology. It is a mile and a half long from east to west, and is divided into nearly equal parts by a kame-like tongue of land, which extends fully a half mile from north to south, leaving at the south shore only a shallow channel about 50 feet wide. It is principally surrounded by gently sloping hills of ledge or till, but a narrow margin of alluvium, 10 feet in height, borders its north-east shore. The materials of the dividing peninsula are sand or gravel, with boulders at its south end. Its width is less than 100 feet and its height about six feet, where it is joined to the north shore. The central portion is about a

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* Jackson's *Final Report on Geology of New Hampshire*, p. 282.

sixth of a mile wide and 30 feet high, gently sloping from the middle to the shores. This is used as a picnic ground, and is covered by pitch and white pines and white birches, the characteristic trees of our sandy plains. The southern portion is most like our ordinary kames, being mainly narrow, and in some places scarcely a rod wide. This peculiar accumulation of modified drift appears to be due to a depression formed here in the ice at its melting, into which these materials were carried by the glacial streams. Afterwards a hollow was left on each side at the disappearance of the ice.

Ashuelot River in Keene and Swanzey.

The principal valley of Cheshire county has its widest development in Keene and Swanzey, as shown on Plate V. When the ice melted here, this basin contained for a short time a body of water somewhat larger and probably deeper than Sunapee lake, which soon became filled by the alluvium of floods which the retreating ice-sheet sent down by every tributary from north, east, and south. The city of Keene is built on the east portion of these level deposits, which are here two and a half miles wide, and extend with nearly the same width two miles to the north and the same distance to the south. The Ashuelot river flows through this basin, lying near its east side above Keene, but crosses to its west side in the north part of Swanzey. Its west portion in Keene is drained by the last four miles of Ash Swamp brook. Three miles south from Keene the Ashuelot river finds an avenue westward, along which it is also bordered by low modified drift for several miles. The straight valley, however, continues to the south through Swanzey, being occupied by the South branch and Great brook, with an alluvial area which decreases from one mile to one third of a mile in width. We thus find here a valley ten miles long from north to south, filled with nearly level deposits which are but slightly higher than the streams, and bordered by steep and nearly continuous ranges of hills, which rise from 400 to 600 feet upon each side. This alluvium consists almost everywhere of sand or fine gravel, perhaps extensively underlaid by clay, which is worked for brick-making near the south edge of the city of Keene. Its height is from 10 to 40 feet above the river; and the whole plain was originally of the same height with the highest portions, which still occupy the greater part of the alluvial area. These are generally separated from the lower interval by steep escarpments, which show that the difference in height is due to excavation by the river.

The only kames found in this area were several small irregular ridges of coarse gravel at Woodland cemetery in Keene. The railroad cut north of the bridge at South Keene shows successive layers of coarse gravel and sand. These are 40 feet above the highest plains, being the delta deposits of the branch which here enters the valley. South from this station for one third of a mile we have irregular ridges 40 feet high at a short distance west of the railroad, resembling kames in form, but scarcely differing from common till. In the south part of Swanzey we find occasional terraces, which are sometimes of coarse gravel, from 60 to 70 feet above Great brook, showing that much material at first deposited here was afterwards channelled out by this stream and carried northward to the wide low plains.

Modified Drift along the Pemigewasset and Merrimack River.

The river which drains the central portion of New Hampshire has a quite direct course slightly east of south. Its only departure in this state from the general direction is between the villages of New Hampton and Bristol, where it makes an offset of four miles to the west. This valley affords one of the few avenues for crossing the mountainous region. It begins in the deep gap of Franconia notch, between abrupt mountain walls, and it is at first closely enclosed by the high ranges which extend thence to the south. For twenty-five miles, or nearly to Plymouth, the valley is singularly straight, as is well seen from the summits of Lafayette and Cannon mountains, which rise at either side of its source; or it forms a beautiful view from hills in Campton, with its fertile intervals and well tilled farms extending for several miles, beyond which, at the end of its long vista, are the serrated mountains cleft by the notch (vol. i, p. 551). Its entire length from Profile lake, Franconia, to Massachusetts line, is comparatively straight, forming a continuous line of depression, which is a principal feature in the topography of the state. The upper and lower portions of the river which occupies this valley are known by different names. For more than fifty miles from its source this river is called

Pemigewasset, and the name Merrimack is applied to it only from the confluence of the Winnipiseogee at Franklin.*

The modified drift of this valley in New Hampshire is illustrated by Plates IV and V; these maps, like those of the Connecticut valley, show the extent of the intervals, terraces, and plains on both sides of the river, with their heights above the sea. The Pemigewasset river has a development of alluvium usually one half to one mile wide, which is bordered by high hills or mountains, forming a deep valley similar to that of Connecticut river along our western boundary. The modified drift of the Merrimack is usually one to two miles wide; its greatest development is in Concord, and in Litchfield and Merrimack, where it has a width of nearly four miles. The hills which border this part of the valley rise with comparatively gentle slopes, and the lowest points of its eastern water-shed are only 350 to 650 feet above the sea, unlike the continuous belt of highland which lies between this river and the Connecticut. After entering Massachusetts the Merrimack river turns east and north-east; and, with scanty deposits of modified drift, threads its way to the sea through a maze of hills which are composed of coarse glacial drift or till. Here the river has no connection with the principal questions in surface geology, which are quite different from those presented for study along its course in New Hampshire.

On the Pemigewasset river we find modified drift first at J. Guernsey's, in Lincoln, five miles from Profile lake. Thence for two and a half miles southward this consists of coarse gravel, much water-worn, extending one sixth to one third of a mile in width on the west side of the river. The mountains extend quite to the river along this distance on its east side. This modified drift has an irregularly smoothed surface, sometimes imperfectly terraced, with its outer margin at the north from 15 to 20, and at the south about 40 feet above the river. Its pebbles are from six inches to a foot and a half in diameter, and sometimes larger. Boulders also occur here and there, from three or four to ten feet in size.

A large plain of similar gravel occurs east of Pemigewasset river, on the north side of East Branch, having a height of from 30 to 40 feet above the river. Material for this plain was brought both from the north

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* The boundaries, area, and topographic features of the Merrimack basin are described in Vol. I, pp. 205, 212, 300, 306, etc.

and east. Nearer to the river here we have a lower terrace only from 5 to 10 feet above it. In the excavation of the gravel deposits, the river has sometimes left numerous and well marked terraces, though small in extent, and differing but little in height. This is well shown near Tuttle's, in Lincoln, where four distinct terraces are seen between the road and the river, with from 3 to 5 feet escarpments, the highest being about 20 feet above the river.

The height of terraces in this valley was determined by levelling only as far north as to the mouths of East Branch and Moosilauke brook, which enter the Pemigewasset, from opposite sides, at nearly the same point. The river here is 710 feet above the sea, or only 242 feet higher than at Plymouth, eighteen miles farther south. Profile lake, its source, nine miles to the north, is about 1,950 feet above the sea, by barometric measurement, showing a descent to this point of more than 1,200 feet.*

The plains above the East Branch, not determined by the level, appear to be somewhat lower than the highest modified drift just south of this stream. This terrace has a height of 70 feet above the sea, and is ten feet higher on the west side. Thence for ten miles southward, or nearly to the south line of Thornton, the highest terrace of the river, commonly well shown on both sides, has a uniform continuous slope of 15 feet to the mile. This is nearly the same as the descent of the river, which has cut its way from 70 to 100 feet deep through its former wide, sloping flood-plain. These remnants, lying at corresponding heights on opposite sides of the river, and sloping with it in the regular lines of the upper terrace, are here very interesting, as seen extending for miles up and down the valley. Nowhere else in New Hampshire is the erosion of the modified drift, by which it has been shaped in terraces, so clearly and convincingly displayed. Here no doubt can remain that an original flood-plain, ten miles long, has been terraced as we see it by the excavation of the river. For most of the way along

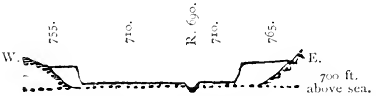

Fig. 17.—SECTION IN WOODSTOCK, 1½ MILES BELOW THE MOUTH OF EAST BRANCH. Length, ⅔ mile.

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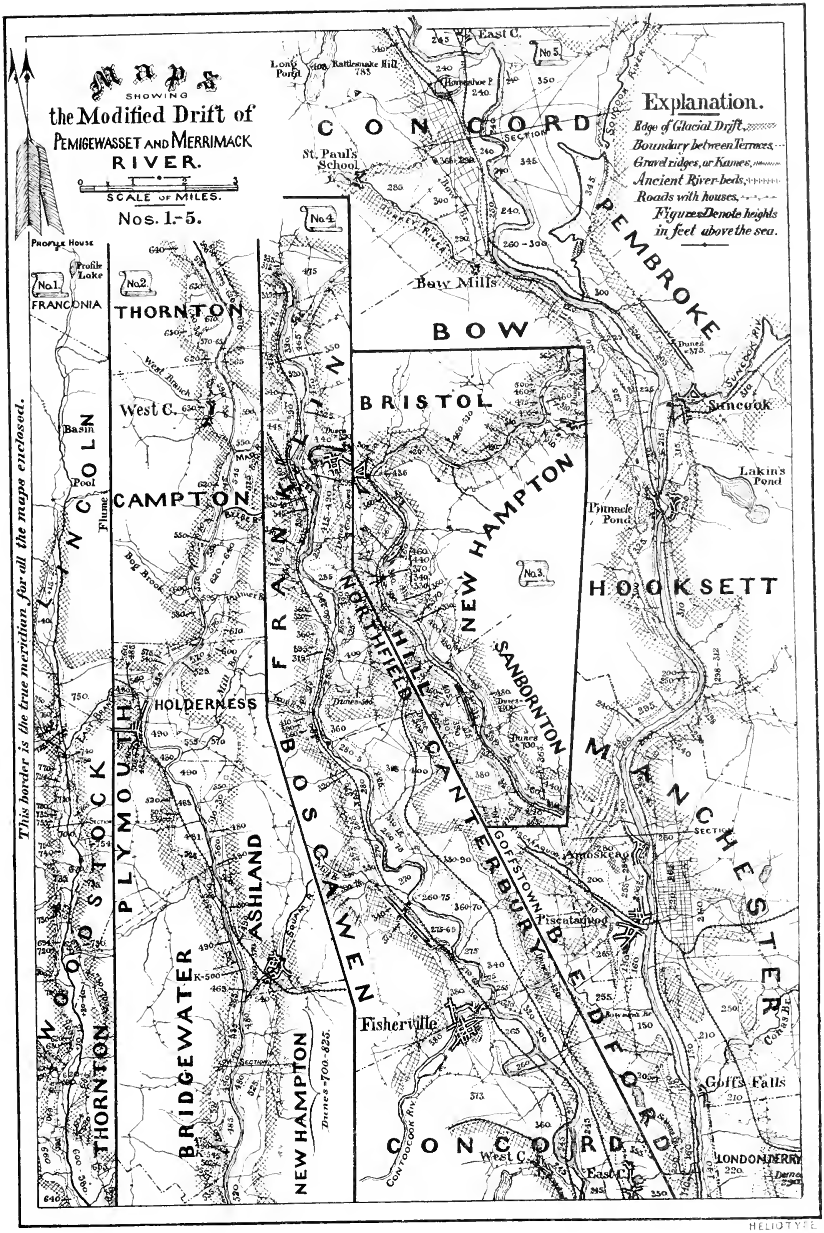
* The errors which occur in Vol. I, pp. 288, 308, and 322, in stating the height of Pemigewasset river at the mouth of East Branch, and of other points in this vicinity, arose by computing barometic observations from Thornton, which, through some mistake, is given 600 feet too high by Prof. Guyot, among the usually very correct altitudes published in his memoir on the "Appalachian Mountain System."

Plate IV.



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this distance, which lies through Woodstock and Thornton, we have two principal terraces, the higher being that just described, and the lower being wholly or in part overflowed by spring floods; but small intervening terraces are also of frequent occurrence.

All the modified drift of this valley, for the first seven miles to Woodstock village, is made up of gravel of different degrees of coarseness. Southward, banks and terraces of sand begin to appear; but gravel still predominates for a long distance below. The stream here frequently occupies a broad, shallow channel, paved with pebbles of all sizes to two feet in diameter, with little admixture of fine gravel or sand, which can accumulate only in deep or sheltered places.

Kames. In the south part of Thornton an interesting kame of coarse gravel is found on the west side of the river, between it and the highway. It extends north and south in a steep, sharp ridge about a fourth of a mile, and is less distinctly traceable for nearly a mile. Its top is 90 feet above the river, or 650 above the sea. Less than a mile farther south the road turns to the west around the steep face of a high plateau of kame-like gravel, which contains abundant pebbles up to a foot and a half in diameter. This deposit is of considerable extent, with its south-east portion nearly level, 660 feet above the sea, or about 100 above the river, but towards the north-west it has a broken surface, which in some places is 10 feet higher. It is from 30 to 40 feet higher than the normal upper terrace, which extends, with its regular slope of 15 feet in a mile, to this point, beyond which it also continues clearly traceable to the south. This higher plateau and the kame, which it resembles in material, date before the formation of the continuous high flood-plain. We must refer the latter to a time when the valley had become free from ice, while the former seem to belong to the period of its melting, owing their shape, in isolated plain and steep ridge, to the presence of ice-walls between which they were deposited.

In Campton the Pemigewasset receives two considerable tributaries from the east,—Mad and Beebe rivers,—which drain basins on the north-west and south-east of the mountain range that culminates in Sandwich Dome. South from the latter stream the upper terrace, increased in height by alluvium from the tributary, forms a pine-covered plain a mile long and half a mile wide. These "pine plains," appearing in a few places on the Pemigewasset and commonly along the Merrimack, we find to be one of the characteristic features of this valley. The modified drift of Campton occurs principally in the upper terrace, which has a normal height of 620 to 575 feet above the sea, or about 70 feet above the river, and in the interval or present flood-plain. At Livermore falls, near the south line of this township, the river passes through a deep, rocky gorge, with a natural fall of 22 feet. The foot of the falls is 483 feet above the sea.

In Plymouth and Holderness both the upper terrace and interval are finely shown; and the extent of the alluvial area, at one point a mile and a half wide, is greater than at any other place on Pemigewasset river. A beautiful interval extends for three miles below the mouth of Baker's river; at the north, mainly on the east, and at the south, on the west side. The broad, high plain belongs to Holderness, being on the east side.

Baker's River. A wide area of modified drift also lies along Baker's river below Rumney. For most of the way it is widest on the north side, reaching back at the widest place to Loon pond, a mile from the river. This likewise occurs in two heights, terrace-plain and interval, the former 40 to 50 feet above the river. The railroad extends over this alluvium nearly six miles in a single straight line.

The upper terrace, in Holderness, Ashland, and in the north part of Bridgewater, is 570 to 560 feet above the sea, or 100 above the river. Thence in six miles to New Hampton village it descends to 510 feet, or 72 above the river. It is best shown along this whole distance on the east side. There is almost always one lower terrace, and sometime several; but we find only small areas that are overflowed south from the large interval of Plymouth. Deltas higher than the normal upper terrace occur at two places near the north line of Bristol, and at the villages of Ashland and New Hampton. Spectacle pond, in the edge of Meredith, probably has its outlet by a subterranean channel, which extends under gravel and sand a mile to the west, appearing near the east edge of New Hampton village in several springs. The largest of these supplies a stream of very cold water two or three feet wide and a foot deep. Gravel ridges or kames bordering the Pemigewasset were seen in Ashland half a mile above the mouth of Squam river, and in Bridgewater at Eastman's falls, four miles farther south. No other deposits of this kind were observed between the townships of Thornton and Franklin.

Dunes in Merrimack Valley.

In the north part of New Hampton, and in many places for thirty miles southward to the north line of Concord, we find numerous dunes or sand-drifts lying at various heights on the east side of the valley, up to 300 feet above the highest terraces. Near their beginning, two miles south of Ashland, these dunes appear in large amount, and reach their greatest height. Here the sand-drifts, one to five feet deep, are strewn in a pathway 10 to 20 rods wide, which extends a fourth of a mile along the hillside, with a north-west to south-east course, rising 300 feet above the ordinary modified drift, or to a height of about 825 feet above the sea. These dunes of the Merrimack valley, like those along Connecticut river, occur only on the east side, consist wholly of fine sand, and lie in trains which ascend from the highest terrace in a south-east direction along the hillside. All these characteristics indicate their origin, through transportation by the prevailing north-westerly winds from the plains below, probably at the period when these had their greatest extent, prior to their excavation by the river, and, we may presume, before the appearance of a forest. They are usually made conspicuous at the present time, by being blown in drifts which are so constantly changing that they give no foothold to vegetation; but when they occur at considerable heights, we generally find the lower portion of the series grassed over, making the upper drifts appear isolated on the hillside. This is the case at the locality described in New Hampton. The upper part of this series, extending an eighth of a mile, is still in motion, and has been gullied and channelled by the wind often 3 to 6 feet deep over spaces 50 to 100 feet long, and carried forward, probably some portions 300 feet ahead and 50 feet higher, within fifty years. The whole train of sand-drifts at this

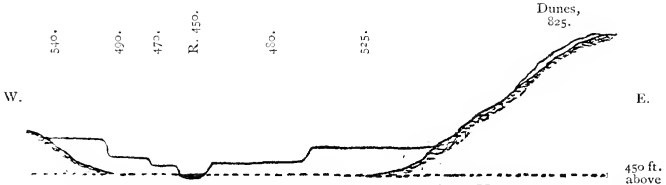

Fig. 18.—SECTION IN BRIDGEWATER AND NEW HAMPTON.
Length, 1⅓ miles.

place is equal, by estimate, to a mass 1,000 feet long, 50 wide, and 2 feet deep, thus containing 100,000 cubic feet, or 5,000 tons, which have been raised by the wind an average height of 150 feet.

Another very good illustration of this transporting power of the wind is found in Sanbornton, a mile south-east from Hill, on a hillside which reaches a height 400 feet above the river, or 700 above the sea. Here the ancient dunes, as in New Hampton, have been swept forward anew since the land was cleared. The sand from a hollow 150 feet long, 40 wide, and 2 to 5 feet deep has been carried in long north-west to south-east drifts 200 to 400 feet farther, and 25 to 30 feet higher up the hill. The depth of recent excavation is shown by a large stump which has been thus undermined. The highest of these dunes have now reached the crest of the hill, covering the originally naked ledges; but they will not stop here, and at length may be found far beyond in the hollow on the east side of this first hill range.

Through Franklin and Northfield these dunes are numerous, occurring from 100 to 300 feet above the upper terrace of the valley, having their greatest altitude, 700 feet above the sea, a mile and a half north of Northfield depot. They are generally found, however, within 100 feet of the highest terrace: at such height they are well shown within a mile north and south from Franklin Falls, near Northfield depot, and in great abundance, extending more than a mile on the north and west sides of Hart hill. In the next five miles no dunes were observed, but they appear again at a similar elevation for a mile in the south part of Canterbury.

The instances of dunes found southward along the Merrimack are soon enumerated. They have a height of 70 feet, by estimate, above the highest terrace in Pembroke, on the west side of the village street, where they are covered with grass; they reach about the same height in Londonderry, two miles south-east from Goff's Falls, where they appear in large amount, forming irregular mounds and ridges; and at a few points in Litchfield and Hudson we find on the high plain, and scarcely raised above it, similar areas of barren, wind-blown sand.

From New Hampton to Bristol the river flows westerly, almost at right angles with its general direction, descending by a nearly continuous slope 86 feet in the four miles, which are the most rapid portion of its course south of the East Branch. The same rapids continue a mile or two below Bristol, so that the total descent in six miles from New Hampton bridge to the mouth of Smith's river is 118 feet, or from 438 to 320 feet above the sea. The westerly course of the Pemigewasset here corresponds to that of Connecticut river along Fifteen-miles falls. These are the only considerable deviations of these rivers from their general direction in the state; both portions are of rapid descent over till; they are alike bordered by sloping hills; and both differ from all the rest of these valleys in being well-nigh destitute of modified drift. Remnants of the original high flood-plain, now forming the normal upper terrace, traceable on both sides nearly all the way from the East Branch to Massachusetts line, appear to occur in the highest of two terraces at the mouth of Ten-mile brook; in a small, gently sloping plain about midway between New Hampton and Bristol; and in a similar area east of the highway a short distance north of Bristol. All these are on the north side of the river, and are from 510 to 500 feet above the sea. At several places along these rapids it appears probable that the channel has been cut through a considerable depth of till.

Bristol village is built almost wholly on till or ledge. Below Main Street bridge the fall in Newfound river is 105 feet, and its total fall from Newfound lake is 238 feet, the lake being 590 feet above the sea. The usual display of terraces again commences opposite Bristol, and thence the alluvial area extends, with the river, unbroken through the state.

At the mouth of Smith's river the highest terrace, 460 feet above the sea, is wide for a mile to the north, and extends in a narrow strip for the same distance to the south. Thence southward to Franklin we find remains of the same, principally on the east side, from 480 to 440 feet above the sea. In the south part of Sanbornton they form an extensive plain, 475 feet above the sea, probably slightly increased in height by the tributary alluvium of Salmon brook, which has cut a channel along its south-east side. From this plain a wide terrace (from 475 to 440 feet) extends south on the east side to Franklin, where the normal upper terrace is again shown on both sides of the valley, forming on the west the high sandy plain, 445 feet above the sea, which extends a mile north-west to Webster lake.

Lower terraces are numerous on both sides for a mile below Smith's river, the lowest being interval. West of Hill village an expanse three fourths of a mile long and a half mile wide is divided, by escarpments 15 and 20 feet in height, into three distinct terraces, the highest of which is 410 feet above the sea. A small terrace, 80 feet higher, is found on its west side. The highest terraces west of the river, well shown much of the way between Hill and Franklin, are from 40 to 60 feet below those on the east. This difference seems to be due to a deficiency in the amount of material supplied, the deposition being influenced by the current, and attaining its full height only on one side.

Kames. A short gravel ridge, projecting five feet above the plain of which it forms the border, and containing pebbles six inches in diameter, was seen in the north part of Franklin, on the west side of the road at one mile south from Hill village. Another gravel ridge, about 20 rods long and 35 feet above the plain on the west edge of which it occurs, was seen in Sanbornton near the river, a mile and a quarter south-east from the last. Both these short ridges are of typical kame gravel; they lie nearly in the middle of the valley, and their heights are about the same, the northern being 385 and the southern 365 feet above the sea. It is not improbable that these are remnants of a formerly continuous kame.

This coarse gravel was next observed at a railroad cut on Bristol Branch, one mile above Franklin depot; an excavation of it may be seen in Franklin village, just north of Webster brook, at the west side of the street; and it is again exposed in the same way a short distance south of the depot. It also forms a ridge, nearly covered by the fine alluvium of the upper terrace, on the east side of the river, one fourth of a mile above the bridge. Southward in this town kames were noted at two places on the west side.

At Boscawen village portions of a well marked kame form the escarpment of the plain, which has about the same height, near the north end of the street and south from the road to the bridge. One mile farther south we find between the highway and the railroad a ridge several hundred feet long, the north part of which is composed of coarse water-worn gravel, while its southern portion seems to be unmodified till.

The ancient highest flood-plain of the Merrimack from Franklin to Massachusetts line is everywhere well shown by the conspicuous upper terraces. Along much of the way these expand on one or both sides into wide, sandy "pine plains," so called because their principal wood-growth consists of white or pitch pines. These are sometimes accompanied by a thick and tangled undergrowth of scrub oaks, which, with the pitch pine, flourish best on the barren plains. Their surface is very level, with a regular but very slight slope, which amounts to nearly the same as the descent of the river. In some places this may be finely seen, as at Concord, where a level set at the same height with the plain on the east side commands a view of its edge for three miles along the river, in which distance it is seen to slope only a few feet, with no undulation to break its straight line.

It is worthy of notice, that in this entire valley, including Pemigewasset river, no important deltas are found. This is in remarkable contrast with the Connecticut valley, where the regular line of the river's highest alluvium is hardly traceable, or is less readily seen much of the way, because of the extensive higher deposits of tributary streams. In this valley such deposits have helped to fill extensive areas, as in Concord, for which it would seem that otherwise the supply must have been deficient, and sometimes they slightly increase the height of the upper terrace, but in no place do they form, as on the Connecticut, frequent and well marked terraces above this normal line. The Merrimack valley is wider than that of the Connecticut, giving room for its ample plains; and its sides slope more gently, forming lower ranges of hills. Its tributaries partake of the same character, and also have a less rapid descent than in the Connecticut basin, allowing the deposition of large amounts of alluvium along their course, as on Baker's, Contoocook, and Suncook rivers. The modified drift of the Merrimack is rendered more simple, but not less instructive, by being free from the confusion of associated tributary deposits.

At Franklin the upper terrace is well shown upon both sides of the valley. It has considerable fall in a short distance here, being 445 and 440 feet above the sea at the north side of Webster brook and Winnipiseogee river, and descending in less than a mile to 430 and 420 feet at their south sides. The mouth of Winnipiseogee river is 269 feet above the sea, the Pemigewasset having descended nearly 30 feet in its last mile, so that the upper terrace here has a height 150 to 175 feet above the river. The highest alluvium for eight miles northward, extending through Sanbornton and including the large plain north of Salmon brook, has an equal elevation above the river, which is greater than in any other portion of this valley. In the next nine miles below Franklin the upper terrace falls to a height of 125 feet above the river, which continues for more than 20 miles to the north part of Manchester, the highest terrace seeming to descend most rapidly near the present falls of the river, so that a nearly uniform height above the river is maintained.

Opposite the Webster place, two and a half miles below Franklin, this high terrace presents a quite remarkable form. Its base is washed by the river, which here sweeps eastward, leaving a fertile low terrace of large extent on its west side. Ascending from the river to the east we have first the steep escarpment, more than 150 feet high, the top of which has nearly the normal height of the upper terrace; but this, without any level space as usual, is succeeded by a sloping surface of sand, which extends to the road, and rises about 120 feet in less than a fourth of a mile, appearing in all except its slope like an ordinary terrace. Very high sand-dunes occur on the hill south-east, and it seems probable that this unusual slope, rising more than 100 feet above the normal height of this terrace, was heaped above it by the north-west wind, soon after the time of its deposition. A similar sloping surface of the upper terrace, but much less in amount, is also seen for a mile or more north and south, and at many other points along the river. Between one and two miles farther south we find the greatest profusion of dunes observed in New Hampshire, the highest of which, however, do not exceed 250 feet above the river.

In Canterbury the upper terrace spreads out into plains, which are at some places a mile wide. The Boston, Concord & Montreal Railroad through the town is upon these high plains, while the Northern Railroad, in Boscawen and Concord, lies on the lowest terrace, being embanked much of the way to raise it above the high floods of spring. The plains of the south part of Canterbury, extending one mile into Concord, show an unusually rapid continuous slope, amounting to 80 feet in four miles, or from 130 to only 50 feet above the river, which is here 250 feet above the sea. The north end of this slope appears to be at the normal height, representing the level of the river at the time of deposition of these plains, while the terrace of Boscawen village, on the opposite side of the river, is 40 feet lower. The south end of this slope is about 70 feet below this normal line, which is here shown on the west side in the plains north and south of Fisherville.

Boscawen village is built on the south end of a similarly sloping terrace three miles long, in which distance it falls 30 feet, and we find 30 feet more fall of the same terrace in less than a mile along the village street. The whole of this terrace is below the normal height, showing a deficiency of 15 feet at its beginning, and of 40 feet at the north end of Boscawen village. It appears as if the supply of alluvium was insufficient, and the direction of the current at first caused it to be deposited in greatest amount at one side, without filling the valley. South of Boscawen the supply of material became still more inadequate, and the lower portion of the sloping plains east of the river was probably 60 feet below the surface of water, which was held back by the extensive plains of Concord, derived in large part from the Contoocook and Soucook valleys.

Although the plains in Concord were obviously brought in from tributary sources, they belong to the ancient flood-plains of the Merrimack, since they form a portion of the series of high terraces and plains which extends with a slightly varying but unbroken slope along this whole valley. Even if no modified drift were supplied, except from the upper part of the main valley, irregularities of slope, as in Boscawen and Canterbury, with increased height below, as in Concord, would still be produced by an irregular rate of retreat of the ice-sheet, allowing long and abundant deposition in some portions, but much less in other portions of the same valley. In this way we must explain the sudden and permanent increase in height of the upper terrace of Connecticut river at North Thetford (p. 36). Probably this cause was combined with the aid of tributaries to produce the high plains in Concord and southward.

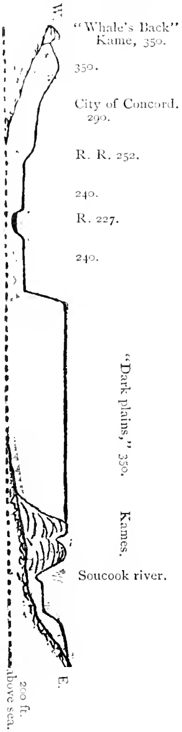

Fig. 19.—Section in Concord. Length, 3½ miles.

Between Fisherville and West Concord these plains have a large extent, lying on the south side of Contoocook river. Their northern and western portions are 125 feet above the Merrimack river at the head of Sewall's falls, but they become slightly lower at the south. The mouth of Contoocook river is 249 feet above the sea. Its descent through Fisherville, in the last mile and a half of its course, exceeds 100 feet. By the Borough dam, at the head of these falls, this river is held level to Contoocookville in Hopkinton, six miles in a direct line. Along this distance and beyond we find extensive alluvial areas at small elevation above the river, continuous with these plains in the Merrimack valley. A description of the modified drift of Contoocook river will be hereafter presented.

The most extensive plains in Concord, and indeed in this entire valley, lie on the east side of the Merrimack between it and the Soucook river. They extend along Merrimack river six miles, from above East Concord to the mouth of the Soucook. Their area of greatest width, which exceeds two miles, is opposite the city, being known as the "Dark plains." The channel which has been excavated by Soucook river is very crooked, lying at first along their east edge, but at three miles from its mouth deviating towards the middle of the plains, and again returning eastward and southward. This excavation is 50 to 125 feet in depth, with areas of low terrace at its bottom bordering the river. The greater part of this large expanse of plain is very level, with occasional gullies, but with scarcely any undulations rising above the general surface. Its slope, in nearly four miles from its north-west limit to opposite the south part of the city, is only 10 feet, with a height 130 to 120 feet above the river, or the same above the river as the plains north and south of Fisherville, their difference in absolute height being equal to the descent of the river at Sewall's falls. Farther south the slope of the plain becomes more rapid, descending 50 to 75 feet in about two miles, the highest portions at the south end being about 100 feet above the mouth of Soucook river, which is 199 feet above the sea. The total descent of the Merrimack in Concord is thus 50 feet, of which 20 feet are at Sewall's falls, four miles above the city, 5 feet at rapids a short distance above the mouth of Turkey river, and 20 feet at Garvin's falls, three fourths of a mile below.

In Boscawen and Canterbury, and through Concord, the lowest terrace for 12 miles occupies a wide area, of which a large part is overflowed by the high water of spring, forming the only extensive intervals on this river south of Plymouth. These are from a half mile to one mile wide, their fertility being in marked contrast with the barrenness of the "pine plains." A fine view may be obtained in Canterbury and Concord from the edge of these plains, whose high bluffs descend abruptly a hundred feet, overlooking the level bottom-lands and the windings of the river for miles north and south. In other parts of its course the river is confined between terraces, which prevent an irregular route. Its meandering course here was signified by the aboriginal name *Penacook*, or crooked place, which was applied to the south part of this territory.

Ancient river-beds are indicated at many places by shallow ponds, which lie in long and frequently curved depressions of the interval, often near the foot of the higher terraces, and but slightly elevated above the river. One of these is seen on the east side of the railroad, a mile south of Boscawen depot; one lies on each side of the river just south of Sugar Ball bluff, near Concord; and others occur east of the south part of the city; but the largest and most interesting is Horseshoe pond, at the north end of the city, which is shaped like a crescent, being a half mile long, nearly as wide as the present channel, and six feet above the ordinary height of the river. This pond is crossed by the Northern Railroad. Its middle portion lies at the foot of a higher terrace, against which the river once swept its full current. The nearest point of the present channel is a half mile distant at the north, where the river bends and now directs its current against Sugar Ball bluff, a mile and a half northeast from Horseshoe pond. The date of these changes cannot be stated, except that it was before the first settlement here, 150 years ago.

Recent Changes of Merrimack River in Concord.

Dr. William Prescott, of Concord, in 1853 collected dates and measurements of many remarkable changes in the channel of Merrimack river which had taken place since a careful survey of this portion was first made in 1804.* From this record it appears that below Federal bridge,

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* *Collections of N. H. Historical Society*, vol. vii. At the time of publication of this volume, in 1863, a statement was added describing subsequent changes to that date.

In the same volume is also found a valuable address on "The Valley of Merrimack," by Joseph B. Walker, Esq., describing its physical features, and recounting its earlier and later history.

near East Concord, the river has changed its entire width from south-west to north-east, and a third of a mile to the east it has changed more than its width in an opposite direction. On the east side of the "Fan" or broad interval opposite the north part of the city, the river flowed in 1804 by a very circuitous route 460 rods, which was shortened to 150 rods by great freshets in 1826, 1828, and 1831, which cut a direct course across two peninsulas then known as Sugar Ball point and Hale's point. Ponds already mentioned occupy portions of the old channel. Ten years later, Dr. Prescott reported the rapid undermining of Sugar Ball bluff, 125 feet high, of which the river had carried away, between 1853 and 1863, a mass 80 rods long and 40 rods wide. This erosion is still going forward, being aided by springs near the foot of the bluff. At Davis's bluff, about a mile south, a width of three rods was swept off in 1863 in three days. Erosion at this point has continued thirty years, requiring a dwelling near the edge of the bluff to be several times moved, and the road changed.

The same undermining of the high plains by the river is also going on at several places north and south of Fisherville. One mile south-east from Boscawen bridge, the plain, 110 feet above the river, is fast wearing away, and portions of it 10 feet wide and 150 feet long had fallen in 1875 10, 20, and 40 feet, remaining nearly level, so that their sapling pines, 10 to 30 feet high, were still upright and growing on the side of the steep sand-bluff. These would be carried away, to be followed by new slides during the next high flood. One mile farther south, and at other points below Fisherville, a similar rapid erosion was observed. A quarter of a mile north-east from Fisherville bridge, a bluff, which has been so recently undermined that it is not yet grassed, is now separated from the river by a wide area which does not exceed five feet above the ordinary height of water. These recent incursions of the river upon the plains, and the rapid changes in its channel upon the intervals, washing away yearly from one bank and adding to the side opposite, leave no doubt that the river has flowed at the foot of the bluffs along their whole extent, occasionally making a deep excavation beyond its ordinary bounds, as on the east side south of Sugar Ball bluff; that the high plain once filled the whole valley; and that the river has swept many times from side to side over the space occupied by its lower terraces and interval.

Important changes in the channel of the Merrimack have also been made artificially in Concord. One mile south of Fisherville depot the course of the river was formerly in a westerly curve, passing around Goodwin's point, two thirds of a mile from its direct course. At the west end of this detour it was fast undermining a long line of bluff 125 feet in height. When the Northern Railroad was built, in 1846, the river was turned, to avoid bridging, into a new channel, by which its course was made straight, being shortened fully a mile. Its old channel remains filled with water, except at its south-west bend, which is nearly silted across; and the erosion of the bluff at times of freshet is greatly diminished. Farther south, at about three miles above the city, the river flowed in two channels, of which the west one was largest, enclosing Sewall's island. The railroad was built across this island, reaching and leaving it by embankments instead of bridges, for which purpose the west channel was dammed, when the river is said by Dr. Prescott to have swept away, to widen its east channel, a width of 20 to 25 rods of its bordering interval for two thirds of a mile.

Dr. Prescott mentions that, in cutting the new channel across the base of Goodwin's point, "the workmen, at the depth of about 12 feet, struck upon a bed or stratum of vegetable matter, consisting of leaves, branches, and trunks of small trees, the latter from three to six inches in diameter, the form of which was perfect, and the bark distinct. This vegetable deposit was found embedded in a stratum of fine blue sand, which at first sight was mistaken for blue clay, and was from one to three inches in thickness. The trunks and large branches were recognized as belonging to the natural order coniferæ." He also describes, from an excavation at the gas-works in Concord, supposed "fragments of the roots, trunks, and branches of trees. They were found deposited in a stratum of ferruginous sand (composed of sand and oxide of iron); and in some instances the fragments of roots and branches of trees were completely incased in a firm coating or crust of the oxide of iron and sand from one eighth to one half an inch in thickness." This was at a depth of ten feet. It appears probable that these were cylindrical concretions of oxide of iron, which often show concentric rings, almost exactly imitating the annual layers of wood. These were found abundantly in the excavation for laying the water-works main, in 1872, near the south line of the city farm, and may be occasionally met with in any alluvial sand.

Between West Concord and the city the upper terrace is from 10 to 30 feet lower than on the east side of the river. The greater part of the city, and a large area southward to Turkey river, are slightly lower, being about 300 feet above the sea, or 75 above the river. In the west part of the city the modified drift, composed of sand or fine gravel, rises unterraced into irregularly sloping hills, the highest of which, crossed by Church and School streets, are 367 feet above the sea, being higher than the plains of the east side.

Kames in Merrimack Valley.

Interesting kames are found at Concord, where they form the uneven east part of Blossom Hill cemetery, and extend south in a nearly continuous series, composed of irregular, short, low ridges and mounds, always with north to south trend, to the intersection of Franklin and High streets, and thence on the same course to Centre street. The south portion of this series is a single steep ridge, from 25 to 40 feet high, called "Whale's Back," which originally extended a quarter of a mile from near the corner of Centre and Pine streets to that of Warren and Liberty streets. The north half of this has been used by the city in making and repairing streets; for which this gravel, when screened to remove its coarse pebbles, forms an excellent surface, and ultimately the whole ridge will thus be removed. The material of "Whale's Back" is mainly very coarse gravel, containing abundant pebbles up to one foot, while the largest reach two or three feet in diameter. These are always well rounded, having the characteristic water-worn form,—not that of glaciated boulders, which are distinguished by flattened, striated sides, with rounded corners and edges. This water-worn gravel lies in a steep, narrow ridge, a section of which usually shows an indistinct anticlinal bedding. The rounded boulders, pebbles, and fine gravel are almost indiscriminately mingled through the whole mass, often with very scanty streaks of sand or other lines of stratification.

This series of kames lies at the west margin of the wide alluvial area, resting upon till 100 to 125 feet above the river. Its extent is a mile and a half, having the same course with the valley. No kame-like deposits were discovered along the east side of the river in Concord, the whole mass of the plains being fine alluvium. Similar ridges were next found just below the mouth of Soucook river, exposed by railroad excavation on both sides of the Merrimack. The kame here cut through by this river is a portion of a series which extends twenty miles from Loudon to Manchester.

In materials, arrangement, and stratification this principal line of kames in central New Hampshire is like the short series just described, but unlike the long single kame of the Connecticut valley. The greater part of these kames is of very coarse, water-worn gravel, with pebbles six inches to two feet in diameter, disposed in irregular ridges from 40 to 100 feet in height, of southerly trend parallel with the valley, a section of which usually shows an indistinct stratification. This, however, varies occasionally to coarse angular materials, mainly consisting of unworn rock-fragments up to four or five feet in size, with no evidence of water action. A mile south of the Pinnacle in Hooksett a gradual transition is seen from water-worn gravel to this morainic material, which continues about a sixth of a mile and then changes back to modified drift, the whole forming a continuous ridge. Other portions of these kames contain considerable amounts of sand or fine gravel, alternating in irregular layers with the common coarse gravel, thus showing very well marked stratification, which is always inclined, being usually anticlinal or arched in the section of a ridge.

This Merrimack series differs notably from that of the Connecticut in being frequently composed of several ridges, nearly parallel to each other, with long irregular hollows between them which sometimes contain ponds. About half is thus made up of two or more parallel ridges, while the other half, in separate portions of a mile or two each, consists of a single ridge. Upon the Soucook river these kames are repeatedly cut through by its present channel, as also near its mouth by the Merrimack, but in the fourteen miles farther south they lie wholly on the west side of the Merrimack, often near the edge of its alluvial area.

The north end of this series has not been fully examined. Its first appearance noted is on Pine brook, half a mile west of Loudon village, where north-west to south-east ridges of coarse gravel occur. They were also seen on the south-west side of Soucook river, near the first bridge below this village; thence they probably occur near the river southward, but have not been explored for the next mile and a half, to near Richardson's mill in Concord. For a fourth of a mile north from this mill, and five and a half miles southward along the Soucook to its mouth, these ridges have been carefully traced, and are found well developed, rising 40 to 100 feet above the river, and nearly continuous, sometimes single, and again two or three parallel and of equal height. These kames, for the first three miles, lie close to the river, almost wholly on its west side. The material is prevailingly very coarse, but for the most part plainly water-worn, with the largest pebbles or rounded boulders two or three feet in diameter, and it occurs in steep, narrow ridges 40 to 75 feet high. The river above Richardson's mill is 307 feet above the sea; hence these kames do not exceed 400, and those west of Loudon are probably about 450 feet above the sea.

At Clough's mill, three miles above its mouth, the Soucook departs from its general course, crossing the line of kames, and turning with a right angle one mile to the west. Below this point the river does not follow, as before, the eastern border of the plain; but we find that the kames continue in a nearly straight course close to this east boundary. For a mile and a half from Clough's mill the kame lies on the east side of the road. In the first half mile of this distance we find a single steep, narrow ridge of coarse, water-worn gravel, 20 to 40 feet above the adjoining plain. Sections of this ridge are exposed by the river at Clough's mill, and by a cut across it for a new road at a short distance south. In the next mile we find the same coarse gravel, lying partly in the form of a ridge, but not so prominently, and partly in a somewhat irregular terrace.

One mile above the mouth of the Soucook, where it comes near the highway, a distinct gravel ridge occurs on its east side; and on its opposite side we have two parallel ridges, separated by a hollow, but with the top of the west one the same in height with the adjoining plain. The largest pebbles seen in this ridge were one foot in diameter. Thence for nearly a half mile no kames are found; but after passing the lowest bridge on this river they are well shown on its east side to the railroad near its mouth, forming a broad ridge of gravel, with pebbles up to a foot and a half in diameter. The direction of this ridge points to the continuation of the series on the opposite side of Merrimack river.

A fine section of the kame has been exposed by excavation for the railroad at the point where it reäppears in Bow, one fourth of a mile north of Robinson's station. Here the water-worn gravel, containing none but rounded pebbles, the largest of which are two or three feet in diameter, forms a well defined, anticlinally stratified ridge about 40 feet high, which is entirely overlaid by the later sand deposit of the ordinary terrace.

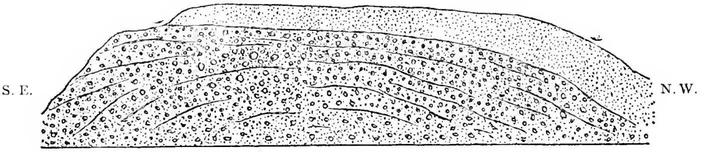

Fig. 20.—Section of Kame overlaid by Sand, ¼ Mile north of Robinson's Station. Scale, 1 inch=50 feet.

Thence the series extends for a mile in a single ridge, which is partially and at some points wholly covered by the fine alluvium. In the next mile we have two ridges nearly parallel, but somewhat irregular in course and in height. The intervening hollow contains a small pond. These ridges form the east border of wide plains, which have nearly the same height with the kames. The sand of the plains is shown to be the most recent deposit by its superposition. It appears that, after the gravel ridges had been formed, great amounts of sand were swept into the valleys; but spaces nearly enclosed between parallel ridges were often protected from this deposition. In the subsequent excavation of a large portion of this sand by the river, producing the lower terraces and its present channel, these coarse ridges have been a barrier protecting the plains on their west side. Opposite the mouth of Suncook river, the eastern of the two ridges lies on the south-east side of a small brook;—here we again found for a few hundred feet numerous angular rock-fragments, of dimensions from one to two and a half feet, while other portions, so far as seen, were of water-worn but often very coarse gravel. A short distance farther south the series is suddenly interrupted, and its direct course is occupied by a high, ledgy hill. An irregular high terrace of gravel and sand on its east and south-east sides may represent the kame. After a mile the series reäppears in its characteristic ridges, and continues five miles quite irregularly and of varying material, but plainly one connected series to its next gap, which begins opposite Martin's Ferry.

In Hooksett the kames are well shown for a mile north from Pinnacle pond. Several small ponds lie in the irregular hollows at the sides of these ridges. A well marked kame forms the east border of the high terrace west of Hooksett village and north-east from the Pinnacle, directly east of which it could not be traced, but it reäppears in a ridge on the south side of the road south-east of this quartz peak, thence turning south-west towards the principal range of these kames, the direction of which seems to lie from north to south across Pinnacle pond. The locality of greatest irregularity in respect to shortness of ridges, inequality in height, variable course, and diverse material, found in this whole series, is the first half mile south from this pond. The scale of the map, however, does not permit details to be shown. A deep, winding hollow extends along the west side of the main ridge from within one fourth of a mile of the pond to a junction with the valley of a small brook nearly a mile south. A considerable portion of this hollow seems to be due to excavation; and for the next mile southward, where a single nearly straight ridge parallel with this brook constitutes all that we have of the series, the plain, which is 30 to 40 feet above the top of the ridge, has been so washed away that a wide hollow has been formed at both sides.

Here the plain is sand or ordinary gravel, but the kame is mainly composed of the very coarse, water-worn gravel, which forms the principal portion of this series. This, however, is here found changing into coarse unmodified material, in which angular boulders, mostly of gneiss or granite, two to five feet in their dimensions, occur almost as closely packed together as possible, with the gravel of the interspaces unmodified by the wearing of water. This forms a well defined narrow ridge, 25 to 40 feet high, which continues a sixth of a mile, or perhaps more, when it changes again to materials rounded and sorted by water, and wears the usual aspect of these kames.

Next below this long single ridge the brook finds a passage to the river; and a very remarkable assemblage of kames, partly water-worn and partly angular, succeeds, covering an area half a mile long and one fourth of a mile wide, with short parallel or irregular ridges, most of which trend from north to south. These ridges are nearly level-topped, with intervening hollows at the north 30 to 40 feet deep. Near the middle of the area a deep hollow runs transversely across the course of the kames from west to east. South from this the space between the ridges has been mainly filled with alluvium, forming a plain upon which the position of the kames is easily traced by their lines of coarse gravel. Occasional boulders, apparently brought by floating ice, lie on the surface of this plain. One of white quartz, six feet long, has thus travelled more than two miles from its parent ledge, which was probably the Pinnacle.

The course of the kames now turns eastward and then westward at the end of a mile, conforming to a bend in the valley. At the north this curve consists of a single low ridge, which is in large part composed of angular rocks up to one or two feet in size, lying between the road and the river. Where it turns to the south-west, opposite Martin's Ferry, we have a broad gravel hill, in which also many of the stones are angular, while other portions are water-worn. Thence for two miles southward the kames have been wholly carried away by the river, which has its channel directly in the line of their course.

On the east side of the river this series may be represented in the high plain one mile north of Martin's Ferry, which has irregular ridges and hollows, and is composed of gravel with pebbles six inches to one foot in diameter; but a large area of similar gravel, extending thence to the north-east, seems to be clearly a tributary deposit. An undoubted remnant of the series occurs half a mile south from this station, in a coarse gravel deposit, showing oblique and irregular stratification, which has been excavated for railroad ballast. Occasional angular boulders, three to six feet in size, which must have been brought by floating ice, were noticed in the same terrace.

In Manchester a fine display of these kames begins at the west side of the river road, a mile and a half above Amoskeag bridge, and their greatest development in the whole series is thence south-west to Piscataquog river, where they cover an area two miles long by one fourth to half a mile wide, closely adhering to the west side of the widened valley. We find here as many ridges as can well occupy this space, all lying in the same course, which is that of the series, and having a comparatively uniform height. Some of them probably extend almost the entire length of this area, while others are short or broken by gaps. Their material is principally water-worn gravel, sometimes as fine as prevails in the Connecticut kame, and interstratified with sand, but more commonly very coarse, as is characteristic of this series. Other portions are unmodified, containing angular stones; and large boulders are occasionally found. Three long hollows, varying from 30 to 50 feet in depth, one being wholly enclosed, lie between these kames for a half mile at their north end, beyond which the hollows have been filled with fine alluvium, producing a nearly level plain. Southward, many irregular long hollows are found, one of which contains a pond. An ancient channel, occupied by the whole or a part of the Merrimack when it first began to excavate its highest plain, extends along the south-east side of this area of kames. Rock Rimmon lies a quarter of a mile farther south-east, and the extensive plain around it is destitute of kames.

This series makes almost a right angle where it is crossed by the Piscataquog river, nearly two miles above its mouth, and turns south-east for a mile, consisting of a single ridge of water-worn gravel, which lies near and parallel to the river. It is well exposed at this angle by excavation for the Manchester & North Weare Railroad a short distance west of its bridge. An exploration of the Piscataquog valley for two miles farther west showed high and low terraces of fine alluvium, but no kame-like deposits. The south-east course of the kame with this river would have led to the conclusion that its origin was from this tributary valley, had not the whole series been traced and found at other places as here closely following the west side of the Merrimack valley.

Near Piscataquog village the course of the series turns to the south, crossing the New Boston road about an eighth of a mile east of the cemetery. This road passes through a gap in the principal ridge, which both on the north and south is filled almost as compactly as possible with angular fragments of rock one or two feet in size. Through this gap a portion of the river formerly flowed, and its ancient channel extends a mile to the south, lying on the west side of the kame. South-east from this gap, and east of the coarse ridge of angular materials, we find a small plateau, which belongs to this series, and is composed of well-rounded gravel, the largest pebbles having a diameter of two feet. A thin covering of sand forms the surface here, but excavations show the coarse gravel, which is prepared by screening for the manufacture of concrete pavement. This series terminates within a half mile to the south. After being traced continuously six miles along Soucook river and fourteen miles along the west side of the Merrimack, it stops here, and similar deposits were next found fourteen miles below in Hudson and Nashua.

These kames at their beginning reach a height about 100 feet above the Soucook river, or 400 to 450 feet above the sea, and they continue at nearly the same height above the river to its mouth, where they are 300 feet above the sea. Along the Merrimack they are 325 to 265 feet above the sea, or 100 to 125 above the river. The only point where a ridge is found much lower than this is at the eastern curve of the series, in the south part of Hooksett, where it is only about 50 feet above the river. The large area of kames in Manchester rises 100 feet above the head of Amoskeag falls; and the ridge and plateau south-west of Piscataquog are 15 feet lower, being 142 feet above the foot of these falls, and 265 feet above the sea. With an irregularity in height which is almost constantly changing within limits of twenty-five feet, we thus find these kames, as a series, preserving a comparatively uniform elevation above the present river, which is about the same as that reached by its ancient flood-plain.

The origin of these remarkable ridges must be explained in a similar manner with that of the long single kame of Connecticut river. The date of their formation was at the melting of the great ice-sheet. The comparatively fine gravel and frequent layers of sand in the Connecticut kame attest a slow melting of the ice, long water-wearing of its material, and deposition from a moderate or even gentle current. The Merrimack kames, as far north as to Loudon and Concord, indicate a much more rapid departure of the ice, which allowed less time for the formation of rounded gravel, and was attended by strong currents. A section of the Connecticut kame shows, by its alternation of coarse and fine materials, that successive summers and winters were occupied in its accumulation. The same appearance is often seen in the Merrimack series, but frequently a section of these kames is without very definite stratification; and all its materials, which are then very coarse but commonly much water-worn, appear to have been deposited by a nearly uniform and very powerful current, like that of a single summer.

The deep ice-channels in which the kames were accumulated seem to have been formed only at or near the mouths of the glacial rivers, not extending far from the melting edge of the ice-sheet. In this lower portion of the Merrimack valley, and elsewhere in eastern New Hampshire and Massachusetts, the retreat of the glacier seems to have been so rapid that extensions of these kames were often entirely deposited in a single year. The ice-walls by which they were enclosed melted back about as fast as the formation of the channels and kames advanced. Though separate portions of these kames were thus probably wholly deposited in a single year, their annual progress was small; and the formation of the entire series, extending 20 miles, occupied a long period.

The substitution of coarse angular materials, instead of the common water-worn gravel, seems to have taken place at times of very rapid melting, whenever such materials happened to be set free from the ice in large amount near the mouth of the glacial rivers. They were then swept by the violent current into the place of the ordinarily water-worn kames. At the most notable of these localities, which occurs in Hooksett (p. 88), a medial moraine, or a similar train of materials which had become enclosed within the ice, seems to have been thus undermined by the glacial river, and left to appear as a portion of this series.

It remains to add a few statements in regard to kames found farther southward in this valley. A fourth of a mile west from Reed's Ferry we noted irregular ridges of partly angular and partly water-worn materials, which enclose small ponds in their hollows. These kames appear to be isolated, not forming a portion of any series. After discontinuance for fourteen miles next below the long series which extends from Loudon to Manchester, we again find lines of kames in the main valley, upon both sides of the river and a mile apart, in Hudson and Nashua. They begin in Hudson, a short distance south-west of Otternic pond, and extend southward two miles. This series may be seen at the north side of the road leading east from Nashua bridge, near where the river road turns off to the south. It is traceable from this point a half mile northward, consisting of two or more crooked ridges 20 to 30 feet in height. This material is considerably water-worn, the largest pebbles seen being a foot and a half in diameter. Following the river road southward, we find but a single ridge, similar in height and material, but nearly straight, which lies for the first third of a mile on the east side of the road, and beyond on the west side, diverging from it towards the river. This ridge is 75 to 100 feet above the river, which is here 93 feet above the sea. The modified drift of the next half mile southward, extending to an exposure of the till, consists of a level gravel plain, 75 feet above the river, which contains pebbles up to one foot in diameter. This very coarse alluvium has a greater height than the finer deposits west of the river. It seems to be of earlier date than these plains, or even than the kames northward, and was probably formed in the same way with the latter, differing only in its greater extent.

In Nashua, excavations have been made in remnants of the kames on the north side of Canal street, and on the west side of the Nashua & Lowell Railroad, a quarter of a mile south from the Concord depot. A short series seems to extend from the latter point to the south-west, principally concealed by later deposits. A mile and a half farther south, near the city farm, we find another ridge which has been excavated for gravel at its north end. This extends south-easterly nearly continuous for a mile, and is from 20 to 40 feet high. The road lies parallel with it on its north-east side for four fifths of this distance, but at length turns to the south, crossing the kame and rising above the alluvial area, of which this ridge forms the border. The material of these ridges is water-worn but quite coarse, containing stones up to one and a half or two feet in diameter. These kames are probably to be regarded as portions of a series which was never connected. A mile southward it appears again, here also at the west margin of the alluvium, between the highway and railroad, south of Little's station. The highest of these kames in Nashua does not exceed 100 feet above the river. This series does not appear to extend into Massachusetts.

Several other deposits of this kind were noticed at the west and northwest within the limits of our map. Fairmount heights, a coarse gravel plain on the north side of Nashua river, west of the city, is a deposit of similar origin with the kames. Near the west line of Nashua, ridges and mounds of this gravel occur on the south-east side of this river. Other kames, forming very coarse gravel ridges, were observed in the north part of Hollis near a school-house and saw-mill, on the south side of Pennichuck brook; and in Amherst, a third of a mile south from the railroad station. Similar deposits, most frequently of small extent, may be found in almost every town in New Hampshire.

The description of the ordinary alluvial terraces and plains of the Merrimack was interrupted at the mouth of Soucook river. Thence nearly to Manchester the average width of the alluvial area is about one mile. Its narrowest place is at Hooksett, where ledgy hills rise close to the river on both sides. The Pinnacle, a sharp peak of white quartz on the west, 350 feet above the river, affords a very beautiful view of the valley north and south, including several villages. The most interesting portion of the alluvium is its highest terraces. These are from 100 to 125 feet above the river, and are usually well shown upon both sides. Their similarity in height on opposite sides and their very steep escarpments facing each other, as already frequently pointed out, indicate their formerly continuous extent. These upper terraces form wide plains in Bow, which have been partly eroded by Moore's brook, and in Hooksett, south of the Pinnacle and north from Martin's ferry. The last of these areas extends back at the north one mile from the river. The greater part of its material is coarse gravel, and its origin seems to have been from the north-east at the time of the departure of the ice, differing from the ordinary fine alluvium, which was slowly deposited from the floods of the main valley.

Valuable beds of clay, extensively used for brick-making, occur in the highest terrace for four miles north from Hooksett, upon the east side. This clay appears to form a nearly continuous stratum, which has a thickness of from 20 to 30 feet, with its top about 100 feet above the river. It is overlaid by a few feet of sand. The upper part of this stratum consists of a hard and compact *gray clay*. At a depth of 10 to 15 feet this is usually separated, by a thin layer of sand one fourth of an inch to three inches thick, from the underlying *blue clay*, which is soft and plastic when dug from the bank. A gradual transition from the gray to the blue clay is rarely seen. These divisions are nearly equal in amount, but in some of the brick-yards only the upper gray clay is exposed. Except the lower part of the blue clay, which is of inferior quality, both layers are well adapted for brick-making. Deposits of the same gray and blue clay, the latter always below the former, are frequently found in the south-east part of the state, near the coast, and along the Hudson river and Lake Champlain.* Two miles above the most northerly of these brick-yards, a

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* *Natural History of New York*, Mather's *Geology of the First District*, p. 128, etc., and Hitchcock's *Geology of Vermont*, pp. 157, 160, etc.

similar stratum of clay about 25 feet thick, overlaid by 15 feet of sand, is worked near Bow Mills. A large alluvial area, including clay-beds, borders Suncook river from one to two miles above its mouth.

These deposits of clay were accumulated in very quiet water. The rivers which flowed from the melting ice-sheet appear to have brought down a greater depth of modified drift in the south part of Hooksett than was supplied along the distance in which the clay-beds occur. A considerable depth of nearly still water was thus held back in this part of the valley during the deposition of the extensive plains of Concord; and the same floods which deposited fine gravel and sand in Concord, carried forward clay to Pembroke and Hooksett. When this channel was nearly filled, and the river began to excavate the barrier below, the current became so rapid that a layer of sand was formed above the clay.

No very extensive tracts of interval are found on the Merrimack south of Concord. The low terrace, lying slightly above the freshets, but having nearly the fertility of an interval, sometimes occupies large areas; but its average extent is much less than that of the high terraces or plains, which often come nearly to the river. From the mouth of the Soucook river to Hooksett the low terrace is well developed on the west side, averaging a quarter of a mile wide. On the east side it is narrow, but attains considerable width between Suncook and Hooksett, where it is interval. Southward to Manchester it is nowhere wide, but nearly all the way occupies a narrow margin on each side of the river. The Concord Railroad, along its entire length, is built on this terrace.

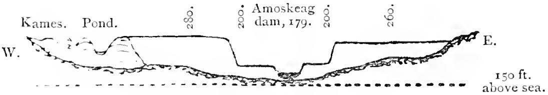


Fig. 21.—SECTION IN MANCHESTER. Length, 2 miles.

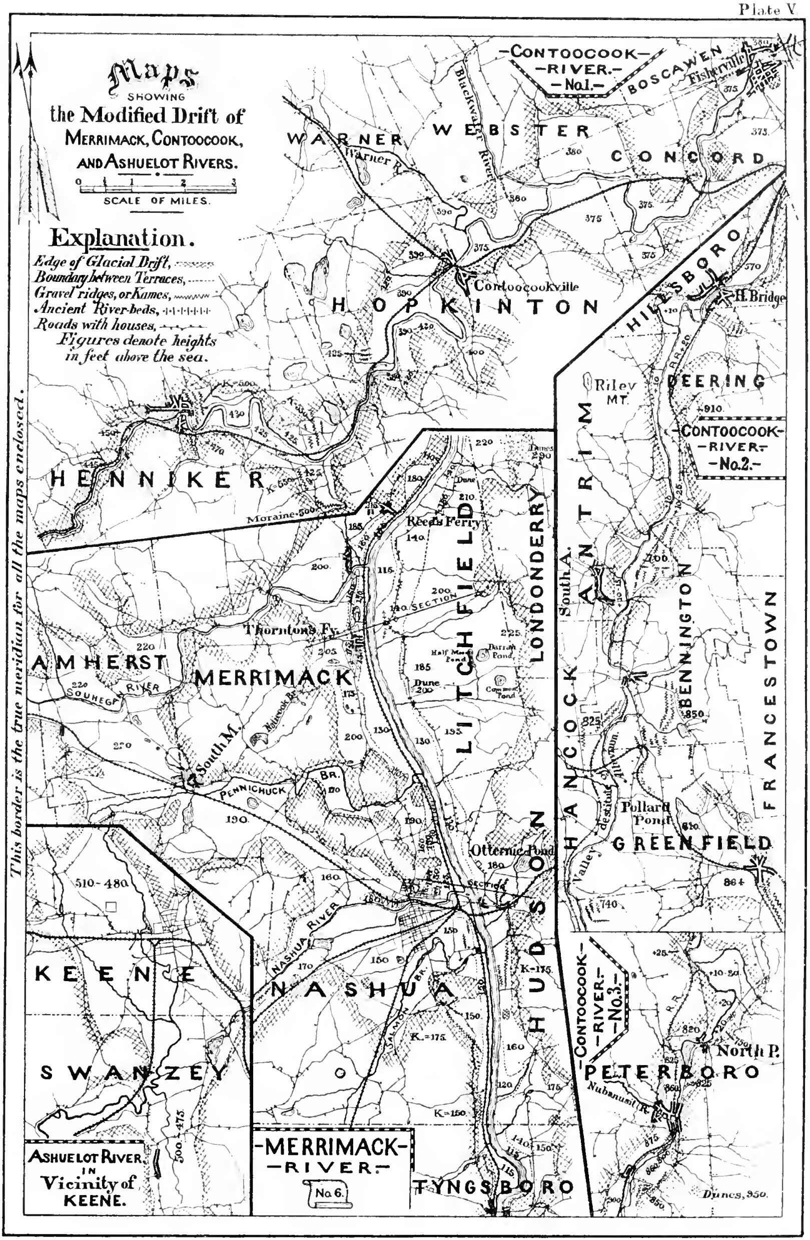
At Amoskeag falls the alluvium is two miles wide, and it averages thus for three miles, the city of Manchester lying at the middle of this distance on the east side. The largest part of this area consists of high sandy or gravelly plains, whose barrenness made this township, under its former name of Derryfield, proverbial for poverty. The Amoskeag falls were then utilized only as a fishing-place. The river here descends 56 feet, from 179 to 123 feet above the sea; and its water-power has within fifty years built up the largest city in the state. The plains on the west side are extensive, both north and south of Piscataquog river, descending from 280 to 265 feet above the sea. The upper edge of the alluvium in the north-east part of the city is from 260 to 265 feet above the sea. Elm street lies upon a terrace intermediate between the high plain and that of the depot. Wells upon this street show about 25 feet of common sand, in the lower part of which water is obtained by the shallower wells; then, 20 feet of quicksand, with no springs, beneath which is a thin layer of clay, lying on unmodified drift or till. The deeper wells find their springs between the clay and till.

Piscataquog village also lies mainly upon an intermediate terrace, which extends a mile to the south, being occupied by the river road. The lowest terrace appears between this and the river; farther south it attains a large width, and is crossed by the river road at Bowman's brook. The same terrace is also wide on the east side north of Goff's Falls.

About a mile south from the city of Manchester an extensive, ledgy hill, isolated in the alluvial area, lies between the Concord and the Manchester & Lawrence railroads. The plain below this barrier to Goff's Falls does not quite reach its normal height, being 210 feet above the sea, or 100 above the river at the mouth of Cohas brook. In the north-western part of Londonderry it is slightly higher, and large quantities of its sand have been blown to the south-east 75 feet above it into irregular mounds and ridges upon the hillsides. Southward, the high plains are continuous and wide to Hudson.

On the west side the plains are wanting most of the way for six miles from Bowman's brook in Bedford to Reed's Ferry. This side of the valley appears to have been specially subjected to the erosion of the river, which has in many portions removed nearly every trace of modified drift, leaving the till or ledge sloping to the present channel. The till is frequently exposed in the banks or bed of the river between Manchester and Nashua, and also sometimes appears on the surface of the extensive plains, showing that the modified drift has not so great a depth as in the widest portions of this valley northward. Nearly opposite Goff's Falls, and on Sebbins brook at the south line of Bedford, the alluvium expands, forming three terraces, the highest in each case being 90 feet above the river.

Plate V.



HELIOTYPE.

In Litchfield and Merrimack the high sandy plains have a larger development than in any other portion of this valley excepting Concord. On the east side we find the modified drift occupying almost the entire township of Litchfield. An area from one fourth to three fourths of a mile wide next to the river is the low fertile terrace,—which is partly interval, as opposite the mouth of Souhegan river, but mostly lies somewhat above high water. East of this is the plain, about 100 feet above the river, coinciding in its eastern boundary nearly with that of the township. Its greatest width is opposite Thornton's Ferry, where it extends three miles back from the river. Its surface is in general very level; a depression is partly occupied by Darrah, Halfmoon, and other ponds. This wide alluvial area becomes narrowed to two thirds of a mile after entering Hudson, but again expands about Otternic pond, which is surrounded by plains. Two miles farther south, below Nashua, this area is contracted to only one fourth of a mile at each side.

The plains of Merrimack extend five miles southward from Reed's Ferry, having the same height as on the east side, and extending back nearly two miles from the Merrimack at their widest portion, which is along Souhegan river to Burnap bridge. Below this the alluvial area averages a mile wide nearly to Pennichuck brook, on whose north side it is interrupted by till which extends almost to the river. More than half of this width is occupied by the plains, which are mostly very level, with scarcely any elevations above the general surface, but having occasional hollows that often enclose small ponds. A considerable portion of the plain at one mile south from Thornton's Ferry has undergone erosion to the amount of 25 feet, now remaining 75 feet above the river. At the south-west part of this terrace clay deposits, which have been used for brick-making, occur near two small ponds. A single low terrace, one third of a mile wide, lies between the southern extension of these plains and the river.

From Reed's to Thornton's Ferry, two terraces are well shown below the plains. The north part of Souhegan village, and the road farther south, lie upon the higher of these, which is about 60 feet above the river. A succession of five terraces was observed south of Naticook brook at Thornton's Ferry. The river here is 100 feet above the sea, and the terraces are 20, 35, 50, 75, and 105 feet above the river, the first being interval, and the last the high plain. They all extend southward beyond the village, except the second, which terminates a short distance south-west of the depot. The third represents the immediate terrace which we noted as commencing at Reed's Ferry. The lower terrace along this distance is now in large part above the reach of the annual floods; but its undulating surface, very noticeable along the railroad, shows that nearly every portion of its area has been at some time occupied by the constantly varying channel of the river. The crescent-shaped pond north of Naticook brook lies in an ancient river-bed; another ancient channel, considerably above that of the present day, is crossed shortly after turning off from the main road in Litchfield to go to Thornton's Ferry. At the east landing of this ferry the bottom of the bank is a thick stratum of clay, which is overlaid by sand.

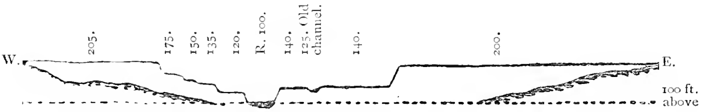


Fig. 22.—SECTION IN MERRIMACK AND LITCHFIELD THROUGH THORNTON'S FERRY. Length, 3½ miles.

Through Nashua we find the width of the alluvium narrowed, and till extending at several places almost to the river. An isolated area of till lies close to the railroad just south of Pennichuck brook. A former channel of this brook is plainly traceable here for a mile; it is crossed by the railroad a short distance south of the bridge, and thence extends southward, forming a long, nearly straight hollow in the terrace between the railroad and the river. A short distance farther south a succession of four terraces appears, at heights of 30, 55, 65, and 95 feet above the river. The highest of these forms a plain, over which the road next to the river extends for a mile south from Pennichuck brook. A small peat-bog lies in a depression on the west part of this plain. Two thirds of a mile north of Nashua river a narrow area of till extends almost to the Merrimack. Much of the till of this section is quite different from that usually seen, as it contains very few large boulders: its coarser portions are mainly pebbles and chips of rock, not often exceeding one foot in size. The former were derived from the neighboring Lake gneiss at the north, and the latter from the compact mica schist and quartzite of the Merrimack group. The kames of Nashua and Hudson differ in the same way in respect to their material from those farther north. South of the till mentioned three terraces occur. The middle one corresponds in height to the extensive plain of the south part of the city, which is 150 feet above the sea, or 57 feet above Merrimack river. This plain averages two miles in width for three miles west from the Merrimack, to Mine falls on Nashua river. It lies mostly on the south side of this river, and also includes the last three miles of Salmon brook within its area. The water-power of Nashua is supplied by these streams, the utilized fall of Nashua river being 51 feet, and that of Salmon brook 57 feet.

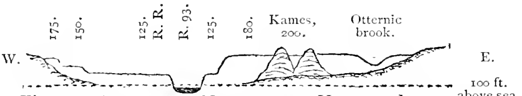


Fig. 23.—SECTION IN NASHUA AND HUDSON, $\frac{1}{4}$ MILE NORTH FROM THE MOUTH OF NASHUA RIVER. Length, 2 miles.

The origin of the material of this plain was partly from each of these streams and partly from the north-west, along the avenue followed by the Wilton Railroad. Salmon brook has considerable alluvial deposits along its whole course. Very interesting kames occur along this brook in Dunstable and in Groton, Mass. They extend several miles, lying north and south, and are well seen from the Nashua, Acton & Boston Railroad. It appears that these were formed when this was one of the principal outlets from the melting ice-sheet. After the full disappearance of the ice the direction of drainage was changed, and a part of the deposits of this area has been carried back northward by this brook.

Main street in Nashua, at the city hall and at the Worcester depot, has the same height with the dam at Mine falls (152 feet above the sea). The descent of the plain eastward in this distance is about 20 feet. Three miles farther south-west, upon the Nashua river in Hollis, we find plains 50 feet higher, or 70 feet above the river, which has a wide alluvial area on both sides to Massachusetts line. Kames, which were probably formed by waters flowing south from the melting ice, occur in Nashua just north of Hollis station, and on the east side of the railroad at the next crossing to the north; and others, previously mentioned, lie near the river, a mile farther north. One of the finest displays of kames to be found in Massachusetts is shown near the head of Nashua river, along the railroad between Fitchburg and South Ashburnham. These kames lie in north-west to south-east ridges parallel with the valley. When they were being formed we must suppose that the ice had gone from the lower east and north-east portions of the river's course, and that the floods of water supplied from the melting ice-sheet at its source were then completing the deposition of these extensive plains at its mouth.

At the same time floods were here poured into the Merrimack from the north-west, where no stream now exists. A continuous belt of alluvium, upon which the Wilton Railroad is built, extends six miles from the Souhegan river in Amherst to the plains of the Nashua river. Its narrowest place, three miles from the city, is a third of a mile wide, while its widest portions, in the north-west corner of Nashua and south part of Amherst, are a mile and a half wide. These plains show a gradual descent from north-west to south-east, amounting to 75 feet in the six miles. They consist of levelly stratified sand and gravel, and in general have a very regular surface; but several ponds, often with no outlets, fill depressions upon their widest portions, as Stearns pond in Amherst, Pennichuck pond near South Merrimack, and Round pond in Nashua. Deposition probably took place very rapidly from floods which brought down the material from the melting ice-sheet. In some cases masses of ice may have remained where we now find these ponds, or they may be due to an unequal supply of material and varying currents. The waters of the Souhegan valley at this period found their way to the Merrimack by three routes. One was along the present course of this river, which, below its extensive plains in Amherst, is narrowly enclosed at two points by high land of till or ledges; a second, similar to the first, was along Pennichuck brook; while the third, which differs from the others in its ample width and direct course, brought the greater part of these floods to the same mouth with the Nashua river. In this way the flood-plains of the last route appear to have become slightly higher than along the present Souhegan river and Pennichuck brook, which therefore became the channels of drainage after the Champlain period.

A half mile below the mouth of Salmon brook, hills approach nearly to the river, beyond which is a plain of similar height with that south of Nashua river. In the remaining three miles to Tyngsborough the alluvial area on the west is narrow, consisting principally of the low terrace, which is about 25 feet above the river. Plains of considerable extent occur on the opposite side, 50 to 75 feet above the river. At Tyngsborough the alluvium is wholly cut off on the west, and nearly so on the east, by hills of ledge or till.

Five miles south of the state line, the Merrimack river turns to the east at North Chelmsford, and thence pursues a devious east and north-east course, at right angles to its valley in New Hampshire, about thirty-five miles to its mouth three miles east of Newburyport. South and south-east from its bend are extensive low alluvial plains. These were deposited by the floods from the melting ice-sheet in New Hampshire, which kept their course south-east to Massachusetts bay. These plains form the very low water-shed between Lowell and Boston, and are the continuation of the slowly descending ancient flood-plain, which we have traced in the upper terraces of Merrimack river through New Hampshire. When these extraordinary floods abated, the river found a lower channel, which had been mainly sheltered from the deposition of modified drift by its crookedness and closely bordering hills.

The area here crossed by the river is remarkable for peculiar accumulations of till, which forms steep, smoothly rounded oblong hills 100 to 200 feet in height. These are set almost as thickly as possible over an otherwise nearly level country. Their prevailing trend, especially north of the Merrimack, as in South Hampton and Kensington, is north-west to south-east, or approximately parallel to the motion of the ice-sheet, which must have heaped them up beneath its mass, and left them at its melting in their present form. The next chapter will contain a full description of these hills, which occur occasionally in many portions of New Hampshire.

At the mouth of Merrimack river a ridge of sand, 25 to 50 feet high and 10 to 40 rods wide, extends several miles both to north and south, facing the ocean. Its gentle east slope forms the beaches of Salisbury and Plum island. This portion of the sand brought down by the river has been swept back again by the waves, and lifted above their reach by the wind. Marshes a mile wide lie on the west side of this ridge. These recent deposits will be described, with those of the coast northward, in a later portion of this chapter.

RECAPITULATION OF MODIFIED DRIFT OF PEMIGEWASSET AND MERRIMACK RIVER.

PLACES.	Distances in miles from Profile lake.		HEIGHTS IN FEET ABOVE THE SEA.	
	Direct course (valley).	Course by the river.	River.	Highest terraces.
Mouth of East Branch,	9.2	9.3	710	780, E. 770, W.
Woodstock, ...	12.5	12.7	627	735
West Thornton, . . .	15.5	15.8	576	685, E. 690, W.
2 miles south, ...	17.5	17.8	565	655, E. 660, W.
4 " "	19.5	19.8	555	630. Kames. 650–670.
West Campton, . . .	21.7	22.1	540	590, E. 630, W.
3 miles south, ...	24.7	25.1	520	620, E. 600, W.
Livermore falls, . . .	26.3	26.8	505–483	600, E.
Plymouth, ...	28.2	28.8	468	555–570, E.
South line of Plymouth,	31	32.5	463	560, E. 525, W.
Ashland, ...	33	34.5	459	565
2 miles south, ...	35	36.5	450	525, E. 540, W. Dunes, 825, E.
New Hampton, . . .	39	41	438	510
Bristol, ...	42.8	45.2	352	502, N. 435, E.
Mouth of Smith's river,	44.8	47.5	320	460, W.
Hill, ...	48	51	305	480, E. 410, W.
Mouth of Salmon br'k,	51.5	54.7	300	475–465, E. 415, W.
Franklin, ...	54.6	58	295–269	440–420, E. 445–430, W.
Webster place, . . .	57	60.7	260	430–550, E. 430, N. W. Dunes, 700, E.
North Boscawen, . .	60	64	256	385, E. 390, W.
Boscawen, ...	63.5	68.4	252	370–360, E. 340–310, W.
Fisherville, ...	66	71.5	249	340–320, E. 380–373, W.
West Concord, . . .	69.5	75.5	229	355–350
Concord, ...	72	79.5	227	350, E. 367, W.

Altitudes for reference, and remarks.

No prominent *tributary deltas* occur in this valley.

Profile lake, about 1950.
Woodstock town-house, 734; bridge, 649.
West Thornton bridge, 596.
Livermore Falls bridge, 561; dam, 511.
Plymouth railroad station, 490.
Ashland station, 562.
New Hampton bridge (centre), 462.
Bristol station, 369; Main St. bridge, 469.
Newfound lake, 590.
Railroad bridge, Smith's river, 336.
Hill station, 335; bridge, 331.
Franklin sta,, 363.26; bridge (centre), 304.
Junc. of N. R. R. and Bristol Branch, 364.
Webster Place station, 295.
North Boscawen station, 290.
Boscawen station, 274.
Fisherville, railroad bridge, 268.
W. Concord sta., 353; E. Concord sta., 246.
Concord station, 252.39; state house, 292.
Datum for city levels (called 0), 225.29.
Top of city water-works dam, 412.
Railroad bridge, Merrimack river, 247.
" " Soucook river, 221.
" " Suncook river, 243.
Hooksett sta., 206; R. R. bridge south, 205.
Martin's Ferry station, 199.
Amoskeag Falls dam, 179; flash-boards, 181.
Manchester station, 180.83.
Datum for city levels (called 0), 108.98.
Massabesic lake, 256.
Manchester & No. Weare R. R. bridge, 169.
Goff's Falls station and bridge, 146.
Reed's Ferry station, 137.
Railroad bridge, Souhegan river, 128.
Thornton's Ferry station, 125.
Railroad bridge, Pennichuck brook, 127.
Nashua station, Concord Railroad, 123.
Datum for city levels (called 0), 93.10.
Reservoir of water-works, 247.
Nashua & Rochester Railroad bridge, 126.
Pawtucket Falls dam, Lowell, 87.
Essex Company's dam, Lawrence, 39.

This river is affected by tide to Mitchell's falls, 2½ miles above Haverhill, Mass.

Along Contoocook River.

Mouth of river, Fisherville, 249.
Borough dam, about 355.
Mast Yard station, 374.
Contoocook station, 373.
River above do., about 365.
West Hopkinton station, 392.
Henniker station, 439.
River below Henniker, 389.
Foot of Long fall, 433; head of do., 546.
Hillsborough Bridge station, 574.
Foot and head of falls in the river at Hillsborough Bridge, 564–591.
at Bennington, 606–676.
" North Peterborough, 714–724.
" Peterborough, 727–734.
Peterborough station, 744.
River at county line, about 875.
East Jaffrey station, 1032.
3 ponds in north part of Rindge, each 1114.

PLACES.	Distances in miles from Profile lake.		HEIGHTS IN FEET ABOVE THE SEA.		
	Direct course (valley).	Course by the river.	River.	Highest terraces.	Altitudes for reference, and remarks.
Mouth of Soucook river,	76.3	85.3	199	300, E. 330, W.	*In the Lake District.* * Mouth of Winnipiseogee river, 269. Cross's mill-pond (Win. river), 415. Tilton station, 458; Winnipiseogee Company's pond (Win. river), 450. East Tilton station, 499; Little bay, 473. Sanbornton and Great bays, 490. Round bay, Laconia, 501. Winnipiseogee lake (high water), 513. Meredith Village station, 556. Wukawan lake and Long pond, 549. New Hampton station 578. R. R. summit 2 ms. S. E. from Ashland, 679. Squam and Little Squam lakes, 569.
Suncook, ...	78.6	88	198	305–315, E. 325, W.	
Hooksett, ...	80.6	90	197–181	315–290, E. 325, W.	
Martin's Ferry, . . .	84.3	94	180	312–298, E. 295, W.	
2 miles south, ...	86.3	96	180	280, E. 290, W.	
Manchester, ...	89	99	179–123	265–260, E. 280–265, W.	
Goff's Falls, ...	92.5	102.6	119–110	210, E. 205, W.	
Reed's Ferry, ...	96.5	106.8	104	210, F. 185–200, W.	
Thornton's Ferry, . .	98.7	109.2	100	200, E. 205, W.	
Mouth of Pennichuck br.,	101.3	112	96	190	
Nashua, ...	104	114.7	93	180–170	
State line, ...	108.3	119	90	175–150	

Slope of the highest terrace in Merrimack Valley.

	Miles.	Ft. per mile.
From mouth of East Branch to south part of Thornton, .	10	15
" Livermore falls, . . .	7	4
" Plymouth, ...	2	15
" Ashland, ...	5	0
" Mouth of Smith's river, .	12	9
" " Salmon brook,	6½	0
" North Boscawen, . . .	8½	9
" Hooksett, ...	20½	3
" Manchester, ...	8½	7
" Goff's Falls, ...	3½	15
" Thornton's Ferry, . . .	6	2
" State line, ...	9½	4
Total distance, . . .	99	6.2

MODIFIED DRIFT ALONG CONTOOCOOK RIVER.

The modified drift of Contoocook river, mapped on Plate V (p. 96), has been explored for a distance of forty miles from the east line of Jaffrey to its mouth. This is the largest tributary in the state. It gives the best example found within our limits of a long valley descending from south to north. The upper twenty-five miles of the distance explored has a quite straight course a few degrees east of north. At Henniker the river turns eastward, and thence flows slightly east of north-east fifteen miles to its junction with the Merrimack at Fisherville. These distances measure the direct course of the valley, not the meandering channel of the river, which exceeds fifty miles.

From the northward course of this valley, we should suppose that the

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* These heights were determined by levelling from Franklin station by Winnipiseogee lake to Ashland, and thence along Pemigewasset river to the point of beginning. By this complete circuit they were proved to be correct, as compared with the altitudes given in Vol. I, p. 258, and also here, for Franklin and Concord.

conditions which prevailed at the melting of the ice, and the modified drift then deposited, would differ from the common type. This expectation was fully justified by exploration for thirty miles, along which distance deposits were found different from any seen elsewhere in the state, together with frequent kames; and it is only after entering Hopkinton, and along the last ten miles of the river, that it is bordered by the ordinary level and continuous alluvial plains.

We will first describe the modified drift of this valley in order, proceeding from its source to its mouth, without intruding any theories; after which, we will seek an explanation of the facts observed. Several ponds in the north part of Rindge constitute the head waters of Contoocook river; and others in the same town are among the principal sources of Miller's river. The water-shed on which these ponds lie is a comparatively level plateau, partly covered by large amounts of coarse, water-worn gravel, and elevated 1,100 to 1,200 feet above the sea.

At the line between Jaffrey and Peterborough, where our special examination of the valley began, the river is about 875 feet above the sea. For the first mile the stream is bordered by coarse, water-worn gravel, containing pebbles one to two feet in diameter, interstratified in nearly equal proportion with sand. These deposits occur in ridges or irregular terraces, which reach a height of 150 feet above the river. They are well exposed by the excavations for the railroad, along which they extend, decreasing in height at the north, to within a half mile of Noone's mill. Thence northward to Peterborough village the principal deposits on the west side are sand, which slopes very irregularly from the river to the height of 100 feet at the distance of a quarter of a mile on the hillside. This was seen in some places to be stratified conformably to the surface, and it is scarcely anywhere distinctly terraced so as to show steep escarpments with a wide, level top. Boulders of various sizes, up to four or five feet in diameter, are frequently found embedded in this stratified sand.

South-east from Noone's mill we find an interesting assemblage of kames, in irregular ridges, which rise from 50 to 75 feet above the river. These are three or four in number, lying approximately north and south and parallel to each other. Their material is water-worn gravel, containing pebbles up to a foot and a half in diameter. At one point a ridge turns abruptly from a northward to an eastward course, enclosing a pond in the triangular hollow between it and the adjoining ridge. A short distance to the north is a hill, about 90 feet above the river, which appears to consist of till overlaid by a gravel deposit. This is surrounded by low alluvium. A little farther north the river flows at the eastern foot of a gravel ridge, which is about 40 feet in height. A boulder six feet in diameter was noticed in this ridge; but such blocks are very rare in these kames, and were nowhere seen in the high gravel deposits farther south.

One mile east from Noone's mill, sand dunes occur on the hillside at a height of about 200 feet above the river, covering some two acres, which are almost destitute of vegetation.

The Contoocook, at the mouth of Nubanusit river in Peterborough village, is 734 feet above the sea. Here till and ledge rise steeply on the east side, which has no modified drift. Half a mile to the north a considerable width on this side is occupied by alluvial sand and fine gravel, which extend in irregular slopes to 100 feet above the river, rarely showing any steeply-terraced or level-topped surface. The most irregular portion of this area is at the cemetery, which is diversified by kame-like mounds and ridges. As we approach North Peterborough the till and ledge again reach to the river. Along this distance on the west side, similar sand and gravel, in irregular slopes, thinly cover the hills to a height of 100 to 150 feet above the river. Occasional boulders are found enclosed in these deposits.

At North Peterborough a broad, terrace-like ridge of sand extends half a mile on the north-west side of the river. This has steep slopes, but its top is nearly level, with a height about 100 feet above the river, being at the south 820 and at the north 810 feet above the sea. The valley here bends for a short distance to the east, so that to one following the river northward this ridge at first appears to lie as a barrier before it. With this huge sand-bank the high deposits of modified drift, which we have found bordering this river continuously for five miles, come to a sudden end.

Half a mile eastward a small terrace, about 50 feet above the river, lies on its east side. Excepting this, we find in the next two miles only low alluvium, which averages a half mile in width, lying mostly on the east side of the river, with a height of 10 to 30 feet above it. Beyond this we find the valley for the next six miles, extending nearly to Antrim, well-nigh destitute of any alluvial or terraced deposits; yet it has along most of the way an ample width with gently sloping sides, which are usually the conditions for the accumulation of extensive plains. In this distance, and for several miles farther north, the descent of the river is small, amounting to 123 feet in the sixteen miles between North Peterborough and Hillsborough Bridge. More than half of this occurs at Bennington, where its fall is from 676 to 606 feet above the sea; for the rest, the average slope is about three feet to a mile.

The only important deposits of modified drift seen along this river for six miles were kames, which appear on the east side near the north line of Peterborough, and are very well shown upon both sides of the valley at one mile south-east and south-west from Bennington. In the north edge of Peterborough these consist of sand or fine gravel, which lie in numerous mounds and ridges, in depths to 20 or 30 feet, upon a sloping hillside of till 90 to 100 feet above the river. These deposits are irregularly stratified, conformably in some places, and perhaps generally, to the underlying surface. They contain here and there embedded boulders, the largest of which observed was four feet in diameter.

From a half mile to more than a mile south of Bennington, on both sides, we have large accumulations of kames. On the west they rise to about 140 feet above the river, and consist of sand in hillocks and north and south ridges, which are 50 to 75 feet in height, lying on till. In the sand, which is irregularly stratified as seen in many places, there also occur occasional boulders up to four feet in size. On the east side these ridges and banks are well shown along the road to Greenfield before coming to Whittemore pond. They are composed in large part of the coarse, water-worn gravel which is characteristic of the kames, interstratified with sand, and containing embedded boulders. These deposits reach a height fully 175 feet above the river, or 850 feet above the sea. Thence to the south-west similar deposits border the north and west sides of the hills to within a half mile of Pollard pond, being well shown on the east side of the Manchester & Keene Railroad, now being built, for one mile south from Bennington station. Here they form nearly level terrace-like banks of fine gravel or sand, 170 to 175 feet above the river, irregularly stratified and rarely containing boulders.

At Bennington station the kames are very well displayed, forming long and narrow steep ridges. One of these has been here cut through for the railroad, and shows very instructive sections. Its base is 40 feet above the river, and its height about 20 feet. Fig. 24 shows the simple transverse section at the south side of the cut; and Fig. 25 shows the section on the north side. The east portion of the last is directly transverse, but its west portion is a longitudinal section, extending farther north.

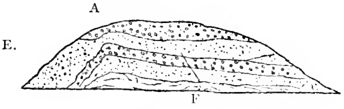

Fig. 24.—South side.

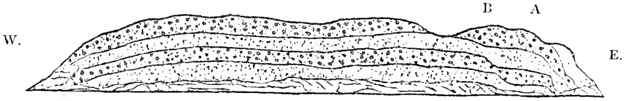

Fig. 25.—North side.
Sections of a Kame, Bennington Station, M. & K. R. R.
Scale, 25 feet to an inch.

This kame showed the following succession of deposits, beginning at the top:

1. Coarse yellow gravel, containing pebbles up to 8 inches in diameter;—thickness, 3 to 5 feet.

2. Fine sand, whitish and yellowish;—thickness, 3 to 5 feet.

3. Coarse dark gravel, containing pebbles up to one foot in diameter;—thickness, 3 feet.

4. Sand, same as No. 2, obscured at bottom by crumbling of the bank;—thickness, 4, perhaps 8, feet.

A–A. Downfall of strata, with irregular, broken steep slope, against which lies an accumulation of sand.

B. Depression of 2 feet, similar to the foregoing (not extending to south side).

F. Fault, seen only on south side;—dislocation of strata, 6 inches.

Boulders up to seven feet in diameter are rarely found on the top of this kame; but none were observed embedded in it. It will be noticed that the alternate layers of gravel and sand preserve a nearly uniform thickness throughout the excavation. It should be added that the gravel usually contains no clear sand and the sand no gravel; and that these succeed each other by a sudden change, not by gradual transition. These sections appear to show the deposition of two years, the coarse gravel being brought from the melting ice-sheet by strong summer floods, and the sand being deposited in autumn and spring. The line of downfall, A–A, appears to show where these materials at first rested against a wall of ice. When this melted, the strata suddenly fell as seen at these points.

In Hancock, a mile and a half farther west, the first excavation for this railroad after crossing the highway shows sand and fine gravel underlying till upon both sides of the cut. (Fig. 26.) This is on the south slope of a hill, at a height for the bottom of the cut of 28 feet above the river. The surface all around is composed of till and covered with boulders. The separation between the modified drift and till is not a definite line; but there is a gradual transition, occupying one or two feet, and the till has thin streaks of sand. No boulders were seen in the underlying deposit.

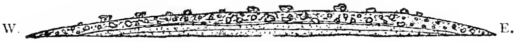

Fig. 26.—SECTION OF MODIFIED DRIFT UNDER TILL, HANCOCK.
Length of Section, 300 feet; height, 15 feet.

1. The unmodified drift, or till, contains boulders of all sizes up to 8 or 10 feet; its thickness is from 6 to 10 feet.

2. The modified drift is stratified in layers of varying thickness; sometimes contorted, but mainly horizontal; consisting of sand (in strata from 2 to 5 feet thick) and fine gravel (with the largest pebbles 3 inches in diameter); thickness exposed, from 5 to 7 feet, also extending below the excavation.

The lack of alluvial deposits in the Contoocook valley is made up where we might least expect it, two miles farther east, at a height of nearly 200 feet above the river, and not in the pathway of any large stream. Following the stage road from Bennington to Greenfield, numerous kames were seen north-east from Pollard pond, principally forming north-west to south-east ridges, and composed of coarse gravel. The road next enters on a nearly level plain of sand and gravel, which extends about two miles to the south, being from one half mile to one mile wide. Its height is from 850 to 870 feet above the sea. Hogback and Bridge ponds lie in depressions of this plain, with steeply sloping shores from 25 to 30 feet high. Pollard pond lies about 50 feet below the plain, of which with its outlet it forms the western boundary.

The first of these ponds has its name from gravel ridges or kames. These are well shown between this and Pollard pond, extending in north-west to south-east ridges, not higher than the plain, but shown as ridges because of intervening hollows. These kames, with most of the plain northward, consist of coarse, rounded gravel, with the largest pebbles from a foot to a foot and a half in diameter. Southward, sand predominates, but much kame-like gravel is also found. These materials are spread out comparatively level, but the excavation for the railroad shows that they have usually an oblique stratification, dipping mostly to the south-east. Greenfield village lies at the east edge of this alluvial area, which extends with its full width a half mile farther south. In this distance we find, on the east side of the railroad, kames containing pebbles up to a foot and a half in diameter, and lying in north and south ridges 20 to 30 feet higher than the plain. These continue along the railroad fully a mile to Cragin pond, forming a narrow belt, which is bordered by hills of ledge or till. Their southern portion is mainly of sand or fine gravel, and they terminate in a sand plain, which lies on the east side of this pond, 25 feet above it.

A water-shed scarcely higher than this plain and lower than the kames, being 863 feet above the sea, separates Cragin pond from the head-stream of Stony brook, which the railroad follows to Wilton, descending more than 500 feet in nine miles. The modified drift of this valley consists of occasional terraces and kames, but presents no remarkable features, and is scanty in amount.

No streams now exist, or can have existed with the present system of drainage, capable of forming the large alluvial plain of Greenfield. Excepting north of Pollard pond, the hills which lie between it and the Contoocook do not exceed the plain in height. Its extent along the outlet of Pollard pond is to the north-east corner of Peterborough, below which for two miles this stream is destitute of alluvium, as are also the low hills and even the valley of the Contoocook on the west.

At Bennington the valley is closely bordered by hills, beyond which we again find the modified drift continuous to Hillsborough Bridge, a distance of nine miles. The Hillsborough & Peterborough Railroad, now being built, is here on the east side of the river, and from South Antrim northward lies on a low and partly swampy plain 15 to 20 feet in height and a fourth to a half mile wide. The old muster-ground of "Cork plain," in Deering, is a part of this long terrace. On the west side the river has a similar but narrower alluvial margin, principally of meadow or interval, not exceeding 10 to 15 feet in height. At the north line of Antrim and Deering these deposits have their widest development upon both sides, covering a mile square.

Kames extend along the east side of this low alluvium from opposite South Antrim to the north line of Bennington. They are disposed in numerous mounds and ridges, which lie mostly north and south, attaining a height of 100 feet above the river, and occupying a third of a mile in width. Their material is sandy gravel, with the largest pebbles about one foot in diameter, but they contain, also, occasional angular boulders of sizes up to five or six feet. Near their north end the surface of ordinary till between these gravel ridges is strewn with massive boulders often ten feet in diameter. Kames are also found a half mile south-east from Hillsborough Bridge, in mounds 10 to 30 feet high.

A very remarkable accumulation of sand and gravel is found on the east side of this valley in Deering, two and a half miles south from Hillsborough Bridge, at a height of more than 300 feet above the river. On its north-west side an abrupt spur of Hedgehog hill, probably 450 feet above the river, projects half-way across the valley; and the same range rises still higher on the south-east. The deposit lies upon the south-west slope of the intervening hollow, reaching to the height of land which separates the hills. It consists of sharp-grained sand, interstratified with gravel, which contains pebbles up to six inches or nearly one foot in diameter. Four or five acres at the top are nearly level, and thence a long slope extends down nearly to the alluvial plain. The stratification of this sand and gravel is seen in gullies formed by rains or very small springs, which are making slow inroads upon the level area at the top, where the undisturbed strata are exposed, dipping to the south-west nearly at the same angle with the slope of the hill. No boulders were observed, either embedded or on the surface. This is the only high deposit of modified drift close to the river in this portion of its valley, and must be of different origin from our ordinary high terraces and plains; nor does any water-course exist by which it could be brought here.

Other notable deposits of sand and gravel, to be hereafter described, occur at nearly the same level on both sides of this valley through Hillsborough county. They are usually two or three miles distant from the Contoocook river, but in most cases border some tributary stream.

At Hillsborough Bridge the river is enclosed on both sides for a short distance by slopes of till. Below this place the alluvium forms low plains between the railroad and the river. The fall of the Contoocook at Hillsborough Bridge is 27 feet, its height at the head of this fall being 591 feet above the sea. At the head of Long fall, near the line between Hillsborough and Henniker, it is 546 feet above the sea, and in the next two miles it descends 113 feet through a narrow valley destitute of modified drift.

In Henniker a small terrace 15 feet above the river is crossed by the railroad near the foot of Long fall. A wider terrace, 30 feet above the river, extends nearly a mile from the west village to the railroad bridge. These are both on the north-west side, and are the only deposits of modified drift west of the principal village. At the east side of this village an interesting assemblage of kames is found, consisting of water-worn gravel, with the largest pebbles one to two feet in diameter, in three or four north and south ridges, 20 to 50 feet in height, nearly parallel with each other. They cover an area two thirds of a mile long and half as wide, and rise to a height of 100 to 125 feet above the river, which below the village is 390 feet above the sea. It will be seen that these ridges lie at right angles with the course of the valley, extending nearly across it, and causing the river to flow around them in a southward bend. East from the kames the river flows through intervals or low plains, 15 to 40 feet in height, which extend, with an average width of two thirds of a mile, through the township.

Two and a half miles east from Henniker village we find on the north side of the river, south-west from Whittaker pond, another group of kames lying in north and south ridges across the valley like the preceding, and reaching a height of 100 to 150 feet above the river. The material of these ridges is in part the usual water-worn gravel, but in some portions it contains principally angular fragments of rock one to three feet in dimensions. Whittaker pond is bordered on the south by a nearly level deposit of coarse rounded gravel, about 75 feet above the river.

Half a mile south-west from these ridges, on the south side of the river, we find a remarkable kame, half a mile long, with a course a little to the east of south, composed of sandy gravel, with pebbles frequently six to eight inches, but not commonly exceeding one foot in diameter. This forms a steep ridge about 100 feet above the hollow which separates it from a high hill an eighth of a mile west, and 125 feet above the low alluvium, which extends two thirds of a mile wide on the east. A small pond lies in this alluvium at the foot of the kame. The next third of a mile south shows no ridge, but it is succeeded by a very interesting moraine, which forms a steep and narrow crescent-shaped ridge, fully half a mile long, lying in a similar position with the kame between the hills and the low alluvial area. Its course is to the south-east and east, with height descending from about 75 to less than 50 feet above the alluvium, and it is separated from the hills by a hollow nearly as deep. The crest of this moraine consists almost entirely of angular boulders of all sizes up to ten feet in diameter, which cover the surface and are piled as thickly as possible, with scarcely any space for finer material. On the sides, and along the top near the east end of the ridge, we find earth and boulders intermixed in the ordinary proportions of the coarse upper till. These blocks are principally of two kinds, derived from the Lake and porphyritic gneiss, which occupy the whole country for more than ten miles to the north. The New Hampshire Central Railroad, now discontinued, was built in the hollow on the south-west side of both kame and moraine.

A noticeable feature of the Contoocook basin is, that its east and south-east water-shed is formed by high, irregular hills near the river, which has no large tributaries from this side. The lowest points of this water-shed usually exceed 400 feet above the river; but one or two miles south-east from this moraine the railroad found a line of depression only 150 feet above the river, or 537 feet above the sea. On each side high hills border this pass, which connects the Contoocook valley with that of the north branch of the Piscataquog river. No extensive or remarkable deposits of modified drift were seen in a hasty journey along the latter valley.

A third of a mile above West Hopkinton the Contoocook river flows between slopes of till 75 feet in height, and so steep as to suggest that the channel here may have been formed by the erosion of the river. A third of a mile from this railroad station, several parallel kames are found extending nearly east and west between the highway and the outlet from Rolfe's pond. These are composed of the usual water-worn gravel, with pebbles up to one foot in size, and form ridges and mounds 25 or 30 feet high and 60 feet above the river.

In the remaining ten miles of its course the Contoocook is almost continuously bordered by extensive low plains, seldom exceeding 30 feet above the river, with occasional areas of interval, but no kames were seen. On the south side of the river, below West Hopkinton, portions of these plains are 50 feet above the river; and on the north side the same height is reached by a delta-like deposit where the outlet from Clement pond enters the alluvial area. At Contoocookville the alluvium is interrupted by low areas of till or ledge, that upon the north side being quite low and scarcely higher than the plains, which seem at the edge of the village to extend across it. Thence eastward low sandy plains, from 15 to 25 feet above the Contoocook, extend nearly level for eight miles to the Merrimack river. Their greatest expanse is in the north-east part of Hopkinton, the north-west corner of Concord, and the south edge of Webster, where they cover an area three miles long from north to south and nearly two miles wide. This at the north consists partly of swampy land, slightly depressed, and with no outlet for drainage. Warner and Blackwater rivers, which are tributary to the Contoocook in Hopkinton, are bordered by considerable alluvial deposits, the former in Warner and the latter in Salisbury.

Three miles above its mouth the Contoocook is enclosed by hills with only a narrow alluvial margin. The proper continuity of its plain is here along the Concord & Claremont Railroad, with a hill between it and the river, east of which the plain is wide, lying principally on the south side of the Contoocook river, at a height of 125 feet above the Merrimack. Below Contoocookville the river has a height of about 355 feet above the sea nearly to Fisherville, where it descends rapidly to its mouth, which is 249 feet above the sea.

We will next consider the course of events in the Champlain period, of which these deposits of modified drift bear witness.

Review and Conclusions.

The continuousness in height of the plains of the Merrimack valley in Concord with those through which the last ten miles of the Contoocook flows, has been already noticed (p. 80). A comparison of this with the deficient height of the terraces of the Merrimack opposite to and for a few miles above the mouth of this river (pp. 78 and 79), leads to the conclusion that a large proportion of the modified drift of Concord was brought into the Merrimack valley by the Soucook and Contoocook rivers. The latter contributed to the plain of East Concord, and alone filled the large area between West Concord and Fisherville.

The extensive plains of the Contoocook, in the north-west part of Concord and through Hopkinton, occupy two basins of unequal size, which we must suppose held lakes at the first retreat of the ice-sheet. These were filled, as the melting of the ice continued, by the alluvium of its floods. A large share was supplied by the tributaries from the north; and the kames near West Hopkinton were formed by a glacial river, which descended at the head of the valley. To this point the formation of modified drift seems to have proceeded quite in the ordinary way.

In the east part of Henniker the first outlet from this valley was probably to the south-east into the basin of Piscataquog river. The moraine and kame which extend along the old line of the New Hampshire Central Railroad, at the south-west side of the alluvial area of the Contoocook, indicate a considerable period in which the terminal front of the rock-bearing glacier remained nearly stationary, succeeded by a period of retreat northward, when a large river, laden with sand and gravel, descended from the melting ice-fields. At the time of formation of this kame a small lake, nearly as deep as to cover its top, lay between the front of the glacier and the outlet of its waters to the south. The glacial river, entering this deep and quiet lakelet, deposited more quickly than usual nearly its whole freight, both of gravel and sand. Somewhat later, but while the outlet was still to the south, the kames on the north side of the valley south-west from Whittaker pond were formed; and we may presume that this date was nearly the same with that of the kames of West Hopkinton, which show that the valley of the Contoocook below was clear from ice. Not long after this time the glacial barrier between these basins disappeared, and drainage took its present course. Whether the kames at the east side of Henniker village were formed before or after this change, cannot perhaps be determined. Their position, transverse to the Contoocook, shows that they were formed by streams from the melting glacier on the north in the valleys of Amy and Warner brooks, while the rapid retreat of the ice to the west and south-west appears to have been delayed by the high hills which closely border the river. It is not improbable that, when these waters first flowed towards the north-east down the Contoocook valley, a barrier of till near West Hopkinton, afterwards eroded by the river, held back a shallow lake which extended to the kames last mentioned. The deposition of the low alluvium of this area was going slowly forward during all the time occupied by this history.

The melting of the vast ice-sheet over New England proceeded from the coast to the north-west and north, so that lakes were temporarily formed in valleys which drain northward. The avenues by which the waters escaped from the upper portion of the Contoocook basin, or that part above Long fall in the west part of Henniker, appear to have been three in number, as follows: Southward, over the water-shed at the head of the valley in Rindge; towards the south-east, through Greenfield; and northward, along the course of the river. The length of this area is nearly thirty miles; and the outlet in Greenfield is about equally distant from its south and north ends.

The conspicuous kames, which extend five miles along the Vermont & Massachusetts Railroad between South Ashburnham Junction and Westminster, show that a large area of the ice-fields on the north-west poured their waters along this course. These kames are less than 200 feet below the plateau in Rindge, twelve miles distant, which forms the water-shed at the head of the Contoocook valley. Although the present drainage of the south part of Rindge and of Winchendon is into Miller's river and the Connecticut, there is no considerable depression; and the separation between this basin and the head of the Nashua valley, in which these kames are found, is not so high as the water-shed in Rindge. This area has not been explored; but the deposits of modified drift in Rindge make it probable that the melting of the ice-sheet, while its outlet continued in this direction, proceeded beyond this divide, including a portion of the Contoocook basin.

The principal outlet from the part of this basin in Hillsborough county appears to have been through Greenfield south-easterly to Souhegan river. South from this pass the east border of the Contoocook valley is formed by Pack Monadnock, Temple, Kidder, and Barrett mountains, which extend in a continuous range through the west portions of Temple and New Ipswich. Northward this valley has a high eastern water-shed two to four miles from the river, with no deep depression till we reach the pass through which we have supposed a former outflow towards Piscataquog river. The culminating points of this water-shed are at its south and north ends, in Crotched mountain and Craney hill.

When the melting of the ice-sheet had advanced so far as to open an avenue from this valley through Greenfield, we may suppose that large streams descended from the glacier to this point, by which the kames on the east side of the railroad south of the village, those between Hogback and Pollard ponds and along the road northward between Greenfield and Bennington, and those at Bennington station and for a mile north-west on both sides of Contoocook river, were in succession deposited. The fine alluvium of these streams was at first spread out in the level plain east of Cragin pond, while ice still remained over the area now occupied by this pond. A small lake was afterward formed by the melting of the ice on the north-west side of the pass. This lake received the finer drift brought down by the glacial rivers, producing the alluvial plain west and north-west from Greenfield.

A channel appears next to have been formed farther to the north-west, skirting the hills upon the east side of the valley and walled on the west by ice. This became filled by the nearly level-topped and terrace-like gravel and sand seen on the east side of the Manchester & Keene Railroad south from Bennington station, which seem to belong to the same date with the kames at this station and about Whittemore pond. The kames were probably formed in ice-channels which were narrow and somewhat higher than the former, with so rapid a descent that only coarse gravel was deposited in them by the summer floods, the sand being carried onward to the quiet waters of the channel below, which was an arm of the lake. With the full melting of the ice, however, such of the kames as had been formed over the middle of the valley sank to its bottom, and are found at a lower level than the principal deposits of fine gravel and sand, which remain nearly at their original height upon the hillside.

The kames which we find south-west from Bennington, and a large portion of those north of Whittemore pond, are principally composed of sand and fine gravel. They were probably deposited at the mouth of the glacial streams where these entered the lake, nearly all the modified drift which was brought from the melting ice being thus accumulated in mounds, ridges, and terrace-like banks. The want of continuity in these deposits appears to be due to the irregular rate of melting and to the varying slopes assumed by the terminal front of the ice-sheet, the latter being determined by this rate and by the contour of the valley.

The lack of stratified drift in the valley west from the Greenfield plain seems to show that the ice over this area, while it still confined the little lake on the east, had been melted nearly to this level, sending its alluvium to form this plain; and that the remainder disappeared from the valley without sufficient currents to form alluvial deposits. All the material which it still held was dropped as unstratified till, unless we except rare instances of kames like the isolated banks of sand seen on the hillside east of the river near the north line of Peterborough.

The first deposit belonging to this period that we meet in going up the valley is the high level-topped sand north-west from North Peterborough. This and other terrace-like deposits extending to Peterborough appear to be of similar origin with those already noticed south of Bennington station. Kames of the common type, composed of coarse gravel and sand, occur one and two miles farther up the valley; and they are increased in amount as we approach the line between Peterborough and Jaffrey, appearing to have come principally from Sharon on the south-east. We may suppose that these, as in Bennington, were deposited at the same date with the sand which partly filled the opening channel below. This was a branch of the lake, and the sand fell in irregular and thin deposits with stratification conforming to the sloping sides of the valley. The occasional boulders which we find embedded in the alluvial deposits of this lake appear to have been dropped by floating masses of ice broken from the glacier which bordered its shores.

Going down the valley we find evidence that the glacial melting advanced beyond Hillsborough Bridge, while its outlet continued to be through Greenfield. The last blockade of the ice-sheet in its retreat to the north may have been at Long fall, in the west part of Henniker, where the high hills leave a narrower space than usual for the passage of the river. The large proportion of sand in the kames of the north part of Bennington is what we should expect, if their deposition was at the mouth of glacial rivers where they entered the lake. The most important testimony, however, is given by high deposits of sand and fine gravel, like that on Hedgehog hill in Deering. The widened lake now filled the whole valley; and these deltas, brought in by glacial rivers or tributary streams, mark its height and shore line, and enable us to gauge the floods which were supplied from the melting ice.

The earliest of these lake-shore deposits are the plain of Greenfield and that of Hancock village. Both of these have the same height with the outlet, over which there as yet flowed only a shallow stream. When the lake had advanced north to Clinton village in Antrim, the depth of its outflow was probably 20 feet, as shown by a level-topped ridge of sand and fine gravel exposed on the north side of Great brook and the road, a quarter of a mile east from Hastings's mill. This deposit extends a quarter of a mile to the north, and also occurs south of this stream, by which it was formed about at the level of the lake. High sand was also found three miles farther north, on the water-shed between Cochran brook and North Branch, at the south-west side of Riley mountain. This is two and a half miles due west from that on Hedgehog hill. Both these deposits are level-topped deltas of glacial streams that descended to the lake from the north, having the place of their inlet determined by the gap of the adjacent hills. Their heights are the same, and show that at the time of their formation 50 feet of water poured over the outlet in Greenfield. Somewhat later, when the lake reached its greatest extent and received its largest tribute from the more rapidly melting ice-sheet, the depth of water discharged was 80 feet, as shown by a delta-terrace half a mile south-west from Hillsborough Centre, and by plains which occur at the same height north-east of Hillsborough Upper Village. All these deposits are level-topped, or nearly so; and their position is generally on steep hillsides, with no barrier, if the drainage had been the same as now, to prevent their being carried forward to the bottom of the valley. Other deltas similar to these might probably be found by a more thorough exploration of the ancient lake shore.

Heights of the Outlet and Deltas of the Lake which filled the Contoocook Valley through Hillsborough County in the Champlain Period.[*]

Outlet of lake, 1½ miles south-east from Greenfield, being the lowest point of water-shed between Contoocook and Souhegan rivers (2 feet lower than the railroad summit), 863.
Cragin pond, 830.
Greenfield station, 834.
Pollard pond, 810.
Delta cut by the railroad ½ mile north-west from Greenfield station, nearly the same in height with the fair-ground, 864.
Delta at Hancock village, 862.
Delta at Clinton village, Antrim, 883.
Delta south-west of Riley mt., Antrim, 912–915.
Delta on Hedgehog hill, Deering, 905–920.
Delta ½ mile south-west from Hillsborough Centre, 940.
Delta north-east of Hillsborough Upper Village, 942.
Kames at church and cemetery between Hillsborough Upper and Lower Villages, 930.

The depth of this lake was from 200 to 350 feet, as will be seen from the following:

Heights along Contoocook River.

Head of Long fall, near county line, 546.
At Hillsborough Bridge, foot of falls, 564; lower dam, 576; upper dam, 591.
At Bennington, foot of falls, 606; Paper-mill pond, 635; Kimball's dam, 645; King's dam, 655; Whitney's dam, 668; Powder-mill dam, 676.
Foot and head of fall at North Peterborough, 714–724.
Same at Peterborough, 727–734.
River at county line, about 875.

At length the melting of the ice along the lower part of the valley at the north-east met the already open portion which extended through Hillsborough county, and the drainage of the basin took its present

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[*] The heights from Greenfield to Paper Mill Village inclusive, given in Vol. I, p. 268, are too low, requiring the addition of 36 feet to agree with recent surveys of R. S. Howe for the Hillsborough & Peterborough Railroad, and with those of Hon. J. A. Weston for the Manchester & Keene and Monadnock railroads, published in Vol. I, p. 271. The heights given above are derived from the profiles of these railroads, or from special survey. They are stated in feet above the sea.

Our levelling to determine the height of deltas gave opportunity to note also the water-power of two tributaries of the Contoocook.

Heights along Great Brook, Antrim. Mouth of brook, 600; Thompson's mill-pond, 624; Goodell's saw-mill pond, 641; Goodell's next pond, 657; Poor's saw-mill pond, 672; Goodell's cutlery-shop pond, 703; Kelsey & Co.'s pond, 717; Baptist and Methodist churches, South Antrim, 719; road at foot of sand delta, Clinton village, 853; hay-scales platform at Clinton village, E. Z. Hastings's house, and his mill-pond, each, 914; Gregg's pond, according to an old survey, 1064.

Heights along North Branch in Hillsborough and Antrim. Mouth of Branch, 592; mouth of Beard's brook, near foundry, 600; Foundry mill-pond, 618; Young's (formerly Dickey's) mill-pond, 702; Tannery mill-pond, 728; still water, ¼ mile above Hillsborough Lower Village, 750. (The following heights of this stream in Antrim are from survey by G. C. Patten, in 1874.) Foot of rapids, ⅓ mile east of W. Curtis's, 755; Curtis's dam, 852; foot of falls at North Branch village, 862; Parkhurst's dam, 902; at Boutwell's bridge, 1 mile above this village, 985; proposed reservoir of 100 acres above do., 1025; J. Loveren's dam, 1077; foot of falls below do., 1024.

course to the north. The erosion of the high deposits in the south part of Peterborough and the tribute of streams near the source of the river now supplied the low alluvium which extends for two miles below North Peterborough. The kames in Bennington probably also suffered considerable erosion, which, with the important streams on the west, furnished the similar low alluvial deposits of Antrim, Deering, and Hillsborough.

Modified Drift of Winnipiseogee and Squam Lakes.

The beauty of Winnipiseogee lake is due to its multitude of irregularly grouped islands, to the three long bays or arms into which its north end is divided, and to the winding outlines of its shores. The water-shed which bounds its basin reaches no point more than seven miles distant from the lake.* It passes over Belknap, Cropple Crown, and Ossipee mountains, and Red hill, which rise from 1,500 to 1,900 feet above the lake; but its other highest points are hills of half this height or less, which descend steeply to the west and south shores but have more gentle slopes on the east and north. Somewhat farther distant, at the north, the view from Winnipiseogee embraces Chocorua, Paugus, Passaconaway, Whiteface, and Sandwich Dome, which form the southern front of the White Mountains; and from many parts Mt. Washington is also visible. To know this scenery fully, the lake must also be seen from the mountains and hills by which it is environed. The most magnificent of these views is that from Red hill, which overlooks both Winnipiseogee and Squam lakes.

The depth of Winnipiseogee lake was measured by the Lake Company at the same time that the survey of its area was made. The deepest place found was a short distance off the east shore of Rattlesnake island, opposite to its southern and lowest peak. The depth at this spot was slightly more than 200 feet. Between Rattlesnake and Diamond islands it was 190 feet; in Alton bay, opposite Fort and Gerrish points, 100 feet, and at three fourths of a mile from its south end, 80 feet; in the broad portions of the lake, between Rattlesnake and Cow islands, from 100 to 150 feet; and between Cow island and Center Harbor, from 50 to

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* The topographic features of this district, and the areas of Winnipiseogee lake, its islands, and its hydrographic basin, are stated in Vol. I, pp. 203–205, 300, and 306–308.

75 feet. The pre-glacial outlets from this basin were along the present course of the Winnipiseogee river and south-east from Alton bay towards Cochecho river. Both of these old outlets are partly filled with till or modified drift; but it is certain that if these materials were wholly removed a large portion of the lake would remain, bordered by rock on all sides.

The lowest points in the water-shed around Winnipiseogee lake, with their heights in feet above the lake, are the following: Summit on railroad between Meredith Village and Pemigewasset valley at Ashland, 166, ten feet below the natural surface; at two and a half miles north from Meredith Village, about 140, and at same distance north from Center Harbor, about 100, these points being the lowest between this and Squam lake; the "Varney pass," between Moultonborough and the Bear Camp valley, about 150; summit on railroad between Wolfeborough and Salmon Falls valley, 164; between Smith's pond and Cook's pond, about 200; summit on railroad between Alton Bay and Cochecho valley, 72; and near Lily pond in Gilford, between the lake and Long bay, about 75 feet. The two last of these places show by their modified drift that they were formerly outlets of the lake.

These lake basins lie upon the south side of the White Mountains, from which source we might expect a greater depth of ice to move southward and cover this area near the close of the glacial period than would at that time remain in other parts of the state to the east and west. The ice-sheet probably lay over Squam and Winnipiseogee lakes in a broad mountain-like ridge till after it was almost wholly melted away over the lowlands of York county, Maine, in the basin of Ossipee lake, and for some distance along the Bear Camp valley. The ice-current was thus changed in direction on this side, and the last striæ marked on the ledges differ much from the prevailing course of about S. 40° E., being deflected towards the east or even to the north of east. This is shown by the following observations, all of which are reduced to the true meridian.*

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* The magnetic needle has a declination of 12° to the west. (See map, vol. i, p. 154.)

Courses of Striæ about Winnipiseogee and Squam Lakes.

On the North-East and East Side.

Nearly all of these are deflected easterly from the prevailing course of the ice-sheet; probably because of its earlier melting in the basin of Ossipee lake.

In Holderness.

Road over Squam mountain, S. 60° E.

In Sandwich.

At west line on road to Ashland, S. 80° E.
Near north-east corner of Squam lake, N. 85° E.
At north foot of Red hill, N. 80° E.

In Moultonborough.

Near south-east town line, S. 55° E.

In Tuftonborough.

Near Melvin Village, S. 25° E.
At Tuftonborough Corner, N. 70° E.
Two miles south of last, N. 80° E.
One half mile farther south, E.
(The two last in Tuftonborough are on the hills west of Lower Beech pond.)

In Wolfeborough.

West side of Trask hill, S. 85° E.
Summit of Trask hill, S. 50° E.
One mile north-east from Wolfeborough Centre, S. 40° E., and E.
Porcupine ledge, S. 60° E.

In Brookfield.

North corner of town, S. 55° E.
Two miles south of last, S. 70° E.
North side of Tumble-down Dick, S. 75° E.

On the West and South-West Side.

These show the general direction of the ice-current, coinciding nearly with the longer axis of Winnipiseogee lake.

Ashland village, S. 40° E.
Center Harbor, commonly S. 40° E.

In New Hampton.

Above clay-bed, two miles south-east from Ashland, S. 35° E.
Harper's hill, S. 50° E.
New Hampton centre, S. 40° E.
New Hampton village, S. 50° E.

In Meredith.

Hill north-west from Meredith Village, S. 40° E.
Meredith Centre, S. 25° E.
Highest hill, Meredith Neck, S. 40° E.

In Gilford.

North part, near lake, S. 35° E.
Hill north-east from Lake Village, S. 35° E.
North-east part, near lake, S. 40° E.

In Alton.

Ridge west of Alton Bay, S. 40° E.
Town line, east of Alton Bay, S 40° E.

In New Durham, commonly S. 40° E.

The departure of the ice-sheet along the Merrimack and Pemigewasset valley appears also to have proceeded somewhat more rapidly than upon the higher land on its east side, so that over Winnipiseogee and Squam lakes the drainage from the melting ice was outward both to the east and west.

The noticeable feature in the surface geology of these lakes is the absence of modified drift. Their shores are chiefly of coarse glacial drift or till, with occasional ledges. The neighboring basin of Ossipee lake, on the contrary, is characterized by very extensive and probably thick deposits of modified drift, presenting a remarkable contrast. These deposits are also abundant in the Pemigewasset valley on the west. Their conspicuous absence from these intervening basins needs to be accounted for, and this seems to be due to different rates of progress in the departure of the ice. The later continuance of the ice-sheet over these lakes turned all the drainage from the south side of the White Mountains into the Ossipee basin and Pemigewasset valley, and even caused the modified drift, which was contained in this part of the ice, to be mostly carried away. Our explanation of the remarkable deflection of striæ on the east border of these lakes is thus attested also by the modified drift, as by a separate and independent witness.

In describing the modified drift of this area, we will proceed from the mouth of Winnipiseogee river to the Wiers, and thence northward, including Squam lake, and passing around Winnipiseogee. The extent of these deposits is shown on the general geological map in the atlas. The interesting beds of clay and rarely of sand, overlaid by till, which occur at numerous places about these lakes, constitute a peculiar class of modified drift found nowhere else in the state. The localities of ordinary modified drift will be first described, and afterwards the instances of clay or sand overlaid by till. An explanation of the probable mode of formation of these different deposits will then be stated.

The mouth of Winnipiseogee river at Franklin is 269 feet above the sea. Its fall in the last two miles of its course is 146 feet, and its whole descent from the lake is 244 feet. (See p. 103.) The modified drift of the Merrimack valley is well shown on both sides at Franklin, its highest terrace being 150 to 175 feet above the river; but the Winnipiseogee, for the last mile and a half before entering this valley, is bordered only by till or ledge. The first area of modified drift that we find on this stream lies between Cross's mill-pond and Tilton, extending about a mile along the river and as far to the south, where it lies principally on the west side of the railroad. This deposit of sand and gravel has a height 30 to 50 feet above the river, slightly exceeding the upper terraces of the Merrimack at Franklin.

At Tilton, and for a mile above, the river has no modified drift. In the upper part of this distance the very steep slopes of till between which it flows indicate that a channel 50 feet deep may have been excavated in this material by the river. We next come to the largest area of modified drift found on this river. This extends nearly two miles along its north-west side, bordering Little bay nearly to East Tilton. A large part of this deposit was brought by the tributary which comes from Sanbornton Square. An interesting kame, forming a ridge of very coarse water-worn gravel, 30 to 40 feet high and a quarter of a mile long, lies on the west side of this stream at the margin of the modified drift. From its east side a plain of coarse gravel, 30 to 50 feet above the river, extends a third of a mile eastward, beyond which to Little bay the height is less, being 10 to 20 feet above the bay, and the material is finer gravel or sand. The edge of the high plain of coarse gravel is cut by the railroad; and the section shows the upper fifteen feet to consist of levelly stratified gravel, with its largest pebbles one foot or more in diameter, underlaid by several feet of sand, which is partly horizontal and partly oblique in stratification. The gravel is interstratified with the upper portion of the sand. This fine alluvium was probably brought by the large stream which comes in from Belmont, joining the Winnipiseogee from its opposite side at a short distance farther east. This tributary is bordered on the north by a wide sand plain, about 30 feet in height, which extends nearly two miles above its mouth. This was deposited in the Champlain period, since which time the stream has excavated a considerable portion of its plain, forming a wide meadow along its last mile. Previous to any erosion, this plain appears to have been continuous across the present channel of Winnipiseogee river; and we thus find a portion of it underlying the coarse gravel which came from the opposite direction, being supplied abundantly at a little later date as the melting of the ice-sheet advanced to the north-west.

The successive expansions of the Winnipiseogee river are called bays. In ascending the river they are met in the following order:

	Approximate area.	Height above sea.
Little bay, ...	.5 square miles.	473 feet.
Sanbornton bay, ...	1.0 "	490 "
Great bay (Winnisquam lake), ...	5.0 "	490 "

Round bay, ...	.5 square miles.	501 feet.
Long bay (of same height with Winnipiseogee lake),	1.9 "	513 "

The east and north shores of Little bay and the south and west shores of Sanbornton bay north to Mohawk point, with the river between them, are destitute of modified drift; but it is found on the east shore of Sanbornton bay, extending along the railroad from Ephraim's cove to Winnisquam station at the bridge between this and Great bay. This deposit consists principally of gravel, much of it containing pebbles a foot in diameter, and it has a height of 10 or 20 feet above the bay. Its origin, and the cause of its accumulation along this margin of the bay, appear to be shown by the kame of coarse gravel, from 10 to 15 feet in height, which forms Mohawk point, and is connected with the east shore by a low bar of gravel and sand. On the west side of the bay, opposite Mohawk point and only a short distance from it, a higher bank of the same gravel occurs. These kames appear to have been formed in the channel of a glacial river, which came down from the north-west at a time when the ice covered the greater part of this bay. It had been melted away only along the east shore, which therefore received from this and other streams a border of modified drift. The sand plain, about 20 feet in height, which extends along the west side of the bay for a mile north from these kames, was brought down from the same direction after the ice had retreated from this area.

The next deposit of modified drift that we find is the sand plain on which the south part of Laconia village is built. This is about one third of a mile square, and from 15 to 20 feet above Great bay. One half mile farther north a small deposit of gravel and sand is crossed by the railroad on the south-east side of Round bay. No modified drift was seen at Lake Village, and the hills rise steeply on each side. In digging for foundation for the dam and mills here, sand is said to have been found under sixteen feet of till. This sheltered situation has probably preserved a remnant of alluvium, which was deposited before the glacial period or during some temporary withdrawal of the ice. A half mile north-east from Lake Village we come to a sand plain, from 10 to 20 feet in height, which extends a half mile to the north and east. Before the ice-sheet was melted away at the Wiers, the waters from the lake had their outlet at this place, passing over the low water-shed on the east near Lily pond. On the north-west side of Long bay a small brook has brought down a deposit of sand and gravel which is crossed by the railroad.

The mouth of Lake Winnipiseogee is a narrow channel called the Wiers, because of dams made here by the Indians for taking fish. No modified drift of the ordinary kind occurs near this outlet or along the shore of the lake north-west to Meredith Village. A small kame-like deposit of coarse gravel and sand, 40 feet above the lake, occurs a short distance north-east from Meredith depot; and alluvial sand about 25 feet in height borders the brook which flows into the head of this bay and extends half a mile eastward along the lake shore. Wukawan lake and Long pond, which lie on the north-east side of the railroad above Meredith, are the same in height, being 36 feet above high water in Winnipiseogee lake. They are separated by a swampy area, but with this exception are surrounded on all sides by till or ledge. Another Long pond, one half mile east of Center Harbor and about 10 feet above the lake, has a small area of alluvial sand and clay at its outlet.

The shores of Squam and Little Squam lakes, like those of Winnipiseogee, are almost wholly composed of till or ledge. The only modified drift seen in a journey by the roads along the east and south sides of Squam lake was at a point a mile and a half south-east from White Oak pond. This consists of kame-like gravel and sand, irregularly stratified, with occasional large boulders on the surface. A well defined kame, 15 to 25 feet high, extends a fourth of a mile west from the bridge between these lakes along the north shore of Little Squam. This ridge contains frequent angular boulders up to three or four feet in diameter. Squam river above Ashland is bordered by low alluvium a few hundred feet wide. Its total descent is 110 feet, nearly all of which is utilized for water-power.

At the head of Moultonborough bay we find swampy land along its east shore for a mile, and farther east an extensive deposit of sand, undulating and partly covered with pines, reaching a mile from the lake, with its highest portions 40 feet above it. The next modified drift is four miles to the south-east at Melvin village. Melvin river here brought down in the Champlain period a small plain of gravel and sand, which since that time has been partly excavated by the stream, and partly undermined and carried away by the lake, so that it now forms a terrace 20 feet high. Another tributary to the lake a mile farther south-east is bordered by terraces of similar height near its mouth. On the north-east side of Twenty-mile bay, two miles south from Melvin village, a bold shore of coarse till, with many large boulders, is bordered by an old beach, about 300 feet long and 100 wide, which slopes from the water's edge to ten or twelve feet above high water. It is composed of fine stratified sand, which is clayey below a foot or two of the surface. No tributary occurs here, but a small stream at an eighth of a mile south-east has brought down considerable alluvial sand, none of which, however, lies more than five feet above high water.

Kames. Half a mile farther south we find a kame extending two thirds of a mile from north-west to south-east along the top of a hill about 100 feet above the lake. It does not form a definite ridge, and could hardly be distinguished from the till by its contour. Its materials are coarse and fine gravel and sand interstratified. Boulders are enclosed in many portions, but a well at Charles G. Edgerly's, 30 feet deep, encountered no boulders, being all the way through sand or fine gravel. Nineteen-mile bay and brook are a half mile farther south. Here the road passes over the alluvium brought down by this brook, which, like that at the head of Twenty-mile bay, is only three or four feet above the lake. Nineteen-mile brook is bordered by considerable widths of low alluvium for two miles above its mouth, to where it is crossed by the road a mile and a half south from Mackerel Corner. From the brook to this village, and for a half mile farther north, kame-like deposits of limited amount are seen here and there at heights of 100 to 200 feet above the lake. East from this road interesting kames extend more than a mile along the north-east side of Nineteen-mile brook. These cover a width of a fourth of a mile, consisting of successive small plains from half an acre to two or three acres in extent, usually surrounded by hollows, and rising one after another from 30 or 50 to 100 feet above the stream, or fully 150 feet above the lake. These small level-topped deposits consist of sand and water-worn gravel, with the largest pebbles about one foot in diameter. Boulders are occasionally but not frequently enclosed. These kames begin about two miles south-east from that described between Twenty-mile and Nineteen-mile bays. These and the similar deposits which occasionally appear about Mackerel Corner probably had a common date and cause. Advancing to the south-east we leave the modified drift, but cross a water-shed which is probably lower than the highest of these kames, and thence follow Hersey brook to Smith's pond. A sandy plain, about 50 feet above the pond or 75 feet above the lake, is found on the west side of this brook near its mouth, covering about half a mile square. The shores of this pond, like those of the lake, are almost entirely till or ledge.

Upper Beech pond, covering perhaps 150 acres and about 300 feet above Lake Winnipiseogee, is situated a mile and a half north-east from the kames last described. Its outlet is to Ossipee lake by Beech river, but only a very slight barrier at its south-west side prevents its flowing to Winnipiseogee lake by Nineteen-mile brook. This barrier consists of a kame, which in its north-west portion is a nearly level plain three or four acres in extent, but for several hundred feet south-east from this it is narrowed to a mere ridge. The gravel of the small plain is but slightly water-worn, the rock fragments being from a foot to a foot and a half in size. The ridge consists of sand or finer gravel, in which fragments larger than six inches are uncommon. This whole deposit is bounded by steep slopes both against the pond and on the opposite side. The height of the plain is 20 to 30 feet above the pond; that of the ridge declines to only ten feet, and at its east end to only three feet above the pond, while its south-west slope falls abruptly to 20 or 30 feet below it. Large springs fed from the pond issue at the bottom of this bank. Except at this point and its outlet, this pond is surrounded by high hills; and no other kame-like deposits occur on its shores or in the steeply sloping valley that descends towards the south-west from this barrier.

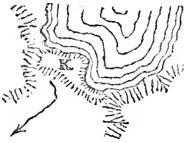

Fig. 27.—South end of Upper Beech Pond, Wolfeborough.
Scale, 1 inch=¼ mile.

The shores of the lake through Wolfeborough have no modified drift worthy of note. It is next met with in Alton, about a mile east from Fort point and the mouth of Alton bay. Proceeding eastward from the mouth of the bay, we soon come to a hill more than 200 feet high, and at its east side find an area of considerable width, which is only 50 to 60 feet above the lake, and extends about two miles from north to south between the lake and the bay at Gerrish point. Where this area is crossed by the road to Fort point, it is a level, sandy plain, but southward it is partly occupied by a similar plain and partly by kames, which form mounds and ridges, extending from north to south, with the intervening hollows 20 to 30 feet deep. The material of the kames is water-worn gravel, containing pebbles up to one or two feet, and often enclosing boulders of all sizes up to six or eight feet in diameter.

On the west shore of Alton bay, south-west from Gerrish point, we find kames and level-topped mounds of interstratified sand and gravel, with occasional large boulders enclosed or on the surface. These rise about 50 feet above the lake, and border its shore for nearly a half mile, extending southward from the mouth of the principal valley or opening among the hills on its west side. With these exceptions, till and ledge form the shores of this bay till we come to its end at the south extremity of the lake.

From Alton Bay station a continuous area of modified drift, varying from one fourth of a mile to nearly two miles in width, extends towards the south-east along Merrymeeting river and across the low water-shed only 72 feet above the lake, which separates this basin from the head of the Cochecho valley. A kame, forming a well defined ridge 40 to 60 feet high, extends nearly a mile southward from the lake. It lies for the first third of a mile on the west side of the railroad, by which it is then crossed twice, thence continuing to the south close upon the west side of the river. It is mainly composed of coarse water-worn gravel, which contains rounded boulders up to two or three feet in diameter. It also contains occasional angular boulders of larger size, and in some portions the ridge is made up almost wholly of such angular blocks one to four feet in diameter. Deposits of fine gravel and sand reach an equal height along this distance on the east side of the river.

Alton village is situated about 60 feet above the lake on a level plain, the north part of which is coarse gravel full of pebbles three inches to one foot in diameter, while its south portion is finer gravel or sand. To the south-east the alluvium is nearly two miles wide, and consists of plains of sand or fine gravel, and low, marshy meadows. The former do not exceed 60 to 70 feet above the lake, or about 30 to 40 above Merrymeeting river. No kames were seen between Alton and New Durham station; but a short distance from this station a kame 25 feet in height was seen on the west side of the railroad. The wide alluvial area here forms a water-shed; and half a mile farther south-east we come to a considerable stream, which is one of the principal sources of Cochecho river. The modified drift continues about a half mile farther, consisting of very coarse irregular kames on the west side of the stream, while on the east side is a plain of fine gravel or sand about 30 feet in height. The next four miles of this valley, extending nearly to Farmington, has a rapid descent, and is nearly destitute of modified drift.

North-west from West Alton frequent kame-like deposits are found along the road for three fourths of a mile. These consist mainly of sand and gravel interstratified, with numerous boulders enclosed or on the surface, and are disposed in nearly level-topped, irregular terraces, with gently-sloping escarpments. Similar kame-like terraces occur in Gilford at two and three miles farther to the north-west. These all lie upon hill-sides of till or ledge, which border the lake, at a height of about 75 feet above it. Alluvial sand only 5 to 10 feet above the lake has been deposited by a small brook near the north-east corner of Gilford, and also by a stream which enters the lake below the last mentioned terrace, coming from the valley east of the Belknap range.

Two miles farther west we come to a large alluvial area, which borders Gunstock river and Meadow brook, extending nearly a mile in width from the lake to Lily pond, thus forming the water-shed probably not more than 75 feet in height between the lake and Long bay. This modified drift is gravel, sand, or fine silt, with a quite regular surface which slopes gently to the lake. A considerable tract of it is interval, being overflowed by the freshets of Gunstock river. A continuous area of modified drift appears to extend north from Lily pond to the lake at a point about one mile east of the Wiers. We here find, south from the bridge to Davis island, very well marked kames, which form north and south ridges 50 feet above the lake. They consist of water-worn gravel, with pebbles up to one foot in diameter, and enclose occasional boulders. A terrace of similar materials borders the hills on their west sides.

All the ordinary modified drift which we found in our exploration of these lakes has now been mentioned. A more remarkable class of deposits, which has not been met with in other parts of the state, remains to be described.

Modified Drift overlaid by Till.

Numerous beds of clay, nearly horizontal in stratification, but overlaid and underlaid by coarse unstratified glacial drift or till, are found on hillsides up to heights 200 or 300 feet above Winnipiseogee lake. Similar beds of sand appear on hills east of Alton bay. In describing these deposits, we will begin at the Wiers, and proceed around the lake in the same order as before.

The first of these clay beds overlaid by till is beside the railroad, a short distance north-west from Wiers station, where it is worked by A. Doe & Son for brick-making. This is blue clay, finely laminated and nearly horizontal, dipping perhaps 5° to the south-east. At one place where the excavation has reached the bottom of the clay, it is underlaid by four feet or more of quicksand. This is at a height of about 25 feet above the lake. The thickness of the clay is fully thirty feet, and it is exposed by an excavation about 100 feet square. The clay is directly overlaid by two to six feet of coarse till, which contains angular boulders up to six feet in diameter. This is upon a hillside which rises 100 feet higher, and appears on the surface to be wholly composed of till; but much of this is probably underlaid by a stratum of clay at no great depth. This clay comes to the surface at A. Doe's house, about 150 feet above the lake, where a well 27 feet deep encountered no other material. The well filled with water from thin, sandy layers; but most of this clay did not show its lines of stratification plainly, and was inclined to break with a conchoidal fracture into small pieces. At both places the clay is free from stones or gravel, except that small boulders, usually less than a foot in diameter, are occasionally found embedded in it.

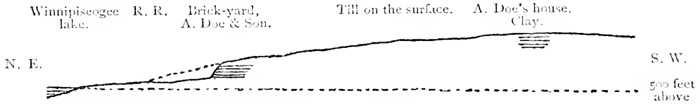

Fig. 28.—SECTION NEAR WIERS. Distance, ⅓ mile; vertical scale, 1 inch=400 feet.

In New Hampton, two miles south-east from Ashland, a large deposit of clay similar to that at the Wiers occurs on land of Oren Plaisted, lying on the east slope of a high hill. The drainage is into the Pemigewasset river. The height of this clay is, by estimate, 350 feet above the river and nearly 250 feet above its highest terraces, or about 800 feet above the sea. A well at Mr. Plaisted's house showed 15 feet of till underlaid by 18 feet of clay. A few rods farther north, at nearly the same height, the clay is covered by only one or two feet of till. About fifteen rods farther north-west, on the steep hillside and some 30 feet higher than the foregoing, a small excavation for brick-making shows a bed of clay ten feet thick, and probably extending deeper, overlaid by two feet of till. This clay is free from pebbles, but occasionally shows layers of sand half an inch thick. Its stratification is nearly level, but slightly anticlinal, dipping a few degrees at the north and south sides.

Some light is probably thrown upon the origin of these deposits by a section (Fig. 29) which was observed by the roadside between Ashland and Little Squam lake. On the surface was coarse upper till, 3 feet deep, showing no marks of stratification, and consisting of sand and gravel mixed with abundant angular boulders of all sizes up to four feet in diameter. Next was a dark blue clay, 10 feet thick, plainly stratified, but not finely laminated, and containing many fragments of rock up to six inches in diameter. Next below, and separated from the former at a definite line, was the compact unstratified lower till, which is here dark and clayey, and contains many glaciated stones up to a foot and a half in diameter.

Fig. 29.—Section in Ashland.

South of Squam bridge the steep north slope of a hill which rises from the shore of Little Squam lake has a layer of clay, stratified and free from pebbles, which is overlaid by one to three feet of till. The clay is four or five feet deep, but how much deeper is not known, and it is said to extend from near the lake shore to a height 150 feet above it.

On the east side of Squam lake the farm of John Wiggin, in Moultonborough, has frequent deposits of clay similar to that last described. At about fifteen rods south-west from the house and about 100 feet above the lake, this was used for brick-making fifty years ago. The side of Red hill, which rises near at hand on the east, is said to have in many places, to a height 300 feet above the lake, a stratum of clay underlying one to three feet of coarse till. On the north side of this lake the clay on land of the Messrs. George, in the south-west corner of Sandwich, which was extensively worked for brick-making fifty years ago, appears from description to belong in the same class with the foregoing.

No deposits of this kind were heard of about the north end of Winnipiseogee lake from the Wiers to Melvin Village. The well of Mr. Stockbridge, in the eastern part of this village, about 25 feet above the lake, showed 6 feet of till underlaid by 10 feet of clay, followed by 6 feet of water-worn gravel, which contained copious springs. Less than a mile to the south-east a well at J. Tate's showed 8 feet of coarse till and then 4 feet of clay, underlaid by coarse, water-worn gravel. Chas. H. Copp's well, 400 feet farther south-east, showed 4 feet of coarse till, underlaid by 23 feet of fine, stratified blue clay, beneath which water came in abundantly from a thin layer of gravel which rested on a ledge. The former is about 30 and the latter about 50 feet above the lake. One mile farther south a similar deposit of clay, about 30 feet above the lake, has been used for brick-making. It lies a short distance east from the school-house near the head of Twenty-mile bay. On the south-west side of Black island, a mile distant from Melvin village, two or three acres, 10 to 15 feet above the lake, have a thin layer of till, with many large boulders on the surface, underlaid by clay, stratified and free from pebbles, at least four or five feet in depth.

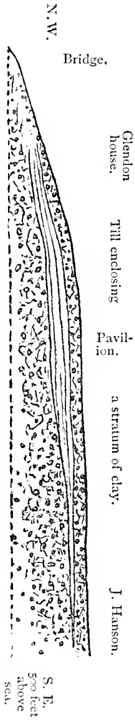

Fig. 30.—Section in Wolfeborough Village. Distance, ½ mile; vertical scale, 1 inch=100 feet. The base of the section represents the level of the lake.

At Wolfeborough, the hillside of till south-east from the bridge has an underlying stratum of clay. Wells at the Glendon house, about 25 feet above the lake, show some 6 feet of till, then an equal depth of clay with till beneath. Near the Pavilion, about 50 feet above the lake, a well showed 8 feet of coarse till, then 2 feet of ferruginous earth, then 12 feet of clay free from stones, underlaid by the compact stony lower till. About thirty rods south-east from the last a well passed through 8 feet of till, and then through 4 feet of clay, which was underlaid by till. About the same distance farther south-east a well at J. Hanson's found this layer of clay only one foot thick, occurring 10 feet below the surface. The last two places are only a few feet higher than that near the Pavilion. Nearly all that part of the village which lies south-east from the bridge is built on a thick mass of till, which encloses a continuous stratum of clay. North-east from the Pavilion a slope descends in about twenty-five rods to a small pond, which is tributary to the lake and of the same height. This slope has a surface of till, with numerous boulders; but excavations for brick-making show that the clay beneath has a thickness of fully 20 feet, with its bottom resting on till only a few feet above the lake. The till on the surface is 1 to 8 feet deep. This clay is free from pebbles, and is finely laminated in its lower portion, while its upper part sometimes crumbles into small angular pieces. No deposits of clay appear to occur in the thinner till which covers the hillside north-west from the bridge.

At Clay point in Alton, three miles south-west from Wolfeborough, the lake shore rises steeply from 10 to 40 feet, and from the top of this escarpment the surface, which is coarse till, has a very gentle upward slope. The lower part of this bank consists of a stratum of clay which was worked forty years ago for brick-making. This was at the end of the point where there was at least fifteen feet, and perhaps considerably more, of finely laminated blue clay free from pebbles, with its bottom nearly at the level of the lake. It was underlaid by a stratum of coarse, water-worn gravel, containing iron-rust. This abrupt bank, which extends around the point fully a quarter of a mile, has resulted from the excavation of the clay by the waves of the lake.

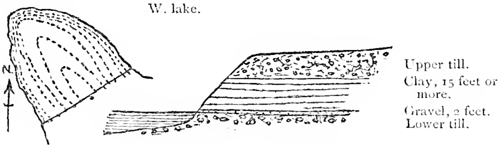

Fig. 31. Fig. 32.

MAP AND SECTION OF CLAY POINT, ALTON. Scale of map, 1 inch=¼ mile. Contour lines are shown for each 10 feet above the lake.

Near East Alton, two miles south-east from this point, a bed of gravelly and somewhat stony clay, at least seven feet in thickness, is overlaid by two or three feet of till at a height of about 200 feet above the lake. A mile and a half west from this place, clay of good quality, finely laminated and free from pebbles, occurs on the north and north-west side of a hill, at a height of 150 feet above the lake. Both these deposits have been used for brick-making, and the latter has been excavated at two places an eighth of a mile apart. It is overlaid by about two feet of till, and a well showed the thickness of clay to be 13 feet, under which was a water-bearing layer of gravel.

From this clay-bed a valley about 40 feet in depth descends to the south at the west base of the hill, which on this side is ledge. The bottom and the steep west side of the valley are composed only of modified drift, being fine silt or sand; while only till with many large angular boulders up to 10 feet in size forms the top of its west bank and the irregular surface, which thence descends westerly to the alluvial area previously described on page 129. The contour of this locality is shown in Fig. 33; and Fig. 34 shows the apparent position of the sand underlying the very coarse till. Less than a mile farther south a similar valley is seen from the highway on its east side a short distance north of M. Adams's house. The contour and probable section at this place are shown in Figs. 35 and 36. Here it

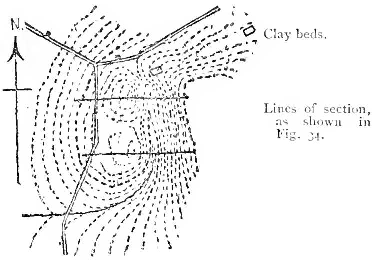

Fig. 33.—MAP OF A SMALL AREA IN ALTON, TWO MILES SOUTH FROM CLAY POINT.
Scale, 1 inch=¼ mile. Contour lines are shown for each 10 feet, the highest being 200 feet above the lake.

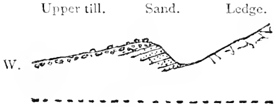

Fig. 34.—SECTION CROSSING FIG. 33.
Horizontal scale, 1 inch=⅛ mile; vertical scale, 1 inch=400 feet. The dotted line at the base represents the level of the lake.

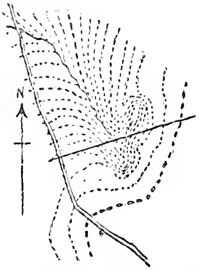

Fig. 35.—MAP OF A SMALL AREA IN ALTON, THREE MILES SOUTH FROM CLAY POINT.
Scale, 1 inch=¼ mile. Contour lines are shown for each 10 feet, the lowest being 50 and the highest 200 feet above the lake.

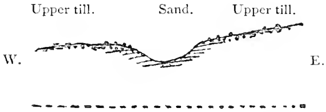

FIG. 36.—SECTION CROSSING FIG. 35.
Horizontal scale, 1 inch=⅛ mile; vertical scale, 1 inch=400 feet. The dotted line at the base represents the level of the lake.

appears that a thick deposit of sand underlies a thin surface of till upon a hillside between the heights of 100 and 200 feet above the lake. These localities have become noticeable because a great depth of sand has been excavated by rivulets. Probably thinner deposits of sand exist in many places underlying till, but not having an economical value like the clay, they have escaped notice.

At the north-west ends of Rattlesnake and Davis islands deposits of clay are found similar to that of Clay point, and in former times it has been excavated at both these places for brick-making. The same abrupt bank from 20 to 30 feet high forms the shore, and the surface of coarse till slopes gently upward from its top. The underlying clay-beds are free from pebbles and plainly stratified.

Review and Conclusions.

These numerous examples make it probable that many other similar deposits exist about these lakes, since their presence is not usually indicated on the surface. In considering the question of their origin, we notice that these beds of stratified clay and sand are uniformly overlaid by a comparatively thin covering of unstratified glacial drift, which in every instance is probably wholly made up of the loose, sandy, and very coarse material which we have called upper till. It is remarkable that no similar deposits are found on the hillsides without this thin covering of till. The examples found, however, do not lie in the pathway of any stream which could be supposed to bring the modified drift, or to excavate and carry it away if any had been left on the surface; instead of this they occur on the rounded slopes of hills at all heights from the lake shore to 200 or 300 feet above it. If any clay beds had been left in such situations without a covering of till, they would remain to the present time, and would be worked in preference to others for brick-making. It is also remarkable that these deposits frequently extend in a stratum of varying thickness over a considerable area of hillside, sometimes appearing to be continuous upon a slope which rises 100 feet or more in vertical height. In all cases, however, where the stratification has been seen, it is approximately horizontal and not conformable to the slope.

The section observed near Squam river in Ashland (p. 132) indicates the probable position and mode of formation of these deposits of clay and sand. They appear to lie between the two members of the coarse glacial drift, which we have denominated upper and lower till. In other portions of the state these are distinct from each other, and in a few instances they have been found to be separated by a thin layer of gravel or sand; but generally they are divided at a definite line, with no intervening stratum of modified drift. This section in Ashland shows that between the lower and upper till a depth of ten feet of stony stratified clay was deposited; and this seems to have taken place beneath the edge of the ice-sheet shortly before the completion of its melting, which contributed the three feet of upper till lying on the surface.

The ice-sheet probably remained in a high mountain-like mass over these lakes after it had disappeared on each side from the basin of Ossipee lake and from the lower part of the Pemigewasset valley. As the melting continued, the drainage over this area was frequently obstructed because the ice-sheet retreated from the lines of water-shed towards the middle of these hydrographic basins. The water seems then to have melted large open spaces beneath the ice near its margin, in which beds of clay and sand were deposited. This would occur at the various heights and in the situations where these beds are found, and the till which overlies them is shown by its material to be that which was contained in the ice-sheet and fell upon the surface when its melting was completed. We thus see how these deposits came to be spread over the slopes of the hills, thinly covered by large boulders and till. The frequent accumulation of such deposits in other parts of the state was prevented by unobstructed drainage from the melting ice. This modified drift overlaid by till does not therefore appear to bear testimony to a warm inter-glacial period, or even to any retreat and subsequent advance of the ice.

The course of the rivers which flowed from the melting ice-sheet over this area can still be pointed out. The extensive deposits of modified drift in New Durham and Alton mark a long continued outflow to the Cochecho valley. When the terminal front of the ice had retreated to a point a short distance north-west from Alton village, it seems to have remained nearly stationary during the deposition of the plain on which this village is built. At the same time the kame which lies between this point and Alton Bay was formed in an ice-walled channel. During the recent or terrace period portions of these deposits have been excavated by Merrymeeting river. The kames on the west side of Alton bay, a mile and a half farther north, were formed at a later date, while the outlet was in this direction. When the ice-sheet had retreated nearly to the mouth of this bay, the outlet from its melting over the lake at the north was along the low area a mile east of Fort point. As the melting of the ice advanced towards the north-west, the kame-like terraces near West Alton, and those in the north-east part of Gilford, were probably deposited at the mouths of glacial rivers. Their height is that which the lake held when its outlet was to the Cochecho valley. The series of kames in Tuftonborough and Wolfeborough (p. 127) was probably formed at nearly the same time by a glacial river from the north-west, after the ice had disappeared from the south end of the lake and from the basin of Smith's pond. The kames between Davis island and Lily pond indicate that the drainage from the ice-sheet was by this avenue before it was melted at the present outlet a mile farther west. A kame on the north side of Little Squam lake marks the outflow from the melting ice-sheet over that basin.

The other deposits of modified drift about these lakes have been brought down by short streams, and are scanty in amount because the principal drainage of this area in the Champlain period was outward on all sides. They appear to have been formed in the same way that deltas are spread out nearly level at the mouths of tributary streams, often at an elevation much above the floods in the main valley. The height of the lakes during this deposition may therefore have been the same as now. If they had ever stood for any long period at a greater height, the hillsides of till would be marked by a line like that of the present shore. This is mostly composed of till, which presents a wall of boulders four or five feet high, its finer portion having been washed away by the waves.

Modified Drift along Magalloway and Androscoggin Rivers.

Mr. J. H. Huntington has kindly supplied information in regard to the modified drift of the Magalloway and the upper portion of Androscoggin river. He has also mapped the alluvial areas along the Upper Ammonoosuc river. The general geological map in the atlas shows the extent of these deposits in New Hampshire, so far as definite boundaries can be drawn.*

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*The Androscoggin river system is noticed in Vol. I, on pp. 224-226, 301, 309-311, and 322.

The level tracts on Magalloway river are described as especially remarkable for the occurrence of sloughs or small ponds, which are almost invariably found at a short distance on one or the other side of the stream. The river-banks are everywhere low, and the wooded plains, extending in places one half mile from the river, with a height rising from 10 to 25 feet above it, consist of gravel, which is not often so coarse as to have pebbles a foot in diameter. These are the characteristic features of this river for most of its length, both above and below Parmachena lake. The only exceptions are the three or four miles just below this lake, and about two and a half miles, called Escahos falls, next above Wilson's Mills, where only the glacial drift is present, over which the river descends in rapids obstructed by boulders. Along the greater portion of its course the descent is very slight, and the crooked stream winds slowly from side to side along its gravel plain. There seem to be no kames on either this or the upper part of Androscoggin river.

The fine alluvium brought down by the Magalloway has filled up a considerable area about the mouth of Umbagog lake, forming an extensive bog at the border of the lake, and reaching a height of 10 to 15 feet along the lower part of this river's course and on the Androscoggin to Errol dam. There are no rapids below Wilson's Mills, and the Magalloway is navigated as far as to Wentworth's Location by a steamboat from the lake. On other sides this lake has mainly hilly and rocky shores. Its height is 1256 feet above the sea.

Clear stream, along nearly its whole course from Dixville notch to Androscoggin river, is bordered by low sandy plains.

The modified drift of the Androscoggin above Dummer, along the distance which has no road, is described as consisting of tracts of swamp, or of stratified gravel and silt in some places one half mile in width, having a height of 10 to 25 feet. These are along level portions of the river, which alternate with rapids where the glacial drift, or till, extends in gentle slopes to the stream.

The exploration of the Androscoggin river, with special reference to its modified drift, extended nearly to the east line of Dummer. Below this point the river flows south-westerly four miles to Pontoocook falls, and in this distance is bordered on the north-west side by considerable areas of alluvium from 20 to 30 feet above the river, extending from one half to three fourths of a mile wide on Newell's brook, and on the stream which is the outlet of Dummer ponds. These tracts consist mainly of sand or fine silt, and are very level and in many portions swampy. On the south-east side the river is bordered by a narrow margin of modified drift, beyond which the hills rise from 100 to 200 feet above the stream.

Pontoocook falls extend about a mile from the most western point reached by the river, which here flows between hills of till or ledge. Near the foot of these falls is Pontoocook bay, which is an expansion of the river containing several islands. This is bordered by sandy terraces; and thence southward for ten miles, extending through Milan and nearly to Berlin falls, the modified drift is continuous, being usually one eighth to one third of a mile wide upon both sides of the river. This consists of sand or gravel, which is not often very coarse. About half of its whole width is interval, being from 5 to 15 feet above the ordinary height of the river; and all above this is irregular in contour, with no well defined terraces, the modified drift reaching in irregular slopes about 40 feet above the river. The Androscoggin along this distance is nearly level, having a height of about 1,050 feet above the sea; and the hills on each side are of moderate height and gentle slopes.

At Berlin Falls the precipitous front of Mt. Forest rises close at hand on the west, and the river here enters the White Mountain area. Along the rest of its course in New Hampshire, and for some distance in Maine, the valley is closely bordered by high and abrupt mountains. From the head of Berlin falls the river descends nearly 200 feet in the first mile, and its current is rapid to the east boundary of the state, which it crosses at a height of 690 feet above the sea. For the first five miles of this distance the course continues to the south towards the highest of the White Mountains; but at Gorham the river turns at a right angle, and after flowing nine miles to the east it enters Maine. The very rapid portion of the river at Berlin Falls is destitute of any modified drift, and the channel is principally ledge. Below these falls the modified drift through Gorham and Shelburne is continuous on one or both sides, though often narrow, and it is nowhere more than a mile between the steep mountain walls which enclose the valley.

Through Gorham, the terraces which border the Androscoggin are 10 to 50 feet in height, and they are best shown on the west and south sides of the river. They consist almost wholly of gravel, which is often very coarse, and in the highest terrace is sometimes but slightly water-worn, and scarcely distinguishable from till. At the sharp bend of the river, a mile north-west from Gorham village, three terraces occur on the east side, 10, 20, and 40 feet in height. The latter appears to represent the ancient continuous flood-plain at the close of the Champlain period. The village of Gorham is built on a lower terrace, 25 feet in height, which extends nearly level for a mile between Moose and Peabody rivers. Remains of the ancient flood-plain form terraces of coarse gravel, from 20 to 30 feet higher, which occur on the north side of the Androscoggin opposite the mouth of Moose river, on the south side of the railroad in the west part of the village, and on Academy hill, which is an isolated remnant that escaped erosion because partly protected by ledges.

Peabody river, for a mile before entering this valley, is bordered by steep banks of extremely coarse modified drift, or perhaps till, from 40 to 100 feet high. The space between these banks was formerly filled with similar material, which has been excavated by the stream during the recent or terrace period.

In Shelburne the modified drift occurs principally at two heights. The upper terraces are the remnants of the river's flood-plain in the Champlain period. They are from 50 to 60 feet above the river, with a nearly level surface, and bordered by steep escarpments. Their material is usually gravel, which is frequently very coarse, but in some places it is mainly sand. A mile and a half east from Shelburne village, several small ponds occur in hollows upon this terrace plain. The lower terrace is interval, being only from 5 to 15 feet above the ordinary height of the river.

It is a noticeable feature of the intervals of this part of the Androscoggin and of the upper portion of Saco river, that they are often composed of a substratum of coarse gravel, containing pebbles one foot or more in diameter, above which is a layer of fine silt three to six feet thick forming the surface. The coarse gravel is like that which often forms the river's bed in the vicinity of the mountains; and these sections, which are exposed in the banks now being undermined by the river, show that it formerly had its channel in nearly the same place as now but at a greater height, having flowed upon the surface of the layer of gravel.

Since that time the river has been changing its course, and the overlying fine silt has been deposited from its floods upon the deserted river-bed.

Modified Drift along Saco River and in the Basin of Ossipee Lake.

The areas which are occupied by modified drift in this part of the state are delineated on the general geological map in the atlas; and a special map on Plate VI shows the extensive plains about Ossipee lake.*

The south-eastern part of the White Mountain district is drained by the Saco, which has its farthest sources in Saco pond and Mt. Washington river. The water-shed at the Crawford house, which divides this from the Lower Ammonoosuc river, is formed by a deposit of very coarse modified drift (p. 62), which was swept down into this mountain pass in the Champlain period. Its height is 1,900 feet above the sea; and Saco pond, which fills a depression in this deposit, is 20 feet lower. The small stream which issues from this pond passes through the White Mountain Notch, falling 600 feet in the first three miles, and nearly as much more in the next nine miles. Along this distance it flows between lofty mountains, whose sides are often precipitous walls of rock. A fine view of this part of its valley is afforded from the top of Mt. Willard. Far above rise the rugged heights of Webster and Willey, almost vertical in their upper part, but below bending in graceful, regular curves, composed of materials which have fallen from each side and form an apparently smoothed hollow for the highway and river. The principal superficial deposits along this steep portion of the river are such rocky débris which has crumbled from the mountains, or the equally coarse unstratified till. In the bed of the stream these materials have become water-worn, but only limited deposits of gravel and sand are found. It is worthy of note, that in constructing the Portland & Ogdensburg Railroad the excavations yielded an abundance of sandy gravel suitable for ballast. To make a gradual ascent, this road is built along the side of the valley; and some of these excavations were two or three hundred feet above the stream.

At the west line of Bartlett the Saco is 745 feet above the sea. In the next eight miles to the mouth of Ellis river, it descends about 30 feet to

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* This river system is described in Vol. I, on pp. 301, 311, and 312.

the mile, flowing over modified drift. This consists of gravel and sand, and above the Rocky Branch these occupy an area one fourth to one half a mile wide, which lies mostly on the south side of the river, forming a nearly continuous interval 10 to 15 feet in height, which slopes with the stream, and irregular terraces which reach 25 feet higher.

From the Glen station in Bartlett to Conway Corner the alluvial area averages fully a mile in width, lying in nearly equal amount on each side of the river. The greater portion of this is interval, from 10 to 20 feet in height, which is often seen to be composed of coarse gravel overlaid by fine silt, as on Androscoggin river. The flood-plain of the Champlain period is shown in the higher terraces of sand or fine gravel, 40 to 60 feet above the river, which are nearly continuous on both sides. North Conway is built on a wide portion of the east terrace. The form of these terraces, with their surface level but usually narrow and bounded by steep escarpments, and their correspondence in height on opposite sides of the valley, make it easy to understand that a wide plain once reached across the intervening area.

Along Seavey's falls, which extend about a mile east from Conway Corner, the Saco is bordered on both sides by slopes of till and ledge. The modified drift of the highest terrace, however, is continuous between Pine and Rattlesnake hills, and thence extends two miles to the east on the north side of the river; and on the south it reaches from Conway Centre to the north-east side of Walker's pond, and thence is nearly continuous, though narrow, eastward to Maine line. East from the outlet of Walker's pond, the interval between this terrace and the river on the south is not wide, but on the north it extends one half to one mile from the river, rising with a gentle slope to a height about 25 feet above it. On this side, the most elevated part of the alluvial area, as at Conway Street, is only a few feet above the reach of high water. The ancient flood-plain, which was from 40 to 50 feet above the present river, as shown by its terrace on the south, may have extended over this whole area. It would then appear that the river here began its excavation on the north side, and has been gradually cutting its channel deeper and deeper as it has slowly moved across this area southward. Remnants of the former high flood-plain are thus found at a nearly constant height above the river for fourteen miles, sloping in this distance more than 100 feet. The height of Saco river at the state line is about 400 feet above the sea.

Kames between Saco River and Six-Mile Pond.

Along the Portsmouth, Great Falls & Conway Railroad a very remarkable series of kames extends six miles, from near Conway to Madison station. The railroad survey shows that the water-shed here is very low. It is 516 feet above the sea, being only 70 feet above the Saco river at Conway, and only 60 feet above Six-mile pond (also called Silver lake). This low avenue is one half mile to one mile wide, extending nearly from north to south; it is bordered on both sides by hills from 300 to 500 feet higher, those on the west side rising in almost perpendicular cliffs. The kame begins at Pequawket pond, a mile south-west from Conway Corner and Saco river. A ridge 40 feet high forms the west shore of this pond, and is thence nearly continuous for about three miles southward, lying on the east side of the railroad and Pequawket brook, which drains the part of this low valley that is tributary to the Saco. This kame is nearly straight, and for the most part consists of a steep narrow ridge 40 to 75 feet high, being composed of interstratified sand and coarse gravel, with occasional large boulders. A quarter of a mile south-west from Pequawket pond the top of this kame becomes 200 to 300 feet wide, and is level like a terrace. An excavation shows that the stratification here is nearly horizontal in the interior of the deposit, which is sand or fine gravel, but it is abruptly inclined on its west side, conformably with the slope of the kame. Low, swampy areas and occasional small ponds lie on the west side of this kame, and are interspersed farther to the south among irregular ridges and mounds. These unfilled depressions prove that very little erosion has been effected by the present streams; and that these deposits of modified drift owe their form to deposition in the channel of glacial rivers, while the ice remained unmelted on each side.

The southern part of this series of kames lies principally on the west side of the railroad, covering an area a third of a mile wide, and bounded on the west by the precipitous face of Pine and Hedgehog hills. Along the lowest part of the valley, near the railroad, the ridges consist mainly of gravel with little clear sand, and are much coarser than in the north part of the series; but their pebbles are plainly rounded, and of such size as could be transported by strong currents of water. These kames are from 25 to 50 feet high, and extend in crooked north and south ridges which are frequently traceable a quarter or a half mile. Large angular boulders are occasionally found embedded in these water-worn deposits. In going westward we find these boulders more numerous; and the ridges, which become shorter and more irregular, are composed partly or wholly of angular materials. Near the foot of the hills these ridges reach about 100 feet above the railroad, and present the very irregular contour of typical kames, having steep sides and narrow tops, and enclosing bowl-shaped hollows; but they consist entirely of angular débris with no water-worn deposits, and in many places their surface is composed only of boulders with no earth to fill the interspaces. Between these moraines and the true kames seen along the railroad there is a gradual transition, the intervening ridges being partly morainic and partly kame-like in material.

A considerable area of low alluvium, without ridges, lies east of Madison station, separating this long series of kames from others of coarse water-worn gravel, which occur on the north-east shore of Six-mile pond. Near the head of this pond a similar ridge forms a small crescent-shaped island, concave towards the north.

Plains in the Basin of Ossipee Lake.

On the north-west side of Six-mile pond no distinct kames were seen, but deposits of very coarse water-worn gravel, with the largest pebbles one or even two feet in diameter, rise from 25 to 50 feet in irregular slopes. The level plains begin about three fourths of a mile south from Madison station, and the material in the next three miles gradually changes to very fine gravel or sand, so that the railroad cuts at the south end of this distance rarely show pebbles an inch in diameter. These plains occupy a large area in the south-west corner of Madison and the east part of Tamworth, and extend south along Six-mile brook, which separates Freedom and Ossipee, to the north-west side of Ossipee lake. (Plate VI.) Their soil is barren, its natural woody growth being scrub oaks and pitch pines. Their height at the north is about 40 feet above Six-mile pond, which is 456 feet above the sea; thence they have a slight southward slope of 15 or 20 feet in a mile, descending nearly to the level of Ossipee lake, which is 408 feet above the sea. In their western portion they are from 40 to 50 feet above Bear Camp river, which along its last six miles flows through fertile intervals. These cover areas from which the river has excavated the higher plain. The upper part of this river is also frequently bordered by intervals and terraces.

The shores of Ossipee lake are mostly low; and it appears that this area remains unfilled because sufficient material has not been supplied by inflowing streams. We cannot thus explain the unfilled hollows of Six-mile pond, and of Elliot and White ponds in Tamworth; for the level plain adjoining them is from 25 to 40 feet in height, and descends steeply to their shores. Probably masses of ice filled these depressions while the bordering plains were being deposited.

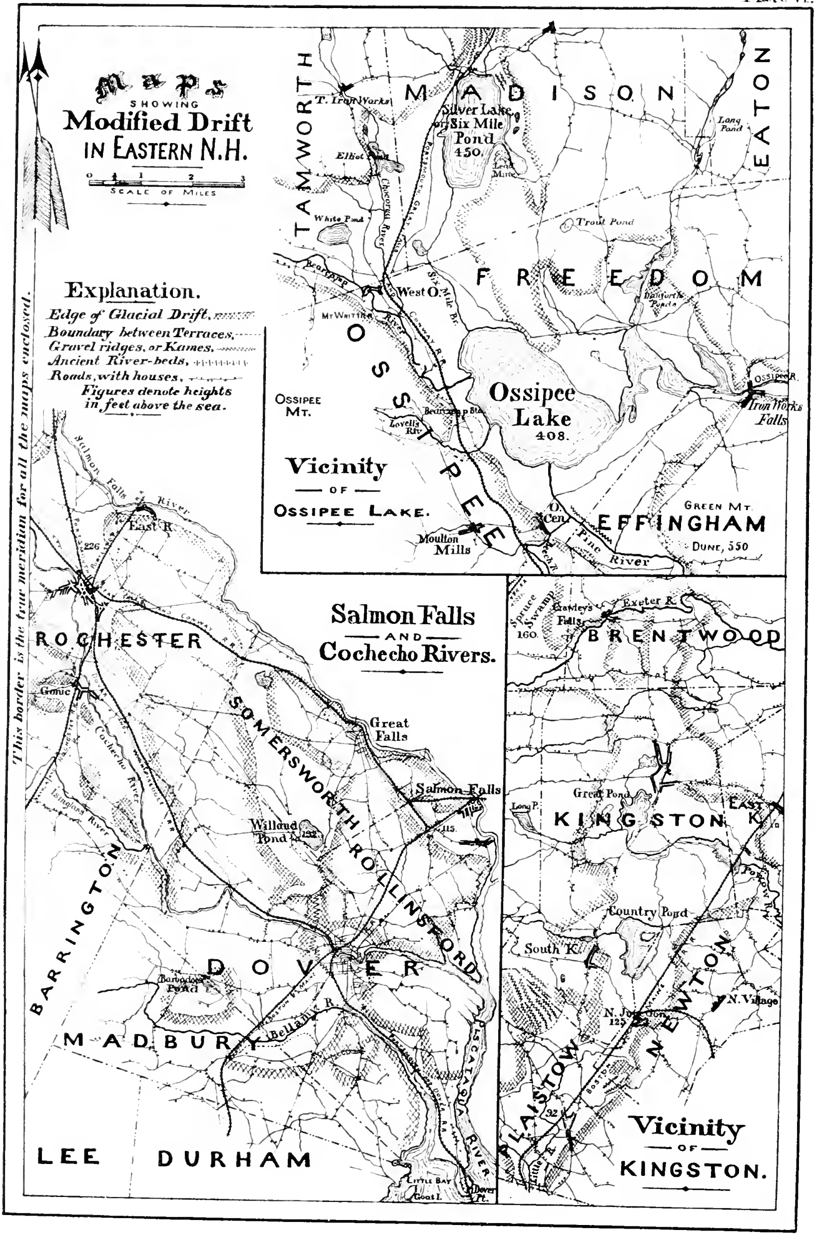
Till extends in a gentle slope to the margin of Ossipee lake along a distance of about a half mile on its north-east side. Barren pine-plains reach thence for three miles to the east. These are divided by the irregular chain of Danforth ponds, which have the same height with the lake. At Danforth bridge these plains are nearly level, and have a height of 35 feet above the ponds, to which they descend in steep escarpments. Their material is mainly sand or fine gravel; but coarse gravel, containing pebbles from six inches to one foot in diameter, is occasionally found, and appears to belong to kames which have been nearly buried beneath the fine alluvium.

Ossipee river, the outlet of this lake, flows over till at Effingham falls, and along its last mile before entering Maine. In the intervening three miles it is bordered by low modified drift, which extends to Swasey pond in Freedom, and forms an extensive tamarack swamp in the north-east corner of Effingham.

On the west and south sides of Ossipee lake the modified drift is one half mile to a mile and a half wide. Its highest portion is a delta-plain on the north side of Lovell's river, 40 feet above the lake. Elsewhere it is low, being swampy in many places, and rises only 15 to 25 feet above the lake, towards which it slopes.

These nearly level areas are bounded by hills and mountains, which rise steeply from the edge of the plains. The supply of modified drift was very abundant here, and fills three fourths of the natural lake-basin which is thus enclosed.

Plate VI.



HELIOTYPE.

A conspicuous dune, blown 125 feet above the low plains, occurs two miles south-east from Ossipee lake on the west foot-slope of Green mountain. A track of sand-drifts, now grassed over, reaches up to this from the north-west; and an old pine stump, standing where it originally grew, shows that since the clearing of the country a portion of the dune seven feet in depth has been swept from beneath it by the winds, being carried to the south-east and somewhat higher up the hillside.

Kames along Pine River.

South-east from Ossipee lake a continuous belt of modified drift extends along the entire course of Pine river, forms the water-shed between Pine River pond and Balch pond, and thence continues eastward along Little Ossipee river in Maine. These ponds are about 20 and 40 feet respectively below the lowest point of the water-shed, which is about 550 feet above the sea, or 140 above Ossipee lake, 12 miles distant. The width of the modified drift here is fully a mile, and it is not much narrower at any point. It occupies a comparatively straight valley, which is commonly bordered by high hills at each side. An exception to this is found in the south part of Effingham, where level sandy plains about 500 feet above the sea extend nearly continuous from Pine river to Province pond. Other level plains occur, as south-east of Duncan lake, between North Wakefield and the mouth of Pine River pond, and east of East Wakefield depot; but the greater part of this modified drift has an uneven surface, presenting small hollows, ridges, and mounds; and prominent kames, in ridges from 75 to 125 feet above the river, extend along the middle of the valley.

This series of kames or gravel ridges borders Pine river south-east from Ossipee Centre, but it is not well shown at the bridge in Effingham. Two miles farther south, where there were formerly a bridge and mills, it consists of a single narrow ridge, 100 feet above the river which flows at its foot on the east, and 30 feet above the plains which extend a mile south-west to Duncan lake. One mile southward this principal kame of the series is said to lie between White and Black ponds. Opposite Ossipee Corner the river crosses the line of this ridge, a half mile of which has been swept away. It next appears east from the mouth of Poland brook, and extends in a single ridge a mile to the south, with a height 50 to 75 feet above the low modified drift on each side, or about 100 feet above the river. It is then cut through by the river, but only a short gap is made; and it continues thence unbroken for more than a mile to the south-east, forming a nearly straight ridge 75 to 125 feet high on the west side of the river. On its east side the modified drift is narrow; and the road passes over a hill which affords a fine view of this kame, and others of less height which extend parallel with it, and fill nearly the whole valley for two miles below Pine River pond. At the mouth of this pond the principal kame seen was just north-east of the bridge, with a height 40 feet above the river. Kames of the same or less height occur along the shores of this pond, and form its islands. The water-shed between Pine River and Balch ponds is an area of kames, its lowest point being a hollow between high parallel ridges; and the same series continues south-east along the sides of Balch pond.

The material of these ridges is almost wholly water-worn, wherever it has been observed. It consists principally of gravel, which contains pebbles or rounded boulders up to two or three feet in diameter. Layers of sand are sometimes interstratified with this gravel; and angular boulders up to five or six feet in diameter are occasionally found. The more level areas of modified drift in this valley are also mostly gravel, with the largest pebbles frequently six inches to one foot in diameter.

The height of this series of kames where it is first met with, one to two miles above the mouth of Pine river, is about 40 feet above the lake, or 450 above the sea. At the water-shed between Pine River and Balch ponds it is about 600 feet above the sea. From this point the kames descend both to the south-east and north-west with the valleys, their slope along Pine river being 15 feet to a mile.

The accompanying plains along the lower part of Pine river are only 10 to 25 feet in height. At North Wakefield they are 60 feet above the river and pond; at East Wakefield depot they reach their greatest height, being 675 feet above the sea, or more than 100 feet above the lowest depression of the water-shed. The same belt of modified drift continues into Maine, forming extensive low plains in Acton and Shapleigh, with a height about 500 feet above the sea.

Review and Conclusions.

From the modified drift of Pine river, Ossipee lake, and Saco river, we learn the history of this part of New Hampshire in the Champlain period. After the ice-sheet had retreated from the coast, it seems for a long time to have still covered the Ossipee Lake basin, and the valley of Pine River and Balch ponds. The kames of this valley were deposited during this time in the channel of a glacial river, which carried forward its finer gravel and sand to form the plains that extend south-east from Balch pond. The coarse material and irregular surface of nearly all the modified drift along the upper part of Pine river indicate that masses of ice still remained at the time of its deposition.

After this, the ice-sheet disappeared from the broad low basin of Ossipee lake, and again for a long time had its terminal front at the border of the low area from which it had retreated. Its moraines fill the west and higher side of the narrow valley between Madison and Conway. These gradually change as we come to the centre of the valley to ordinary water-worn kames. This appears to have been the first outlet from the melting of the ice-sheet over the Saco valley and the south-east side of the White Mountains; and the material brought down was spread out to form the extensive sand and gravel plains about Ossipee lake and Six-mile pond. The comparatively small amount of levelly stratified drift associated with the kames in Madison and Conway makes it probable that the present outlet by Saco river was opened before the ice here had wholly disappeared, so that the later alluvium was carried by this river into Maine.

MODIFIED DRIFT IN THE BASIN OF PISCATAQUA RIVER.

Under this title are embraced nearly all our observations in Strafford and Rockingham counties. The streams which drain this district are united before reaching the ocean in Great bay and Piscataqua river.* Salmon Falls and Cochecho rivers are the largest of these, and have been the most thoroughly explored. Wide plains extend between these rivers in Rochester. Very interesting kames and kame-like plains occur

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* The topographic features of this basin are described in Vol. I, pp. 213–215, 302, and 313.

about Dover, and are found frequently southward through the state. Isinglass, Bellamy, Oyster, and Lamprey rivers are known to be bordered in many places by intervals and low terraces and plains, but their modified drift has not been specially explored.

The valley of Exeter river contains large areas of modified drift. One of these diverges from this river at the south-east corner of Fremont, and extends to the south through Kingston, Newton, and Plaistow to Haverhill, Mass. This belt of modified drift reaches nearly fifteen miles, and is continuous from the Exeter to the Merrimack river. Along most of this distance it forms extensive plains. Several ponds in Kingston, which lie in depressions of these plains, are the sources of Powow river.

In Newington and Portsmouth a kame-like plain of gravel and sand is the highest land between Great bay and the Piscataqua river; but their shores, with the islands of this river below Portsmouth, are almost everywhere gently-sloping hills of till or ledge.

Marine shells and other organic remains have been found in the lower portions of this valley, showing that the ocean stood at a higher level when the modified drift in which they occur was deposited. The more particular description of this district will be taken up in the same order as in the foregoing summary.

Salmon Falls River. The source of this stream is East pond, which lies partly in Wakefield and partly in Acton, Me. It has an area of nearly three square miles, and a height about 500 feet above the sea, below which it can be drawn 18 feet, to supply the mills at Great Falls and Salmon Falls. This river and the Piscataqua form a part of the eastern boundary of New Hampshire. The descent below East pond is shown by the following heights, which are in feet above the sea: Horn pond, 479; at Milton Mills (fall), 440 to 416; at Milton Three Ponds dam, 412 to 400; above East Rochester, about 200; at Great Falls, 166 to 90; at Salmon Falls, 65 to 25; at South Berwick, 20 to tide-water. Salmon Falls and Cochecho rivers, along their lower three miles, and the Piscataqua river, which is the name applied below their junction, are affected by the tide, and flow with a strong current alternately towards and from the sea.

The north-west side of East pond is bordered by a low and partly swampy area of modified drift, which reaches a quarter to a half mile in width, enclosing Round pond. Except on this side, its shores are till or ledge. No examination has been made between this pond and Milton Mills. In the two miles from this village to Branch river, the modified drift rises in irregular slopes to a height of 20 or 30 feet.

Along Branch river the modified drift is well shown, forming swampy areas and terraces of sand or gravel 20 to 40 feet in height. Kames were noted in Wakefield a quarter of a mile west from Wolfeborough Junction, and at several other points southward to Union village. At one half mile to two miles south from this station they are finely displayed along the railroad, mostly on its west side. They are composed of coarse water-worn gravel, in ridges 25 to 40 feet high, with their trend generally north and south. These kames descend with the valley from about 575 to 475 feet above the sea.

The valley of Salmon Falls river in Milton contains three natural ponds, through two of which the river flows. The two south-west ponds lie near the east foot of Teneriffe mountain. They are bordered by kames on their west and south sides; and low, sandy plains extend between them and the North-east pond. They are all flowed to the same height by the dam at Milton Three Ponds village, which has been recently raised a few feet, overflowing a large meadow above North-east pond, and holding the river level six miles, or to within a half mile of Milton Mills. Below this dam the river descends about 200 feet in the next three miles, its channel lying between ledges or steep slopes of till.

The next modified drift is in the north part of Rochester (Plate VI, p. 146), where for a distance of two miles it occupies the entire area a mile and a half wide between Salmon Falls and Cochecho rivers. This tract is crossed by the Portsmouth, Great Falls & Conway Railroad. It consists of sandy plains, 25 to 40 feet above the river, or of extensive swamps and peat-bogs. The latter were scantily filled with modified drift, while it was more abundantly supplied on all sides, preventing drainage. Salmon Falls river here turns to the south-east. A straight course would carry it southward across this area, bringing it to a junction with the Cochecho at Rochester. In the Champlain period the highest floods of these rivers were united here, and nearly all the modified drift which they brought down was deposited in these plains.

At East Rochester a narrow belt of alluvium, from 20 to 30 feet high, borders the river. In the north part of Somersworth, sand and ordinary gravel extend from the river to the railroad and Cole's pond. These deposits lie in irregular slopes, nowhere presenting the usual level terraces. Thence very coarse kame-like gravel, spread out in level plains, extends southward, and forms the water-shed west of this river to Willand pond. In the next four miles to Salmon Falls, east of these kame-like plains, the valley of the river consists of till or ledge.

Below Salmon Falls the river has excavated its channel between prominent terraces, upon which the villages of South Berwick and Rollinsford are built. Their height is nearly the same at both sides, being about 80 feet above the river, or 100 feet above the sea. The same terrace-plain extends west to Rollinsford junction, where its height is 115 feet above the sea. The last mile and a half of this river is bordered on both sides by level plains about 40 feet in height. On the west these are a half mile wide, terminating in Rollinsford point.

Cochecho River. The water-shed between Winnipiseogee lake and this river is composed of modified drift (p. 130), which is very scanty or wanting along the next four miles to Farmington. Three streams, which are the head waters of this river, have here brought down large amounts of gravel and sand, forming the low and partly level area west of Farmington village. Below this place the modified drift, lying principally in kames, or irregular mounds and ridges, is continuous on both sides of the river, being one half to three fourths of a mile wide for five miles, beyond which it expands into the extensive plains of Rochester. These mounds and ridges rise from 20 to 30 feet above the intervening hollows, reaching a height about 50 feet above the river. Their material is coarse, water-worn gravel, with occasional layers of sand; and sections usually show an anticlinal or arched stratification. A half mile east of Farmington these kames enclose numerous bowl-shaped depressions, some of which contain small ponds. This part of the Cochecho valley is bordered on both sides by hills, which rise 300 to 400 feet above the river.

Two and a half miles above Rochester the area of modified drift widens on the east, reaching to Salmon Falls river (Plate VI, p. 146). Thence level, sandy plains, in many places underlaid by clay, extend along the Cochecho eight miles. The coarse kame-like gravel continues on the west side of the river nearly to Rochester; but the wide plains at this place consist wholly of fine alluvium, and no coarse deposits were seen farther south. Below Gonic these plains extend a mile wide to a distance of two miles west from the Cochecho, and, excepting isolated hills, they occupy the whole area between this and the Isinglass river.

The height of these plains at Rochester is 226 feet, and at Gonic 200 feet above the sea, being at each place about 30 feet above the river. Southward, the stream falls more rapidly than the plains, lying 75 feet below them in the south part of Rochester.

These deposits terminate near the mouth of Isinglass river; and the next four miles of the Cochecho valley are destitute of modified drift, which next occurs a fourth of a mile above the city of Dover. The river has here cut through the ridge of a kame which extends from the kame-like plain of Willand pond to that of Pine Hill cemetery. These were deposited by glacial streams, while the ice-sheet still remained unmelted on both sides. After the ice had disappeared, Cochecho river brought down the alluvial plain, composed of clay overlain by sand, on which the north part of the city is built. The south part of this plain has been excavated by the river, leaving the rest in the form of a terrace. Its height is 70 feet above tide-water, which extends to its foot at Dover landing. East of the city the river is again bordered by slopes of till or ledge.

Fig. 37.—OBLIQUELY STRATIFIED SAND, ROCHESTER.
Scale, 1 inch=10 feet.

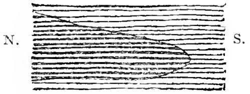

Fig. 38.—SECTION IN CLAY, ROCHESTER.
Scale, 1 inch=10 feet.

Beds of clay are worked for brick-making a half mile south from the Rochester depot, on the east side of the railroad, and a half mile farther south on the west side of Cochecho river. At the former brick-yard the clay is overlain by 5 to 8 feet of sand, which occurs principally in layers separated by nearly level lines, as shown in Fig. 37, but obliquely laminated with varying southward dip. About 15 feet of clay is exposed here, the upper part being *gray*, and most of the lower part *blue*, definitely separated from each other. The section shown in Fig. 38 was observed near the south end of this brick-yard. A mass of uniformly blue clay occupies a wedge-shaped space in the midst of gray clay. No difference, except that of color, could be seen; and the lines of stratification are plainly continuous through both.

At the second brick-yard 3 feet of sand overlies 15 feet of clay, which rests on a ledge. The upper part of this bed is compact gray clay, inclined to break into small fragments, the sides of which are stained with iron-rust; its lower portion is tenacious, and bluish gray in color.

Near Gonic the stratum is worked at four places, all on the east side of the river. Here the surface is 1 to 4 feet of sand. Next follows 10 to 15 feet of gray clay; this changes abruptly to blue clay, which is several feet thick, and extends below the excavations.

The brick-yard at Dover landing shows the following deposits, separated by definite lines: Sand at the top, 8 feet; gray clay, 12 feet; blue clay, 15 feet. A brick-yard beside the Piscataqua river, half a mile north from Dover point, shows 30 feet of clay,—its upper portion gray and its lower portion blue. The brick-yards on the south-west side of this point expose only the gray clay, which is about 15 feet thick, overlain by 2 or 3 feet of sand. We find here the features which usually mark the gray clay. Near the top it is free from sand, and is hard and compact, not showing its stratification, but breaking into small angular pieces, which are separated by films of iron-rust. In its lower part it shows lines of stratification, and sometimes contains sandy layers. Through the whole deposit pebbles up to six inches or one foot in diameter are rarely found. A well at one of these yards showed the bottom of this gray clay interstratified with sand and gravel, beneath which was blue clay.

The brick-yards along the Boston & Maine Railroad are similar to the foregoing. Half-way between the stations of Exeter and East Kingston beds of clay are found in kame-like banks, 20 to 30 feet in height, at both sides of the railroad. The top of these deposits is a few feet of sand or fine gravel, irregularly bedded as if laid down by strong and conflicting currents. The clay is nearly level in its stratification, and has a depth of about 20 feet. It is principally gray, but changes gradually near the bottom into blue clay. Another brick-yard of the same kind is found a mile farther south. These seem to be isolated deposits, having been formed like the kames in hollows of the melting ice-sheet. They lie on the till, and can hardly be supposed to be remnants of any formerly level deposit. The beds of clay near Dover point may be of similar origin.

The clay worked at Plaistow is alluvial, and was deposited in the quiet water, held back by a barrier of kames. The order here is as follows: sand at the top, 5 to 10 feet; gray clay, about 10 feet; gradual transition from gray to blue clay, 3 feet; blue clay, 5 to 10 feet, underlain by sand.

Beds of gray and blue clay are also found in the high terraces of Merrimack river, and in the valley of Hudson river and Lake Champlain (see pp. 94 and 95). In Vermont, where they contain marine shells, they were called by C. H. Hitchcock *Champlain clays*, from which this name has been applied to the period in which the ice-sheet disappeared.

The height of these deposits of clay in Hooksett and Pembroke is about 300 feet above the sea; in Rochester, about 200; at Dover Landing and Point, 20 to 50; and in East Kingston and Plaistow, about 100.

The wide distribution and unvarying order of the gray and blue clay suggest that they have some special meaning, which it may be important to understand for the right interpretation of our other records in surface geology. To what conditions and causes do these clays owe their difference in color?* Without being able to explain this, we have presented our observations as fully and plainly as possible.

Kames and Kame-like Plains about Dover and southward. Near the coast from Dover to Newburyport are frequently found massive kame-like deposits, consisting of high plains or broadly rounded ridges of gravel and sand, which often form water-sheds between wide valleys 100 to 200 feet below. The absence in these valleys of the terraces which mark erosion through modified drift, shows that they were never filled with the same materials, and that these remarkable plains and ridges were deposited in their present isolated position, with wide areas of lower land at each side. How this took place we can only explain by referring the

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* These clays were the most finely pulverized portion of the abraded material contained in the ice-sheet. Their iron, which is always present in such quantity as to give the burnt bricks a red color, was in the same state of combination as in the rocks before pulverization, principally in ferrous sulphides, silicates, and carbonates. This is its condition in the dark and often blue clayey paste of the lower till. Has the underlying blue clay been washed from the ice-sheet by glacial rivers, transported many miles, and deposited, without the separation and further oxidation of its iron, which would give the clay a gray, brown, or reddish color? and have these changes been partially effected in the overlying gray clay? Or, did these changes take place quite fully before deposition, to be followed by deoxidation through the agency of organic matter, as has been shown by Dawson to be true of the mud now being deposited in the Gulf of St. Lawrence? In either case, the conditions which produced difference in color between the lower and upper portions of the clay remain to be explained. The anomalous section shown in Fig. 38 adds to the difficulty of this question.

formation of these deposits to the same causes which produced the kames. The ice-sheet still remained unmelted upon each side at the time of their deposition, filling the valleys and wide areas of low land, over which this gravel and sand must otherwise have been spread by the current of the floods on which they were brought.

The most extensive of these plains occur about Willand and Barbadoes ponds, near Dover, and in Newington and the north-west part of Portsmouth. Broadly rounded deposits of the same class occur frequently in this district; and southward, along the sea-coast, they form the elevations on which the villages of Rye, North Hampton, and Hampton are built. A very interesting ridge of this kind extends from north-west to south-east through Newburyport.

Willand pond* is situated principally in Somersworth, two and a half miles from the city hall in Dover. Its area is 84 acres, and its height above low tide in the Cochecho is 192 feet, as determined by survey of Hon. James A. Weston and Joseph B. Sawyer, made in 1871, in reference to supplying the city of Dover with water.† Their report says of this pond:

"It has no visible inlet worthy of consideration, and at ordinary stages it has no visible outlet. The ordinary annual high-water mark was about two feet above its surface at the time the survey was made. It appears that when the pond reaches this height, the surplus water, if any there be, runs off through a piece of low, wet, bushy ground (called a heath), of some 10 to 15 acres in extent, which lies on the northern border of the pond,—the water finally escaping through a slight artificial channel or ditch into a brook, which is tributary to the Salmon Falls river.

"On all other sides the pond is bounded by a dry, gravelly plain, which is from 12 to 17 feet above low water, and which extends from a quarter to a half mile from the pond. This plain is bounded in most directions by lower plains and valleys having a retentive clayey soil, which, being lower than the surface of the pond, contribute nothing to its waters.

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*The plain about this pond, and the kame which extends thence to the south, are shown on Plate VI, p. 146.

†Other heights in Dover, measured in this survey, are the following, stated in feet above low tide in Cochecho river: Lower step of front door of city hall, 45; do. of American House, 73; summit on Franklin st., near Dr. Horne's, 86; corner of Locust and Silver sts., 98; first floor of Belknap school-house, 123; threshold of tool-house at Pine Hill cemetery, 152; highest point on Garrison hill, 297.

"On the contrary, there are several large springs on the borders of the lower plains, which are supplied from the body of sand constituting the plain above, and probably in some instances from the pond itself. On the side next the city the springs are about 41 feet lower than the pond, and are of such size that they supply the water for the Cochecho Aqueduct Co. It is probable that these springs are subterranean outlets for the water of the pond, and undoubtedly these and all the others drain some portions of the sandy plain surrounding the pond. * *

"How extensive the area is which furnishes water to the pond we have no reliable means of determining, because the water-courses and divides are hidden beneath the surface. It may be stated in a general way that the wells sunk into this plain indicate that the water-table rises towards the north and west, and falls towards the south and east."

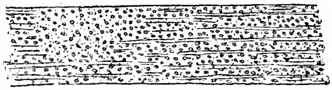

Fig. 39.—SECTION OF PLAIN AT WILLAND POND, SOMERSWORTH. Depth, 25 feet.

In 1876 a water-pipe was laid from this pond to Dover, for which a ditch was dug 25 feet deep for a quarter of a mile through the bordering plain. This ditch (Fig. 39) showed the plain to consist of interstratified gravel and sand, the former predominating, and containing abundant pebbles, of all sizes up to a foot and a half in diameter. The whole appearance is kame-like, but the materials are nearly level in stratification. The layers of sand were from a few inches to two feet in thickness, but were short, not being apparently continuous over large areas. At some points only the coarse gravel was found, with no clear sand. No boulders were seen on the surface or in the excavation.

This plain about Willand pond is the highest land between Salmon Falls and Cochecho rivers, the descent to which is over uneven areas of ledge or till. The shores of the pond on all sides rise steeply to the level of the plain. Much of this escarpment appears to have resulted from the undermining action of waves. In other portions the gravel and sand were deposited with this slope, which, near the point where water is taken for the city of Dover, continues to a depth of 60 feet below the surface of the pond at ten rods from its shore. At that time the hollow which is now filled by the pond, and the wide valleys to the east and west, appear to have been occupied by portions of the departing ice-sheet.

On the south this plain descends 25 to 50 feet in an escarpment, below which the edge of the gravel and sand is overlain by a peculiar clayey stratum, which extends with an undulating or nearly level surface south-easterly to Garrison hill, and is also well shown south-west from Dover, between the city and Bellamy river. Its margin reaches 125 to 150 feet above the sea, and is marked by numerous springs. This deposit resembles the gray clay of the brick-yards in its color; its usually obscure stratification, which is, however, sometimes distinctly shown; its occasional division into small fragments, stained with iron-rust; and its containing infrequent pebbles from two or three inches to a foot in diameter. Except these isolated pebbles it is wholly a fine, clayey silt. On any exposed bank it is marked by many little channels, which have been formed by the rains, and are preserved through dry weather by the hardening of the surface.

The kame-like gravel of Willand pond extends three miles northward, to Cole's pond and the alluvial area of Salmon Falls river, near the east corner of Rochester. Southward it is narrowed to an ordinary kame, which is cut through by Cochecho river a quarter of a mile above the city of Dover. A very instructive section of it is shown by a railroad cut on the north side of this river (Fig. 40). The kame consists of gravel and sand, and is overlain on both sides by the widely spread gray clay. Numerous angular boulders, 2 to 5 feet in diameter, had been stranded on the north-west side of the kame before the deposition of the clay. An excavation between this section and the river exposed a boulder 8 feet in its greatest diameter and weighing 16 tons, with another two thirds as large, which were embedded in the kame.

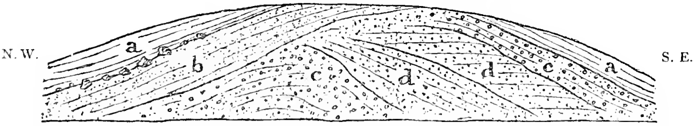

Fig. 40.—SECTION OF KAME ON DOVER & WINNIPISEOGEE RAILROAD, ½ MILE NORTH-WEST FROM DOVER STATION. Length, 300 feet; height, 40 feet.

The base of the section is about 40 feet above Cochecho river, or 75 feet above the sea.

a, a, gray clay; b, fine sand; c, c, coarse gravel containing pebbles from 6 inches to 1½ feet in diameter; d, d, fine gravel.

In the west part of the city this kame consists almost wholly of sand, and extends in a broad ridge to Pine Hill cemetery, being in some places overlain by till, but more frequently by gray clay. On the south side of Fourth street an excavation (Fig. 41) shows it to be horizontal in stratification, except at its sides, where it is obliquely bedded, conformably to its slope. Here its west side is overlain by the unstratified upper till, in which are numerous angular boulders 2 to 4 feet in diameter. This till also forms a layer two feet thick over the top of the sand, containing frequent rock-fragments of smaller size. Another section, showing 15 feet of irregularly bedded sand, overlain by a similar deposit of upper till, was observed a quarter of a mile farther south, at a height of about 140 feet above the sea. At these points it seems probable that the sand was deposited in an open glacial channel, bordered by overhanging walls of ice, from which the upper till fell upon the side and was partly strewn upon the surface of the kame.

Fig. 41.—Sand overlain by Till, Fourth Street, west of Cochecho River, Dover.
Length of section, 250 feet; height, 30 feet; base of section is about 75 feet above the sea.

Ridges of till overlain by sand, which is overlain by gray clay.

Fig. 42.—Section along Silver Street, south of Riding Park, Dover.
200 feet long; 6 to 9 feet deep.

Gray clay overlying sand.

Fig. 43.—Same, 300 feet east of last; 100 feet long; 8 to 10 feet deep.

Gray clay overlying sand, which overlies till.

Fig. 44.—Same, 500 feet farther east; 100 feet long; 7 to 10 feet deep.

A ditch for laying water-pipe on Silver street showed this sand deposit overlain by gray clay (Figs. 42, 43, and 44). The junction of the sand and clay was by a gradual transition, occupying one or two feet, and three or four feet of the clay next above was plainly stratified. The rest of the clay was very compact, with no evident lamination, breaking into iron-stained, angular pieces, and contained occasional pebbles. In the midst of this clay (Fig. 43) a horizontal sandy layer was very distinctly shown for a distance of 150 feet. Near its east end, iron-stained gravel and several stones a foot in diameter were found between the clay and the west edge of the underlying sand.

Eastward, these deposits lie in a kame-like ridge, a section of which (Fig. 45) shows one side of it to be wholly gray clay, while the other side is mainly sand; but their junction is concealed by the abutments of a bridge. The outer edge of the sand, however, is overlain by similar clay.

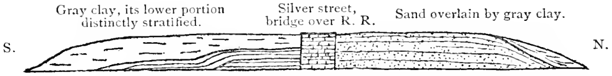

Fig. 45.—EXCAVATION FOR THE PORTSMOUTH & DOVER RAILROAD, 1000 FEET EAST FROM FIG. 44.

Length, about 500 feet; depth, 20 feet; top of section is about 100 feet above the sea.

Pine Hill cemetery, a half mile farther south-east, is a level plain of horizontally stratified sand, 150 feet above the sea. It is bounded on the north and west by escarpments, which descend steeply 30 feet. The deposition of this sand appears to have been confined here by walls of ice. On the south-east are ledgy hills which are somewhat higher, in whose hollows are low mounds or ridges of gravel and sand, one of which was observed to contain masses of till, one to three feet thick, full of angular boulders up to two feet in diameter (Fig. 46). These materials probably fell from the glacier upon the margin of ice at its foot, and when this was broken up, they were floated away on rafts, which at length melted, dropping their freight to be thus embedded in modified drift. The pebbles which we have mentioned as occurring here and there in the gray clay, were distributed in the same manner. This clay and its pebbles were deposited at a later date, following the withdrawal of the ice-sheet by which the earlier gravel and sand were confined in these kame-like plains.

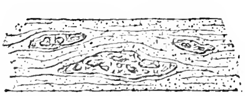

Fig. 46.—SECTION IN A KAME SOUTH-EAST OF PINE HILL CEMETERY, DOVER.

Scale, 1 inch=10 feet.

The sea in this period stood at a higher level than now; and the clay was probably a marine deposit brought down from the melting ice-sheet at the north-west. It is well shown in Dover, Madbury, Durham, and Newington, forming the surface of much of these towns, but not observed at a greater height than about 150 feet above the sea. On the borders of Great bay and Piscataqua river it seems not to exceed a height of 50 feet. A well near the Boston & Maine Railroad, about a mile west from Dover, passed through 20 feet of this compact, pebbly gray clay, below which was a water-bearing stratum of sand. A neighboring well showed 10 feet of similar gray clay; then 2 inches of clear sand; beyond which this clay continued 16 feet lower, and was underlain by 1½ feet of mud, apparently containing sticks and leaves, and lying upon ledge.

At the county farm, three miles north-west from Dover, and about 150 feet above the sea, a well showed 50 feet of this clay; which contained sandy layers, but otherwise was obscured in its stratification. Stones were frequently found, the largest of them weighing about 100 pounds. Below this was a stratum of gravel and sand, which seemed "like the bed of a stream," and yielded an abundance of water. This deposit lies upon till, which is exposed at forty rods to the north. On the west side of Cochecho river, at a bridge slightly farther distant to the north-west, is a kame that probably marks the mouth of the glacial river by which this marine delta was formed.*

Barbadoes pond, crossed by the line between Dover and Madbury, is surrounded by an elevated plain of gravel and sand,† about 175 feet above the sea, of the same kame-like origin with that about Willand pond. This plain is bounded by an escarpment 10 to 40 feet high. At its foot on the south-east are springs which supply the west part of the city of Dover.

Southward we find other extensive deposits of the same origin. On the south side of Bellamy river, for a mile and a half east from Madbury station, is a broad ridge of coarse water-worn gravel and sand of about the same height with the plain at Barbadoes pond, and 50 feet higher than the adjoining land, on any side. One mile south from Sawyer's mills in Dover, and in the same line with the foregoing, is a similar ridge two thirds of a mile long and about 150 feet above the sea. The ridge, about 125 feet in height, between Bellamy and Piscataqua rivers at one to two miles north from Dover point, is shown by wells to be the same

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* A recent journey has brought to our notice an alluvial plain on the west side of the Cochecho, opposite to and lower than this delta. It was probably fluviatile, belonging to a later date when the ocean held a lower level. The rounded delta and the imperceptibly sloping plain show the contrast between deposition in deep and quiet water, as of a lake or arm of the sea, and that which takes place from the shallow floods of rivers.

† The extent of this deposit, and of others described at the south-east, may be seen on Plate VI, p. 146.

interstratified gravel and sand. In this class, also, are, a ridge noted at the west line of Durham, half a mile south-west from Oyster river; the deposit, shown in Fig. 47, cut by the Nashua & Rochester Railroad at the divide between Oyster and Lamprey rivers; the gravel plain of Lee Hill village, 190 feet above the sea; and the plain of nearly the same height, two miles west from Newmarket, on the road to Wadley's Falls, composed of coarse gravel at the west, but of clear sand to a depth of 30 feet in its eastern portion.

Fig. 47.—SECTION IN SAND NEAR WHEELWRIGHT POND, LEE.

Height, 30 feet. Base of section is about 150 feet above the sea.

One of these deposits near Newmarket Junction, composed mainly of sand with no rocks embedded in it, has its surface strewn with angular boulders, the largest of which are 10 feet in their greatest diameter, weighing 30 or 40 tons. The sand was deposited in the channel of a glacial river. When the ice on both sides and beneath it melted, this fell to the bottom of the shallow sea, which probably stood 150 feet above its present height. The boulders were then dropped on its surface by blocks or rafts of floating ice.

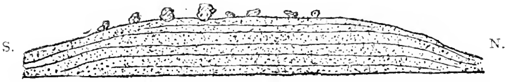

Fig. 48.—SECTION ON BOSTON & MAINE RAILROAD, ¼ MILE NORTH OF NEWMARKET JUNCTION.

Length, about 600 feet; height, 35 feet. Base of section is about 50 feet above the sea.

The academy in Greenland is built on a broadly rounded, kame-like ridge of gravel, which at a short distance to the south-west becomes a nearly level plain 40 or 50 rods wide, but still farther to the south-west is narrowed to a typical kame. The length of this deposit is a half mile. Its height is nearly 100 feet above the sea.

At a school-house half a mile south from the academy, we rise to a plain about 125 feet above the sea, which extends a mile to the south and south-east, descending with a gentle slope 25 to 40 feet in that distance. This plain forms the highest land between Winnicut river and Berry's brook. Its north-west portion is quite thickly strewn with boulders, the largest of which are 5 or 6 feet in diameter; and over nearly its whole extent these have been sufficiently abundant for walling the fields. Four wells, however, between the school-house and the Eastern depot, varying from 20 to 30 feet in depth, passed all the way through stratified gravel, sand, and blue clay. In three of these wells the upper portion was fine gravel or sand. One of them, a half mile south-east, and a cistern a quarter of a mile south from the school-house, showed at the top 10 feet of very coarse but water-worn gravel, which was underlain by clear sand.

Two thirds of a mile farther east, beyond the railroad and Berry's brook, a well at the house of L. & F. A. Berry (county map) encountered 10 feet of coarse gravel, below which were interstratified fine gravel, sand, and blue clay, extending 16 feet to ledge. Mussel shells which still retained their purple color, but were easily broken in pieces, were found in this well eighteen feet below the surface. Three fourths of a mile south from the school-house, a well at N. Norton's (county map) passed through 40 feet of coarse gravel containing pebbles up to 5 or 10 inches in diameter, with layers of sand. At a depth of about 25 feet in this well several white pine cones were found, and about 5 feet lower numerous mussel shells, both being well preserved and distinct. The two last wells are one and a quarter miles apart, each being at the surface about 100 feet above the sea.

The very thin covering of till and frequent scattered boulders which lie on the north-west portion of this plain, were probably in large part distributed by floating ice; but this appears to have taken place at a time when the ice-sheet paused in its retreat, and once more overspread areas from which it had withdrawn. Evidence of a reädvance of the ice-sheet was also afforded by a well in Stratham, a third of a mile east of Barker's hill. Here the surface was 5 feet of upper till, which also extended fully twenty rods on every side, containing boulders up to 6 or 8 feet in diameter, underlain by 21 feet of sand and fine gravel, the bottom of which was not reached. A hill in the north-west corner of North Hampton, which rises 75 to 100 feet above the lowland by which it is entirely surrounded, or about 150 feet above the sea, is covered to the top on its north side with very coarse glacial drift, containing abundant angular boulders of all sizes up to 10 feet in diameter; yet this hill is shown by wells to be principally composed of modified drift, a large part of which is clay.* On its south side the surface is gravel, with few boulders, none of which exceed 4 or 5 feet in diameter.

The last of these kame-like deposits which remains to be described within the limits of Piscataqua basin, is the extensive plain of Newington and the north-west part of Portsmouth. This is three miles long from north to south, and for most of this distance averages a mile in width, forming a plateau 60 to 100 feet above Great bay and Piscataqua river on each side. Outcropping ledges and scattered boulders are seen in many places upon its surface; but numerous wells show only modified drift to depths of 30 or 40 feet, being first coarse gravel, 3 to 10 feet in thickness, succeeded below by interstratified fine gravel and sand. The entire western edge of this deposit is a gently sloping escarpment, which descends 10 to 30 feet. On the north and east it rests mainly on ledges, but at one place falls in an abrupt slope more than 50 feet. A section at its base in the north part of Newington showed sand overlain by gray clay, as at Dover. Southward, near the Concord & Portsmouth Railroad, its surface is sand, obliquely stratified. Between this and the Eastern Railroad it is changed to a broad ridge, 25 to 30 feet high, composed mostly of pebbles six inches to a foot in diameter, packed as compactly as possible with no layers of sand. This gravel is finely exposed in an excavation, from which it is teamed two miles for repairing streets in Portsmouth. The deposit terminates south-east from the Eastern Railroad in a small plain of horizontally stratified sand.

Exeter River and the Plains at Kingston and southward. The principal part of Exeter village, and several square miles bordering Exeter

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* The following are sections of wells upon this hill, noted in order from north-west to south-east:

1. A well dug three years ago at C. C. Barton's, about 30 feet below the top of the hill, showed till on the surface, 4 feet; gray clay, plainly stratified and sandy in some layers, but containing occasional pebbles seldom more than 6 inches in diameter, 38 feet; clear sand, with water, 1 foot; blue clay, 9 feet, extending lower;—total depth, 52 feet.

2. The former well here, about 150 feet distant to the south-west and nearly the same in height, was through till, 4 feet; gray clay, as in new well, 4 feet; sand and fine gravel, 15 feet; gray clay, 27 feet;—total depth, 50 feet. The last eight feet were bored, and at the bottom the auger "fell," and a powerful flow of water came up.

3. At A. Wiggin's, near the top of the hill, a well 52 feet deep through unknown material becomes dry in summer, and was recently bored 12 feet lower through sand without striking ledge;—total depth, 64 feet.

4. At E. F. Wiggin's, perhaps 30 feet below the last place, the order was till containing boulders up to 500 pounds in weight, with layers of gravel and sand, 20 feet; interstratified fine gravel, sand, and clay, 20 feet; very compact gray clay, nearly free from rock fragments, 16 feet, underlain by quicksand with abundant water;—total depth, 56 feet.

5. A well dug two years ago at T. E. Marston's, about 20 feet lower than the last, passed through coarse waterworn gravel, with the largest stones 1½ feet in diameter, 8 feet; sand and fine gravel, 10 feet; gray clay, stratified and containing layers of sand, 20 feet;—total depth, 38 feet.

river on the south and extending into Kensington, are alluvial sand and gray clay, 30 to 60 feet above the sea.

A map on Plate VI (p. 146) shows the belt of plains which extends south from this river to the Merrimack at Haverhill, Mass. At the north line of Kingston their height is about the same as that of Spruce swamp in the east part of Fremont, which is shown by the survey for the Nashua & Rochester Railroad to be 160 feet above the sea, or about 30 feet above Exeter river. Half of the township of Kingston is occupied by these sandy plains, which slope to a height of 125 feet above the sea at its south line. Numerous ponds, which are the sources of Powow river, mark where portions of the ice-sheet remained unmelted while the deposition of modified drift went on rapidly at each side. A large area of kames is indicated on the map in the northern part of Plaistow. Their southern portion consists of the ordinary water-worn gravel in short, steep ridges and mounds. At the north and north-west, these pass gradually into very coarse morainic débris, containing angular blocks of all sizes up to 10 feet in diameter, much of which is accumulated in low ridges like those of the kames. In Plaistow the plains continue their slope to about 90 feet above the sea. In Haverhill a large portion of the original deposit has been excavated by Little river; and its south end has been partly undermined by the Merrimack, on whose north side it forms a conspicuous terrace west of the railroad bridge.

Fossils. Although it seems probable that the sea stood about 150 feet higher than now during the deposition of most of the modified drift in this basin, only very scanty relics of the life of this period have been found. A whale's vertebra, now in the museum of Dartmouth college, was discovered in Somersworth in 1843 by the caving in of a gravel bank, but no other bones were found. Several wells in the village of South Berwick show marine remains at a depth of about 30 feet in a stratum of fetid mud, which resembles that of the tide-flats, and frequently renders the water unfit for use, at least through a part of the year. The humerus, radius, and ulna of a seal, and shells of *Nucula Portlandica* (see foot-note on next page), are mentioned by Jackson from wells at this place, which are about 100 feet above the sea, the fossiliferous stratum having a height of about 70 feet. The surface here was three feet of sand, the whole depth below which was clay, the upper portion gray and the lower blue. A third of a mile to the south, near the landing, two wells at about 50 feet above the sea show 20 feet of gray and 10 feet of blue clay, succeeded by a layer of fetid mud with numerous clam and mussel shells 30 feet below the surface, or only 20 feet above the sea. Casts of clam and mussel shells were found in a brick-yard worked twenty years ago on the shores of Bellamy river, a half mile north-west from Dover point. They also occur in the brick-clay of Eliot on the east side of the Piscataqua.

Shells[*] of *Saxicava rugosa, Mytilus edulis, Sanguinolaria,* and *Astarte castanea* were found at several places in Kittery within 30 feet above the sea by Mr. John L. Hayes. He also discovered *Nucula Portlandica*[*] and *Sanguinolaria*[*] in Portsmouth near Wibird's hill. The shells at this place were 15 feet below the surface and 30 feet above high tide, in blue plastic clay. Mussel shells are reported at two localities in Greenland (p. 163); but farther to the south no fossils appear to have been discovered within the limits of this state, although there is considerable modified drift which was probably deposited beneath the sea. The shells found in Portsmouth and South Berwick show that an arctic climate prevailed during the deposition of the beds in which they occur; but the presence

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[*] Jackson's *Final Report on Geology of New Hampshire*, pp. 94, 121, and 281.

The shells here mentioned are all species now living. One of them is confined to arctic seas; of the rest, all but one are circumpolar, extending south to our latitude, while one has its northern limit at Nova Scotia, and is most abundant southward. Their synonyms and range, fossil and living, are as follows:

Nucula Portlandica, Hitchcock; *Leda truncata*, Brown; *Leda arctica* and *Portlandia glasialis*, Gray; *Yoldia arctica*, Sars (but not of Möller and Mörch). This shell gives its name to the *Leda clay* of Canada. Fossil in New Hampshire, Maine, New Brunswick, Province of Quebec, Labrador, Norway, and Scotland. Portsmouth, N. H., is the most southern locality at which it has been found. Now living only in arctic seas; found at Spitzbergen in depths from five to thirty fathoms.

Saxicava rugosa, Linn.; *S. arctica*, Deshays. Variable, having been described under five genera and fifteen species. This shell gives its name to the *Saxicava sand* of Canada. Fossil from New England to Labrador and in Europe; var. *distorta*, Say, is found in the Miocene of Maryland. Now living in arctic seas, and abundant southward to Cape Cod, and less common to Georgia; also extending south to the same latitude on the Pacific coast of America and in Europe. It occurs from low-water mark to a depth of fifty fathoms.

Mytilus edulis, Linn. Common mussel. Fossil from New England to Greenland and in Europe. Now living in arctic seas, extending south in the Atlantic to North Carolina and the Mediterranean sea, in the Pacific to China and San Francisco. Littoral to fifty fathoms.

Sanguinolaria (obsolete); *Macoma*, Leach. Two species of this genus, *Macoma Grænlandica*, Beck (*M. fragilis*, Adams), and *Macoma sabulosa*, Mörch (*M. calcarea*, Adams), are common as fossils from New England to Labrador and Greenland, and the latter also in Europe. Both are now living on our coast from the Arctic ocean to Long Island; the latter is also found in northern Europe, and extends south on the coast of Asia to Japan.

Astarte castanea, Say. Fossil at Nantucket and Point Shirley, Mass., and at Kittery, Me. Now living from New Jersey to Nova Scotia; common as far north as Massachusetts bay. Abundant in Provincetown harbor at low-water mark, but more frequently occurring at depths from five to fifteen fathoms.

Mya arenaria, Linn. Long clam; the common clam of our coast north from Cape Cod. (*Venus mercenaria*, the round clam, or quahog, is the common species south from New York.) Fossil from South Carolina to Greenland, in Europe, and in the Miocene of Virginia. Now living from the Arctic ocean to South Carolina,—very abundant as far south as New Jersey; also extending south to France and China. Between high and low tide, and thence to forty fathoms.

of *Astarte castanea* at Kittery is proof that the ocean became as warm as now before it sank to its present level.

KAMES IN THE SOUTH PART OF ROCKINGHAM COUNTY AND IN NORTH-EASTERN MASSACHUSETTS.

This district contains very interesting and instructive series of kames, which differ from those described along the Connecticut and Merrimack rivers, and in the basin of Ossipee lake. It will be remembered that those series lie along the middle and lowest portion of valleys. The series of kames now to be considered do not follow the present water-courses, but run directly across the Merrimack and other rivers, which here have no well marked valleys, being not much lower than the hollows between the hills on either side. Occupying these hollows or lying against the side of the hills, the kames extend long distances in a somewhat devious, but for the whole series, quite straight course, which is about half-way between south and south-east.

Rev. George F. Wright, of Andover, Mass., has given much attention to the surface geology of this district, and has kindly supplied the following description of these kames: *

A formation of gravel, known at Andover as "Indian Ridge," has long been familiar to the citizens, and has been remarked upon frequently by tourists and geologists. We could not improve the description of the main features of similar formations given by Dr. Edward Hitchcock in 1842.† He writes,—"Our moraines form ridges and hills of almost every possible shape. It is not common to find straight ridges for a considerable distance. But the most common and most remarkable aspect assumed by these elevations is that of a collection of tortuous ridges and rounded and even conical hills, with corresponding depressions between them. These depressions are not valleys which might have been produced by running water, but mere holes, not unfrequently occupied by a pond."

By reference to Map 1, Plate IV, the characteristics of this formation may easily be apprehended. At the flax mills near Andover depot, a dam raises the Shawshin river 14 feet. Measuring from the river-bed below the dam, the ascent to the peat-bog, *o*, at the base of the east ridge, is 41 feet. Taking this bog as a level, the heights of the successive ridges,—East ridge, Indian, and West,—at the points *a*, *b*, and *c*, are 41 feet, 49 feet, and 71 feet. The point *c*, however, is in a characteristic depression of the

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* For some further particulars and facts bearing on the origin of these series of kames, see a paper by Rev. Mr. Wright in *Proceedings of the Boston Society of Natural History*, vol. xix, pp. 47-63.

† *Transactions of the Association of American Geologists and Naturalists.*

ridge. On either side of it, north and south, prominences project 20 feet higher, making them 91 feet above the base assumed at *o*, and 132 feet above the river, or 182 feet above the sea.

Branches not adequately indicated on the map run off at various points and form enclosed basins, which have no outlet except as channels have been cut through the loose material of the ridges, either by natural or artificial means. Quite an extensive body of water was included, till long after the settlement of the town, in an enclosure between *b* and *c*. It has been drained, partly by a channel of its own formation and partly by artificial means, and is now occupied by a muck swamp, which is 20 or 30 feet deep. A trigonometrical section of the west ridge, near the point *c*, gives the height above this swamp 61 feet, with a base of 250 feet. The rate of descent from the apex at this point to the base is therefore one foot in two.

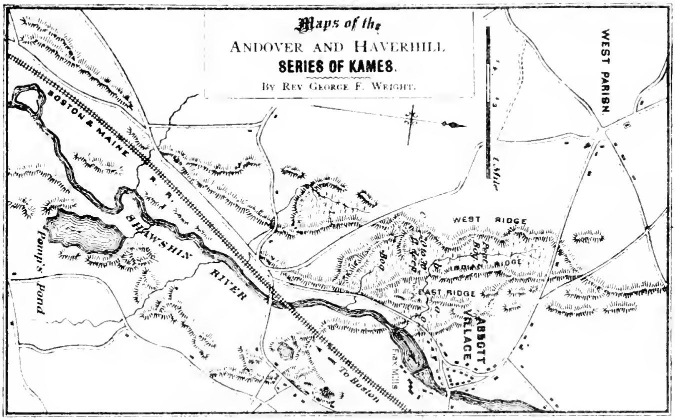
A few rods east of the point *o* there are irregular remnants of ridges of the same general character with the others, running south-east across the Shawshin river and Boston & Maine Railroad. East of this railroad it is apparently pushed into a great number of irregular prominences enclosing numerous bowl-shaped basins, one of which, of oblong shape and about fifteen feet deep, is at the very summit, the rim of which rises to a height of about 100 feet above the river. A mile south, at Pomp's pond, and partially connected by intervening ridges, is a similar cluster of rounded hills and enclosed basins, surmounted by a sharp peak of still greater height.

We should also observe that clusters, or ganglions, of such irregular ridges, encircling bowl-like reservoirs and rising into sharp peaks, occur at frequent intervals along the whole belt of the formation we are describing. Frequently, as a ridge is suddenly pushed up into a pinnacle, it will put out a spur, returning to itself and forming a closed basin at or near its top.

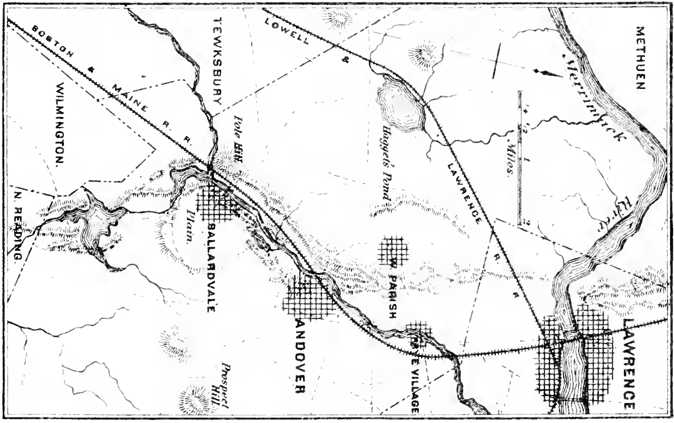
These ridges are ordinarily composed of sand, gravel, and pebbles, the latter from a few inches to two or three feet through, sometimes irregularly stratified, the coarse material being as likely to abound near the top as at the bottom; at other times, 10 or 15 feet or more in thickness will give no signs of stratification whatever. The top of the ridge is usually just wide enough for a foot-path; and pebbles a foot or two in diameter dot its course at frequent intervals. Usually, also, the base of the ridge is partially hid by subsequent accumulation of stratified sand and fine gravel, or by peat-bogs.

Another point of importance is, that the fragments of rock in the ridges are nearly all somewhat rounded and apparently water-worn, though it is evident that they have not all been subjected to the same amount of attrition. I have searched in vain among the débris of the formation for scratched stones, though striated stones are found in abundance near the surface in the immediate vicinity. Furthermore, the pebbles are not of local origin. Merrimack slate abounds, as does a porphyritic gneiss, whose position is well determined in central New Hampshire. In Topsfield, a portion of the pebbles are clearly from ledges only a few miles to the north-west.

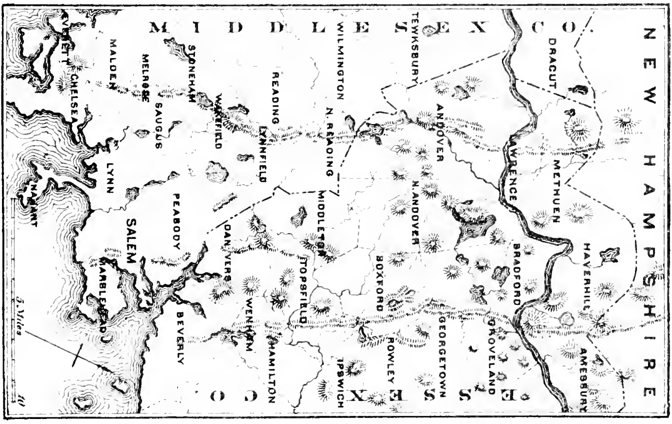
The formation does not lie at a uniform altitude above the sea, but rises over hills



Map 1.



Map 2.



Map 3.

HELIOTYPE

and descends into river valleys in a certain apparent independence of the natural configuration of the country. The land, however, though undulating and somewhat broken, nowhere in this part of Massachusetts rises more than 300 or 400 feet above tide-water; and even these heights are reached only by peculiar accumulations of unmodified drift or till, which here forms massive rounded hills. The gravel ridges plainly belong to the superficial deposit, since they everywhere overlie the ground-moraine or till. They rest upon the flanks of these hills at Lawrence near the reservoir; at Ballard Vale, on Pole hill; at Wakefield, near the rattan works; in the north-east part of Middleton; and on the north bank of the Merrimack in Haverhill, opposite to and a little below Groveland.

Sometimes the ridges disappear in a sandy plain, in which case, however, there are usually bowl-shaped depressions in the plain along the line of general direction. This is noticeable east of Ballard Vale. These depressions are frequent in Kingston, N. H., near Great pond. But the most remarkable instance is near the cemetery in Marblehead, a half mile south-east from the lead mills in Salem. Here is a cluster of depressions within a depression. The outer rim has a north-to-south diameter of 605 feet, and an east-to-west diameter of 735 feet. A hollow at the south side descends to the tide-level, with a depth of 60 feet and an east-to-west diameter at the top of 360 feet. A similar though shallower hollow occurs at the north-west side. Numerous minor depressions intervene. The material of these circular ridges is partly of local origin, and partly not. Plant them upon higher ground, and they would be called the reticulated portion of a kame. Many lakelets are but these depressions full of water.

These ridges have been found in two well defined series, as shown in Map 3, Plate VII. The westernmost or *Andover series* may be represented in Rockingham county by kames observed near the Manchester & Lawrence Railroad, north-west from Wilson's crossing in Londonderry, near West Derry station, and at a point a mile and a half farther south on the west side of the railroad; also near Goss pond in the south-east part of Londonderry, where there are bowl-shaped depressions, and thence southward to West Windham station on the Nashua & Rochester Railroad; also near a granite quarry a half mile west from Salem Depot.

In Massachusetts this series extends through Methuen, Lawrence, Andover, North Reading, Reading, Lynnfield, Wakefield, and Melrose, terminating near the south end of Prospect hill in Malden. It is continuous from Messer's crossing and Mystic pond in Methuen to the pumping-station of the Lawrence water-works, being well shown on the hillside south-east of the reservoir. On the low land near Spicket river these ridges show stratification; but higher up, as north-west of the Catholic cemetery, they are for the most part unstratified. Bowl-shaped depressions abound.

This series is finely developed near Andover, as shown in Maps 1 and 2, forming the banks of Pomp's, Foster's, and Martin's ponds. Numerous sections of these ridges show the central portion unstratified, the pebbles of large size being in and resting on the clay, loam, and unwashed sand; but sometimes we find stratified material under an unstratified mass, or pockets of partly stratified material in the unstratified.

In North Reading and Reading this series winds its way through extensive swamps, intersected by Ipswich river; in Wakefield much of its material has been removed by human agencies; in Melrose it is characterized by a plain with depressions. Its length in Massachusetts is about twenty-five miles.

The *Haverhill series* of kames is nearly parallel with the preceding, and about seven miles distant. It appears in the north-east part of Auburn, near Eaton's mills; in Chester, near Asa Wilson's; in Sandown, with extensive sandy plains and numerous ponds; and in East Hampstead, where the ridges are well defined, extending to the west side of Mt. Misery at the north line of Plaistow. A mile south-east from Mt. Misery the kames occupy a large area, and are thence continuous through Plaistow and the east part of Haverhill. They are well shown in Haverhill, near the old Whittier house; near the East Parish church; and near Burns's mill. At the Whittier house they seem to have been composed of coarse pebbles in contact with each other, sand having subsequently sifted into the interstices.

In Groveland they are partly covered with alluvium north of the depot. Rock pond in Georgetown is bordered by a spur of this series, and divisions of it extend south from both sides of Bald Pate hill. Wood pond and Four-mile pond in Boxford, Pritchard's pond in Ipswich and Topsfield, and Muddy pond, Cedar pond, and Wenham lake in Wenham and Beverly, are surrounded by these deposits, which extend nearly to Beverly Cove. This series is not less than forty miles in extent.

Between the southern portions of these series of kames an intermediate one appears in Map 3, running from Topsfield with some interruptions to the depressions, or "dungeons," which we have described in Marblehead. Near Danversport these kames are stratified, but farther north two or three fresh sections show no stratification.

Kames also occur in a series still farther to the east, though perhaps less closely connected with one another than the foregoing. They are well developed in the west part of Spruce swamp in Fremont, where one of these ridges is occupied by a road. Kames and bowl-shaped depressions border Great and Country ponds in Kingston. In the east part of Newton and the south-west corner of South Hampton a large area is covered by reticulated ridges, 20 to 60 feet in height, and containing boulders 2 to 4 feet in diameter. The long arm of Kimball pond in Amesbury is bordered on its northeast side by the continuation of this series, which is here a single ridge of ordinary gravel 20 to 40 feet high.

Modified Drift along the Sea-Coast.

The oldest and most prominent deposits of modified drift near our coast are kame-like hills, elevated plains, and broad ridges, composed of gravel, sand, and clay, the description of which is here continued from page 164. The gently-sloping hill on which Rye village is situated, nearly 100 feet above the sea, is mainly stratified gravel from 25 to 40 feet in depth. It is coarse for the first ten feet, with the largest pebbles a foot in diameter; below, it is fine, but has little clear sand.* Breakfast hill, about 150 feet above the sea, and the plain about 50 feet lower, which extends southward to the first railroad crossing in North Hampton, are composed of coarse gravel and sand. Thence similar deposits, 100 to 125 feet above the sea, extend in nearly level plains south-west to North Hampton village, forming the water-shed between Winnicut river and the ocean. They are bounded in many places by escarpments which descend steeply 25 to 50 feet; and a hollow, about an acre in extent and 50 feet deep, is half filled by Knowles pond. This formation continues southward with nearly the same height to Hampton village, where it terminates, falling in gentle slopes towards the sea.

Nine miles farther south, part of the city of Newburyport is built on a broadly rounded ridge of gravel and sand, which, like the foregoing deposits, probably had a similar origin with the narrow and steep ridges of the kames, having been bounded by portions of the melting ice-sheet. The series of kames noticed by Rev. Mr. Wright in Newton and Amesbury may be continuous south-east to the Newburyport ridge. So far as traced, this deposit appears first in the south part of Amesbury. It has been cut through by Merrimack river, and on its opposite side rises to a height of about 150 feet in Moulton's hill. A quarter of a mile farther to the south-east it is depressed to 75 feet, and shows the sharp ridges and knolls of typical kames. From this point it extends, with a nearly uniform height of about 100 feet, along High street to the middle of the city, and thence continues on the south-west side of this street to the Upper Green. Here it is interrupted for a little distance, beyond which it lies on the north-east side of this street, extending to within a half mile of Old Town hill. It is thus at least six miles long. No other high deposits of modified drift are found in this vicinity; and wide areas

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* The character of these deposits will be seen from the following sections of wells, 1 to 1½ miles south-west from Rye village, on the water-shed south of Berry's brook, and about 100 feet above the sea:

1. At J. Philbrick's (county map), said to be the deepest well in Rye, coarse gravel, 25 feet; sandy, gray clay, very compact, free from pebbles, 28 feet;—total depth, 53 feet. The only rock found in the clay was an angular block weighing about 200 pounds, 40 feet below the surface.

2. Near L. Brown's, coarse gravel, 8 feet; sand, 8 inches; coarse gravel, 6 feet; very coarse gravel, 10 feet, much of it composed of rounded rocks of nearly uniform size, about a foot in diameter, with scarcely any earth, so that "one could look down among the pebbles;" ordinary gravel, with layers of sand, 20 feet, resting on ledge;—total depth, 45 feet.

3. At R. Shapley's, coarse gravel, 10 feet; fine white sand, 15 feet, resting on till or ledge. Several other wells in this neighborbood, 30 to 40 feet in depth, encountered nothing but stratified gravel, sand, or clay.

of lowland lie on both sides. Excavations in the north-west part of the city show the ridge there to be composed mainly of water-worn gravel, with the largest pebbles about a foot in diameter. A railroad cut, known as March's hill, two miles farther south-east, has only occasional layers of gravel, with the largest pebbles six inches in diameter, very irregularly stratified with sand, which is here four fifths of the whole deposit. The depth of modified drift forming the ridge is shown by wells to be from 50 to 90 feet.

Portions of Seabrook and Salisbury are sandy plains, 25 to 50 feet above the sea. These are probably marine beds, deposited in a considerable depth of water, but they are not known to contain organic remains.

The most recent deposits of modified drift are the *beaches and salt marshes* bordering the ocean. Along much of our coast, at a distance varying from a quarter of a mile to one mile or more beyond the natural shore of hard land,—that is, of ledge, till, or ordinary modified drift,—we find a beach-ridge of quartzose sand, which becomes gravel or shingle near rocky shores. This ridge of loose material has been heaped up by the waves nearly to the highest point reached by them at high tide during storms; and when it is composed of sand, the wind piles it still higher in irregular hills, mounds, and ridges, which are constantly changing in form. The beach-ridge of Plum island, at the mouth of Merrimack river, is thus blown into dunes 50 feet high. On the side away from the sea, this formation slopes somewhat steeply to the solid bottom, 10 to 40 feet below the sea-level; towards the sea, it often slopes away very gently, with a wide area of hard sand between the lines of high and low tide. For a quarter of a mile out from these beaches the water is shallow, and the waves break upon shifting banks of sand.

The area from the beach to where the land rises above the reach of the sea is usually occupied by salt marsh, which has a level surface two or three feet below the highest tides. This is composed of fine, clayey mud, brought in and deposited by the tide, which cuts channels for its flow and ebb. None of our forest trees can endure salt water; and the marshes are left to a rank growth of the grasses and sedges peculiar to the sea-coast. On the south side of Long Island, and thence southward, the beach is frequently divided from the shore by extensive sounds or shallow bays, which are partly filled with salt marsh.

The shores of Rye and North Hampton are principally till or ledge, with frequent beaches and marshes of small extent. About forty rods south from the United States life-saving station and cable station, near Straw's Point, the stumps of a submerged forest are exposed at low tide on the north end of Jenness's beach. In July, 1877, more than seventy-five stumps could be counted here, the largest of them two feet in diameter and three feet high. Numerous specimens of the wood then obtained seemed to be all alike, and are pronounced by Mr. William F. Flint to be white cedar (*Cupressus thyoides*). Other stumps farther out projected above the water, and they are said to extend out to a depth five feet below the lowest tide. They have not been so well exposed for several years before this, and in 1874, when the cable was laid, they were not seen, being covered with sand. The most probable explanation here is that given by Mr. John L. Hayes,* who supposes that the forest grew at a higher level on the surface of a peaty swamp, which was protected from the sea by a beach. The beach has since been driven .inland, and the mud of the swamp has been washed away; but the trees were interlaced by their roots, and all sank together, so that they are now covered by the sea. Stumps occur in salt marshes near the head of Sagamore creek, on Little river, and in Hampton, probably where swamps have become more compact and settled within reach of the tide. If any change in the relative height of land and sea is now going forward on our coast, it would appear to be a very slow submergence of the land, not amounting to a foot in a hundred years.

Little and Great Boar's Head are bluffs of till, about 50 feet in height, which are being undermined by the waves. South from the latter point, a beach-ridge extends 15 miles, broken only by Hampton and Merrimack rivers, and bordered all the way on the west by a salt marsh, which averages a mile in width. The beaches of Hampton, Salisbury, and Plum island are on its east side. A large part of these deposits was probably carried out to sea by the Merrimack river, and then turned back by waves and tide.

It has been shown that the sea stood in the Champlain period 150 feet

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* Letter in Jackson's *Final Report on Geology of New Hampshire*, pp. 280 and 281. A valuable essay was published by Mr. Hayes in the *Boston Journal of Natural History*, vol. iv, 1844, on the "Probable Influence of Icebergs upon Drift."

higher than now, from which level it sank to its present height, or lower; but no well marked beach-ridges have been discovered inland.

Review of the Champlain and Terrace Periods in New Hampshire.

The *Champlain period* embraces the time occupied by the final melting of the great ice-sheet. At first its nearly level surface of pure ice lay above our highest mountain summits. As the melting advanced, it was moulded into basins and valleys, which, near the terminal front of the ice, coincided nearly with the contour of the land. At last the surface of the ice became covered with the abraded material which had been contained in its mass. A large part of this material was washed away by its streams, to be deposited in the modified forms of kames,* kame-like plains, and valley drift. Through the whole of every summer during

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* Since writing the first part of this chapter, I have learned that, as early as in 1872, Prof. N. H. Winchell, state geologist of Minnesota, had been led by his observations of kames in Ohio and Minnesota to an opinion respecting their formation similar to that presented in pp. 12–14, which, when first announced in August, 1876, was supposed to be entirely new. (See citations below, under *Ohio* and *Minnesota*.)

For the benefit of those who may be interested in this subject, and may wish to see descriptions of these deposits elsewhere, we append the following list of authors who have treated, more or less fully, of kames:

Canada. Principal J. W. Dawson, *Notes on the Post-Pliocene Geology of Canada*, 1872, pp. 26, 40, 107, and 112; *Acadian Geology*, 1868, pp. 82 and 324. *Geological Survey of Canada; Report of Progress for* 1870–71, p. 349 (Robert Bell); *do. for* 1875–76, pp. 262 (G. M. Dawson) and 340 (Robert Bell).

Maine. Prof. C. H. Hitchcock, *Agriculture and Geology of Maine*, 1861, pp. 271–274; *do.*, 1862, pp. 388–391. Prof. L. Agassiz, *Atlantic Monthly, vol. xix*, February, 1867, pp. 213–215.

New Hampshire. Dr. Edward Hitchcock, *Transactions of the Association of American Geologists and Naturalists*, 1840–42, p. 198, Plate viii; also, *Smithsonian Contributions, vol. ix*, 1857, pp. 36 and 45. Warren Upham, *Proceedings of American Association for Advancement of Science, vol. xxv*, 1876, pp. 216–225.

Vermont. Prof. C. H. Hitchcock, in *Geology of Vermont, vol. i*, 1861, pp. 95, 102, 150–152, and 190.

Massachusetts. Dr. Edward Hitchcock, *Geology of Massachusetts*, 1841, pp. 356 (Figs. 62 and 65) and 366–370; *Transactions of the Association of American Geologists and Naturalists*, 1840–42, pp. 190–203, and Plates viii and ix; and *Smithsonian Contributions, vol. ix*, 1857, p. 44 (lowest paragraph). Rev. George F. Wright, *Proceedings of Boston Society of Natural History, vol. xix*, 1876, pp. 47–63.

Connecticut. Prof. James D. Dana, *Transactions of the Connecticut Academy of Arts and Sciences, vol. ii*, 1870, pp. 70 and 71.

New York. *Geology of New York, Second District*, E. Emmons, 1842, pp. 186, 323, 333, and 364; *do., Third District*, L. Vanuxem, 1842, p. 247. In this and other states bordering the great lakes, ridges of sand and gravel are found, which must be distinguished from the kames, being apparently ancient beach-ridges, formed when these lakes were held at higher levels during the Champlain period. Their present outlet through the St. Lawrence valley was obstructed by the ice-sheet, which seems here to have retreated from south-west to north-east.

Ohio. Dr. J. S. Newberry, *Geology of Ohio, vol. ii*, 1874, pp. 7, and 41–46. Prof. N. H. Winchell, *Proceedings of American Association for Advancement of Science, vol. xxi*, 1872, p. 165.

Michigan. E. Desor, in Foster and Whitney's *Report on Geology of Lake Superior*, 1850, pp. 196 and 205; *do., part ii*, 1851, p. 258.

Minnesota. Prof. N. H. Winchell, *Geology of Minnesota, First Annual Report* (for 1872) p. 62, etc.; *Report for* 1873, p. 194, etc.

Ireland. G. H. Kinahan, *Geological Magazine, new series, vol. i*, 1864, pp. 34, 89, and 189; *do., Decade ii, vol. ii*, 1875, pp. 86 and 87.

Scotland. James Geikie, *Great Ice Age*, 1874, American edition, pp. 209–237; *do., second edition, revised*; London: 1877, pp. 210–252.

Sweden. James Geikie, *Great Ice Age*, 1874, American edition, pp. 357–367; *do., second edition, revised*, pp. 407–416.

the Champlain period, our rivers were swollen as we see them now in the floods of spring, but they were laden with far greater amounts of alluvium. The valleys were thus gradually filled with modified drift, which took the same slope with the descending current. In some instances (pp. 65, and 116–119) there is evidence that the ice-sheet in its departure was for some time a barrier, holding back lakes where there are now empty valleys, sloping to the north or west. If the principal lines of drainage throughout the state had been in these directions, such lakes must have been frequently formed during the retreat of the ice towards the north-west. With these exceptions, the deposition of our valley drift appears to have taken place in the same manner that additions are made to bottom-lands by high floods at the present day.

The modified drift, though extensive, constitutes only a part of the material which was contained in the ice-sheet. Probably more escaped erosion than was carried away by the glacial streams. When the ice was wholly melted, the part remaining fell upon the striated ledges and ground-moraine, being the loose upper till, with numerous angular boulders, which forms the surface generally throughout the state. Outcropping ledges, however, are frequent; and both the kames and valley drift rest upon the upper till.

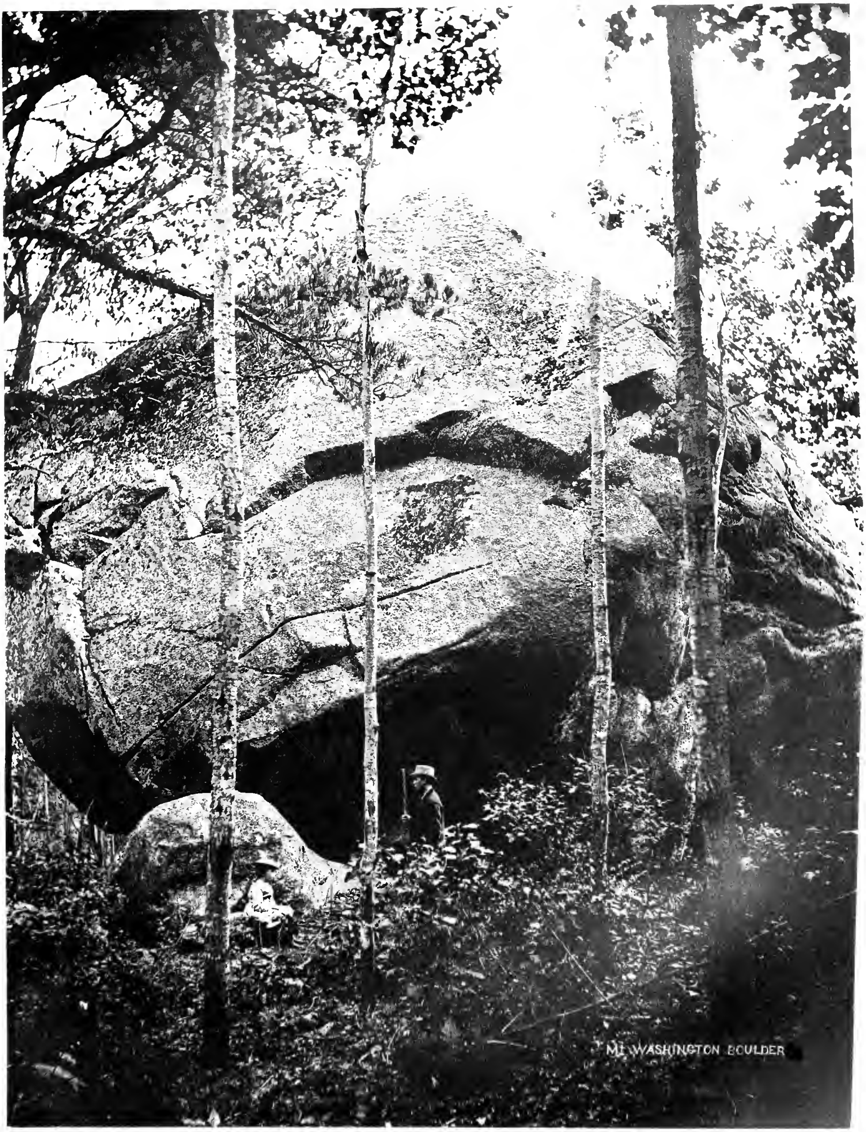
The modified drift deposits show that the ice retreated slowly, and with varying rates of progress (pp. 36, 39, 121, 122, and 149). Evidence of its reädvance has been found in only a few places, near the coast (pp. 163 and 164). The ice-sheet appears to have continued uninterruptedly through a very long period (pp. 7–9). Doubtless it resisted the influence of the warmer climate and changed conditions before which it disappeared, continuing late like the snow in spring. Its departure at the last was correspondingly rapid; and the hardier forms of vegetable and animal life were soon established near its retreating margin.

During the *recent or terrace period* the work of deposition by the streams has not been equal to that of erosion, and they have excavated deep and wide channels in the Champlain deposits (pp. 15 and 16). In this process terraces have been formed, sloping with the stream. Neither the deposition nor terracing of the modified drift requires any submergence, as by lakes or the sea. These deposits have the form which they must naturally take, in being rapidly brought into the valley by floods, and in afterwards being partly excavated by the rivers in the process of deepening their channels.

A table is added, showing the formations which have been described in this chapter, arranged in the order of their deposition, beginning with the oldest.

GLACIAL AND CHAMPLAIN DEPOSITS IN NEW HAMPSHIRE. (DRIFT, QUATERNARY, POST-PLIOCENE, PLEISTOCENE.)

	FORMATIONS, AND THEIR DISTRIBUTION.	SYNONYMS.	REMARKS.
	Lower till, p. 9, deposited during the glacial period, pp. 4–11; found throughout the state, p. 4; often accumulated within 25 miles from the coast, and rarely farther inland, in massive, oblong, rounded hills, 50 to 200 feet high, pp. 10 and 101.	Till; ground-moraine; glacial, unmodified, or unstratified drift; boulder-clay; hardpan.	Characterized, p. 9, by its glaciated stones, its dark and usually bluish color, and its compactness and hardness. Formed, pp. 5 and 9, by long continued wearing and grinding, beneath the moving ice-sheet; overlying rounded and striated ledges, pp. 4 and 5.
DEPOSITED DURING THE CHAMPLAIN PERIOD, p. 11.	*Intercalated clay and sand*, pp. 6, 17, and 18; about Winnipiseogee and Squam lakes, frequent, varying in thickness up to 30 feet, pp. 131–137; elsewhere, rare, pp. 108, 163, and 164.	The hypothesis of Mr. Jas. Croll, that an ice-sheet was accumulated and melted away several times during the glacial period, is considered in pp. 5-9.	In the Lake district, deposited where drainage was obstructed, in hollows melted under the margin of the departing ice-sheet, p. 137. Near the sea-coast, the Champlain period was interrupted by a reädvance of the ice, p. 163.
	Upper till, p. 10, found throughout the state, p. 4; thickness, usually less than 10 feet, but varying up to 20 feet or more.	By many writers not distinguished from lower till, both being included as till, glacial drift, or boulder-clay.	Characterized, p. 10, by its large angular boulders, its yellowish or reddish color, and the comparative looseness of its whole mass. Contained, with the modified drift, in the ice-sheet, and deposited when this melted.
	Kames, p. 12, found throughout the state, the extent of series varying up to 25 miles or more, and the height of ridges varying up to 250 feet. Connecticut series, pp. 43–48. Merrimack series, pp. 84–93. Ossipee series, pp. 144–149. Andover, Mass., series, pp. 167–170. Haverhill, Mass., series, p. 170.	Gravel ridges; horsebacks; moraine terraces; eskers, in Ireland; asar, in Sweden. A list of authors upon this subject is given in the foot-note on p. 174.	Deposited, pp. 13 and 14, by glacial rivers at the final melting of the ice-sheet, in channels formed upon the surface of the ice. When the bordering ice-walls and its separating ridges and masses disappeared, the gravel and sand remained in long, steep ridges, or in irregular short ridges and mounds, enclosing bowl-shaped depressions.
	Kame-like plains and broad ridges, pp. 17, 18, 155, and 156; found near the coast, about Dover, and southward to Newburyport, varying in thickness up to 100 feet, pp. 155-164, 170 and 171.	NOTE. The valley drift, kame-like plains and broad ridges, kames, and intercalated clay and sand, are all embraced under the title *modified drift*, which is defined at the top of p. 4.	Kame-like, in having been deposited, pp. 155 and 156, while the adjacent valleys and lowland were still occupied by portions of the departing ice-sheet.
	Valley drift (gravel, sand, blue and gray clay, sand), p. 15; in valleys throughout the state. A large part of these beds has been excavated by the rivers during the recent or terrace period, pp. 15, 16, 21, 27, and 82. The highest terraces are remnants of flood-plains which were annually overflowed at the end of the Champlain period, varying in height up to 200 feet above the present streams.	The blue and gray clay, pp. 94, 95, 153–155, and 158–161, are probably equivalent to the Champlain clay in Vermont, the Leda clay in Canada, and the Erie clay in the basin of the great lakes. Deltas, above the highest normal terrace, pp. 16, 29–31, 33, etc. Dunes, blown upward from the valley drift, pp. 17, 41, 73, and 147. See note in the next space above.	Brought down by glacial rivers from the melting ice-sheet, filling the valleys generally to the level of their highest terraces. This deposition and the subsequent formation of terraces required no submergence nor change in the height and slope of the land, pp. 15, 16, and 18. The height of the sea in the Champlain period was about 150 feet above its present level, as shown by marine shells, pp. 18, 165, and 166.


MT WASHINGTON BOULDER

CHAPTER II.

GLACIAL DRIFT.

ALLUSION has been already made to the former existence of an immense thickness of ice over the whole of New Hampshire, as well as the entire northern portion of our continent. This ice-sheet is supposed to have been the natural accumulation of frozen moisture from the atmosphere, requiring thousands of years' time for its gathering together. Like the similar glacial masses upon both poles of the earth, this one must have been slowly moving towards the equator, especially near the melting edge. A formal proof of our statement is unnecessary, since the phenomena presented to us universally over the state speak for themselves; and it will be difficult for any one to read an account of the striation and embossment of the ledges, about to be described, without believing in the existence of this sheet. As the subject is one of great interest, and sound generalizations can be drawn only from observations taken in every part of the state, much attention has been devoted to the collection of facts during the whole time of our survey. Such of these as are especially important will be named: hundreds of them will not be mentioned. Many facts belong to a class, and we need therefore describe with particularity only one example of them. Should the want of time and space prevent a full discussion of the causes inducing the cold climate, the method of transportation, the chronological date of the period, and other related topics, the reader will find an excellent summary of conclusions of this nature in the preceding chapter. Treatises have been written by several geologists upon these subjects, which can be consulted by those desiring further information. It is obvious that our first duty is, to state whatever facts have been observed, and then discuss the general bearings of the subject, if an opportunity is presented. It may be premised, however, that the glacial theory of the origin of the cold and of the dispersion of the materials seems to explain all the phenomena better than the older view of the agency of icebergs.

Any complete discussion of the phenomena must relate partly to the effects produced upon the ledges by the ice-movement, and partly to a description of the materials transported, their position, shape, size, amount, etc. We will first speak of the action upon the ledges. The ledges have been broken, rounded, or embossed, planed down, smoothed, and striated. The formation of pot-holes took place after the ice began to melt.

FRACTURED LEDGES.

Since the Helderberg period, the rocks of New England had been subjected to sub-aerial decomposition, whereby they were softened and rendered friable to great depths, often as low as the water level, or as much as a hundred feet. The change was mostly chemical, consisting of the removal of the alkalies, and the disappearance of lime and magnesia, by solution, the residue being clayey. Hence the ledges were in excellent condition for removal by the ice-sheet. Enormous quantities would be easily rubbed off, and then assorted by water. Besides the decomposed rocks, the ice removed perhaps as great a mass of the solid portions, which now constitute boulders and the pebbles of the till. Still, this ice action does not represent all the erosion that has taken place in our state, as may be proved by calculations of the mass that has been removed from the ledges to fill up gaps in the strata. It has been generally estimated that this amounts to as much as the average height of the land above the sea, or 1,200 feet in New Hampshire. The condition of the surface in the Southern states, in Brazil, and in certain sheltered spots in Minnesota and Massachusetts, as described by Hunt, Hartt, White, and others, illustrates the nature of the land surface with us, before the ice acted upon it.

In the earlier New England reports, several cases of ledges fractured by the drift have been described. Clay slate is very readily broken; and the simplest cases of fracture are those noticed in that rock, as in the quarries at Guilford and Northfield, Vt. Sometimes the fractures have been produced by the expansive force of freezing. Water, penetrating the seams, freezes, and thus, by expansion, wedges apart considerable masses. These, if on a precipice, fall to the base, and accumulate in large amount. Nearly every precipice in the state exhibits more or less of this work. It will be seen, also, in the flumes about the White Mountains, and has been described in Volume II, page 158.

The frontispiece of Volume I exhibits the condition of the ledges in a certain stage of decomposition, between the upper limit of trees and the snow line. Doubtless many square miles of surface were thus covered by angular blocks before the ice-movement commenced.

The most striking evidence of the action of ice breaking ledges is where the stone has been fractured by a lateral thrust. These are commonly seen about large quarries. A single example will suffice for many that have been observed. Fig. 49 is a sketch of this phenomenon at the Amoskeag granite quarry in Manchester. It is upon the north-west slope of a hill, in a position where it could be struck by the ice descending the Merrimack valley. The surface is smoothed and striated. For eight or ten feet in depth the granite is broken into irregular pieces, so that it cannot be used for underpinning. Beneath these pieces, the stone is sound at least to the depth of thirty feet, or as far as the excavation has proceeded. One can readily see the line between the broken and sound stone upon the east side of the quarry. That the fracture was occasioned by the ice-movement is proved by the fact of the smoothness of the surface fragments. The pieces can be taken out and matched together again, just like a pavement. Had they been fragments prior to the ice-action, they would have been moved away by it. The same phenomenon occurs, though less noticeably, at Bodwell's quarry, close by. If the ice had reäppeared in the Merrimack valley, these broken fragments would have been removed, and a new smoothed and striated surface would have been planed upon the solid granite.

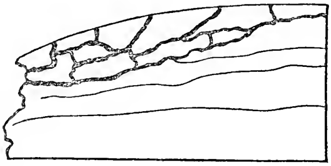


FIG. 49.

There is reason to believe that examples similar to the above exist by the hundred. They are not usually visible, except where excavations have been made.

PLANISHING AND EMBOSSMENT.

Should the earth be entirely removed from the ledges, the majority of them, save where subsequent erosion has obliterated the marks, would show upon their exposed sides a planing down and rounding. These ledges are not planed down flat, like a floor, but are rounded, retaining essentially their original forms. It is a common sight, when travelling along the deeper valleys, to observe, above the line of the modified drift, numerous rounded, dome-shaped ledges. A close scrutiny will disclose the fact that these have been worn the most upon the northern side, while the southern escarpment may be rough and uneven. Hence it is obvious from which direction the force proceeded which planed down the ledges. The sides most worn are those which have been struck. We often speak of the struck or *stoss* and the *lee* sides of these rounded ledges.

The embossed ledges are often grouped in considerable numbers, looking as if there were an assemblage of haystacks closely crowded together. Precisely similar phenonena occur in the glaciated region of the Alps, where De Saussure applied to them the name of *roches moutonnes.* An example of them, as seen in New Hampshire, is given in

FIG. 50.—EMBOSSED ROCKS ON MT. MONADNOCK.

Fig. 50. This represents an area of about five rods square on the southwest side of Mt. Monadnock. Here they occur near the summit of the mountain, not along the sides of a valley.

There are many examples of embossment in the state as good as these. I have noted a few of them: The top of Mt. Kearsarge; about the Lake of the Clouds, between Mts. Washington and Monroe, though the action of the frost is injuring their perfection; along the Pemigewasset valley in Woodstock; Baker's River valley, in the west part of Plymouth and the east part of Rumney,—also higher up, less perfectly; along the Northern Railroad, between Orange summit and Grafton Centre; Sanbornton, west of Cawley's pond. The Huronian and Cambrian slates of the Connecticut valley abound in fine examples of these rock domes. Others are specified in the column of remarks about striæ, further along. The narrow belt of rock in which the principal mica quarries are located, between Groton and Keene, is noticeable for the very fine embossment of the ledges all over its course. Granitic and calcareous rocks decompose readily; but the general form of the embossment will remain after the markings have been obliterated, so that a practical eye will recognize the fact of their glaciation.

Striation.

By far the most important effect of the ice-movement is the striation. All these domes and the worn sides of ledges exhibit lines more or less distinct, or passing into grooves which have been produced by hard rock fragments frozen into the bottom of the ice-sheet. As the mass moved along, these fragments acted as chisels or gouges, deeply scratching the ledges. It is obvious that the grooving instrument must have been harder than the rock affected; hence pieces of soft rocks, like limestone, would not leave any mark of their passage. These markings are often obliterated by disintegration, and it is difficult to find their direction. Several expedients may be resorted to: First, search for veins or projections of tough materials, upon which faint lines may possibly be found. These harder substances show the action, because they have successfully resisted disintegration. Again: it may be necessary to wet these projections, or the whole surface of a smoothed rock, in order to discover the direction of the striæ. Sometimes deep grooves may be found, which will indicate the course as well as scratches.

These markings vary from the finest scratches visible to deep furrows. They may be straight or curved, the latter where the abrading chip turned to one side, and was speedily crushed. Again: pieces of the rock may be chipped off, as if the chiselling fragment was not held down firmly to the ledge, but had a jarring motion. Then there are the lunoid furrows. Vose describes them upon the Green hills in Conway. Some seen on their northern slope have axes running about S. 40°–48° E., and are from one to four inches in diameter. A section of one is given in Fig. 51. It appears that the steep side, A, is always on the up-hill end of the furrow. Four others were noted at the south end of these same hills, upon a horizontal surface near the summit. They are figured in Fig. 52, are 11 inches long, 7 wide, and 4 deep, their direction being that of the dotted line, N. W. and S. E. These axes indicate the course of the ice-movement.

LUNOID FURROWS.

FIG. 51.

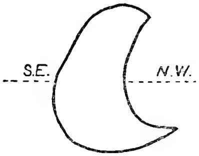


FIG. 52.

The origin of the lunoid furrow is given as follows by Dr. A. S. Packard, Jr., who observed several of them on a hill near Goodrich falls in Bartlett, with the course S. 17° W., also on Mt. Baldface: * "It is known that the glacier is in constant motion, advancing a few inches in summer, and then contracting in winter. Now imagine a stone frozen into the ice, and thus acting as a gouge. Pushed onward, and then withdrawn by the powerful hand of the ice-king, it soon wears this peculiar shaped hole, then turns out of the rut, and catches again in some inequality of the rock, and makes another lunoid furrow, or, perhaps, a series of four or five, often very regular in form, though the distance between them may vary."

The striæ in New Hampshire vary considerably in their direction. Before discussing the reasons for this variation, it will be proper to present a list of all the observations of their occurrence that have been recorded. They are all my own, except the few that are otherwise noted. I have carefully reduced the compass to true courses. I hope to present in the atlas a map showing these marks laid down with great care in connection with the relief features of the ground. A very few observations may be added for the adjoining territory, or what is included in our general map.

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* *American Naturalist*, vol. i, p. 265.

Courses of Striæ in New Hampshire.

LOCALITY.	ROCK.	TRUE COURSE.	REMARKS.
Pittsburg,—mouth of Indian stream	Slate	S. 58° E.	
1 mile S. E. from Back lake	Huronian	S. 58° E.	Numerous embossed ledges.
Outlet of Connecticut lake	"	S. 64° E.	
Saw-mill near do	"	S. 44° E.	
D. Merrill's	Whetstone grit	S. 44°-50° E.	Very distinct. J. H. Huntington.
Col. Huggins's	Diorite	S. 43° E.	" "
Mt. Carmel	"	S. 25° E.	Grooves. " "
Stewartstown,—mouth of Bishop's br.	Slate	S. 24° E.	
J. Brainerd's	"	S. 17° E.	Local glacier. J. H. Huntington.
South hill	Calc. mica schist.	S. 34° and S. 52° E.	Very distinct. " "
Clarksville,—M. Perry's	"	S. 34° E.	
S. W. corner, top of hill	"	S. 34° E.	
J. Gethercole's, "	"	S. 44° E.	
J. Keyser's	"	S. 44° E.	J. H. Huntington.
Colebrook,—J. S. Chase's	"	S. 38° E.	
Young's—east part	Huronian	S. 35° E.	
Dixville,—top of Dixville mountain	Mica schist	S. 54° E.	
Dalton,—near Sumner house	Huronian	S. 8° E.	
Copper mine	Clay slate	S. 2° W-S. 3° E.	
R. Miller's	"	S. 3° E.	
Monroe,—A. Mason's	Lisbon group	S. 2° E.	
East of Albee's house	Lyman group	S. 2° E.	Striæ abundant in North Monroe.
Top of hill, do	"	S. 2° E.	
G. Lang's	Lisbon group	S. 2. E.	Finely embossed ledges.
Top of Gardner's mountain	"	S. 12° E.	
Way's copper mine	"	S. 8° W.	
Top of Gardner's mountain	"	S. 12° E.	
Lyman,—No. 1 shaft, Paddock mine.	Lyman group	S. 6° W.	Deep grooves.
Land of Martin and Swett	Conglomerate	S. 2° E.	
Near do		"	
Hill back of Steery's house	Slate	"	
Dr. Brown's barn	"	"	
Near Bedell's house	"	S. 3° W.	
Near Bath line south from Dow's.	Conglomerate	S. 12° E.	Running up hill.
Hill opposite J. Williams's	Slate	S. 2° E.	
North of S. B. Presby's		S. 35° E.	Down small valley. Different from the usual direction in the neighborhood.
North of Young's pond		S. 8° W.	
Moulton hill	Lyman group	S. 8° W.	
Dan. Miner's	"	S. 2° E.	Diagonally up hill.
S. W. part of Parker & Young's.	"	S. 3° W.	
Stakes 17 P. to R. (vol. ii, p. 296).	Clay slate	S. 2° E.	Numerous and fine.
Near R-6	"	"	
U-14	Slate	S. 8° W.	
J-6	"	S. 2° E.	On vertical wall.
C-17	"	S. 12° E.	Up hill, athwart valley of Smith brook.
B and A-17	"	S. 2° E.	Top of hill.
H-21	"	"	
Littleton,—Mann's hill	Conway group	S. 12° E. and S. 7° E.	
A. Annis's	"	S. 2° E.	
R. Moore's, south of Cow brook.	Huronian	S. 4° W.	
Ridge between Cow and Parker brooks	"	S. 7° E.	
Near Dalton	"	S. 2° E.	
Farr hill, near fossils	Clay slate	S. 8° W.	
Milliken's saw-mill	Huronian	S. 2° E.	These striæ cross the Conn. valley.
East of G. Wheeler's—hill	"	S. 3° W.	
A. P. Hubbard's	Clay slate	S. 8° W.	
West side Fitch hill	"	S. 27° E.	
Haverhill,—Woodsville	Huronian	S. 2° E.	
Soapstone bed		S. 13° W.	
¼ mile N. W. from limestone	Gneiss	S. 21° E.	
Newbury, Vt.,—village	Huronian	S. 2° E. and S. 22° E.	The second set only a few stragglers.
Dam—Wells river. G. Leslie	"	S. 8° W.	
George Swasey's	"	S. 7° E.	
Errol,—S. E. part	"	S. 73° E.	Numerous. G. W. Hawes.
Carroll,—hill back of Twin mount'n	Bm. gneiss	S. 33° E.	
Lancaster,—near P. McLary's		S. 23° E.	
Ridge west of Mt. Pleasant	Quartz rock	S. 10° E.	Very distinct. J. H. Huntington.
Milan,—west part	Huronian	S. 42° E.	Magnificent.
Hodgdon hill	"	S. 42° E.	J. H. Huntington.
Lisbon,—near Mink pond	Coös schists	S. 18° W.	
Near poor-house (further east)	Gneiss	S. 18° W.	
Sugar hill, near Quimby's	Coös schists	S. 12° E.	

Courses of Striæ—Continued.

LOCALITY.	ROCK.	TRUE COURSE.	REMARKS.
Hill-top east of Bronson hill	Gneiss	S. 5° W.	
Hill south of Atwood mine	Huronian	S. 8° W.	
Between Streeter pond and N. Lisbon	Clay slate	S. 8° W.	
Jesseman's	Limestone	S. 2° E. and S. 28° E.	Two different localities, the same course.
Bethlehem,—west part, top of hill	Gneiss	S. 3° W.	
South slope of Mt. Agassiz	“	S. 3° W.	N. W. slope Agassiz range abundantly striated similar to this.
C. Kenney's and Quimby's	Gneiss	S. 28° E.	
Line of Bm., near iron works	Gneiss	S. 3° W.	Struck side very evident.
Mt. Agassiz—top	“	S. 8° W.	
¼ way up from toll-house	“	S. 12° E.	Up hill.
C. Huntoon's	“	S. 28° W.	
L. Blondin's	“	S. 4° W.	
Landaff,—high hill above J. Clough's.	Quartzite	S. 3° W.	
Bath,—I. Cooley's	Lyman group	“	
Top of Gardner mountain	Huronian	S. 12° E.	} Very fine.
West side	“	S. 3° W.	
Franconia,—R. Wallace's	Gneiss	S. 8° W.	
PRESIDENTIAL RANGE.			
White Mountains,—ridge N. E. of Mt. Madison	Montalban		Rock struck on north-west side.
Mt. Adams, west side—5500 feet high	“	S. 58° E.	According to W. G. Nowell.
Mt. Adams, smaller S. W. peak, south part	“	“	
Near gap between Adams and Jefferson	“	S. 33° E.	
Top of Mt. Washington	“	S. 43° E.	Smoothing distinct; striæ obscure.
200 ft. above Lake of the Clouds.	“	S. 30° E.	
Lake of the Clouds	“	S. 22° E. and S. 52° E.	Intersecting.
Between Pleasant and Franklin	“	S. 30° E.	
Between Pleasant and Clinton	“	“	
Near top of Clinton, north side	“	S. 47°–52° E.	Very distinct.
Clinton, south peak	“	S. 50° E.	
South end of Mt. Webster	“	S. 37° E.	
Top of Mt. Webster	“	S. 30° E.	Rock face; 200 by 40 feet exposed. N. E. clearly the side exposed.
Mt. Washington carriage-r'd,—lower end	Coös	S. 22° W.	Well defined example of the same on vertical walls.
2 miles up	“	“	Upon an easterly dipping slope of 30°.
2½ miles up	“	S. 8° W.	Intersecting; wall surface freshly uncovered.
5 miles up	“	S. 2° E. and	
Glen house	Montalban	S. 15° W.	
Do. ½ mile south	“	S. 3° W.	
Head of Tuckerman's ravine	“	S. 55° E.	Modern striæ made by falling stones.
Gorham,—about village	“	About S. E.	Stoss side points up valley.
Shelburne,—hill 150 ft. above R. R.	“	S. 88°–N. 87° E.	
Extreme north point of curve	“	S. 63° E.	
Clement's brook	“	S. 73° E.	
Near Maine line	“	S. 58° E.	
White Mountains			
Mt. Lafayette, above Eagle lakes.	Lake gneiss	S. 8° W.	Many large boulders above lakes.
Bald mountain	Porph. gneiss	S. 2° E.	Large boulder of B'm gneiss on top.
Mt. Field, side towards Mt. Willard	Granite	S. 37° E.	
Small local ones across preceding		N. 73° E.	
Mt. Field—top	Slate	S. 50° E.	
Mt. Willey—top	“	S. 42° E.	
Hart's mountain	Montalban	S. 52° E.	
Mt. Tom—N. E. side	Slate	S. 57° E.	Wall.
“ S. side	“	“	Down hill.
Mt. Pequawket—part way up	Granite	S. 45° E.	C. T. Jackson.
“	Slate	S. 40° E. and S. 60° W.	Intersecting. G. L. Vose.
“ ⅔ way from top to saddle between Pequawket and Bartlett mountain, 2500 feet high		S. 42° E.	
The “Notch,”—south side Mt. Willard and near railroad		S. 2° E.	Down valley.
On railroad south side of Willey brook	Slate	Southerly.	Down valley; seen both sides of track.
Top of Mt. Willard	“	S. 23° E.	
West side Sandwich notch near top	Gneiss	S. 70° E.	

Courses of Striæ—Continued.

LOCALITIES.	ROCK.	TRUE COURSE.	REMARKS.
Saco valley, below Bemis's	Gneiss	....	Wall; down valley; recently excavated by railroad.
Duck Pond stream	"	S. 18° E.	Wall inclined 45° W.
Ossipee mountain—Mt. Whittier—top	Granite	S. 47° E.	
Same—east side	"	S. 32°–S. 37° E.	Intersecting.
Bartlett,—N. E. part	Granite	S. 53° E.	G. L. Vose, in gap between Goodrich and "Sligo."
Hill adjoining Goodrich falls	"	S. 17° W.	A. S. Packard, Jr.
Jackson,—last house next Carter notch	Montalban	"	A few cross valley, S. 33° and S. 83° E., curving around a ledge.
Thorn mountain—top	"	S. 38° E.	A. S. Packard, Jr.
Mt. Baldface—top	Granite	S. 23°–28° E.	" "
Thorn mountain, depression on north side	Slates	S. 55° E.	G. L. Vose.
Cook's	Mica schist	....	Down valley.
Benton,—Mt. Moosilauke—top	"	S. 22° E.	
20 rods east of summit	"	S. 27°–32° E.	
Mt. Moosilauke, ¾ way up	"	S. 52° E.	Local or slide. (?)
Warren,—back of Merrill's, lower end of turnpike	Gneiss	S. 57° E.	Down tributary of Baker's river—local.
Berry brook	"	S. 37° E.	Down valley.
"	"	S. 22° E.	Grooves down the valley.
1 mile south of Kelley pond	"	S. 52° E.	Down valley; rather obscure.
North of I. H. Kelley's	"	S. 12° E.	
Wentworth,—near village	"	S. 22° E.	
Rumney,—West Rumney, north side of river	Mica schist	S. 37° E.	Wall 5 feet high.
Hill south-west of village	Mica schist	S. 35° E.	Very distinct. J. H. Huntington.
Lower down	"	S. 37° S. 42° S. 57° E.	Corresponding to bend of valley.
Baker's River valley	"	S. 52° E.	Wall.
1 mile east of village	Andalusite schist	S. 62° E.	
Up hill towards Groton	Montalban	S. 52° E.	
A. Kelley's	"	"	
E. Blodgett's	"	S. 57° E.	On wall 40 feet high; hill opposite high and precipitous.
Plymouth,—west line	"	S. 42° E. and S. 57° E.	
Village—W. edge R. Easter	Gneiss	S. 62° E.	
South side Plymouth mountain, ½ mile east of Hebron line	....	"	
Line of Hebron and Plymouth	Montalban	S. 22° E.	Down hill across valley.
Top of Wolf hill	Granite	S. 52° E.	
½ mile south of village	Ferrug. gneiss	S. 42° E.	Partly on wall.
Hebron,—summit near line of Plymouth	Montalban	S. 29° E.	
Hill east of Newfound lake	"	S. 22° E.	
North end " "	"	S. 37° E.	
West part	"	S. 33° E.	Acres of embossed ledges at north base of Kimball hill.
Groton,—Down valley, S. Groton	Porph. gneiss	S. 42° E.	
Just in town, 450 feet above railroad at Rumney	Montalban	S. 52° E.	
At M. V. B. Kinne's, height of land	"	S. 32° E.	
West part	....	S. 22° E.	
Summit between Groton and Orange	Gneiss	S. 32° E. S. 32° E.	J. H. Huntington.
I. D. Southwick's	"	S. 40° E.	
PEMIGEWASSET VALLEY.			
Mt. Pemigewasset, Lincoln	Granite	S. 12° E.	J. H. Huntington.
North Woodstock	Porph. gneiss	S. 22° E.	On vertical wall, with valley.
Woodstock post-office	Gneiss	S. 2° E.	Magnificent embossment of mountains.
Lower	"	S. 34° E.	
South part	....	S. 30° E.	
Thornton	....	S. 22° E.	
"	....	S. 27° E.	
"	....	S. 22° E.	
top of mountain south of Russell pond	....	S. 23° E.	Faces Pemigewasset river.
S. W. from H. Fifield's	....	S. 32° E.	
Near M. Sargent's	....	S. 22° E.	
" H. K. Hill	Porph. gneiss	S. 26° E.	
Towards Sandwich notch, three fourths mile from Mad river	Montalban	S. 70° E.	W. Upham.
1 mile S.E. from West Thornton	....	S. 15° E.	
West Campton	Porph. gneiss	S. 22° E.	
Campton north line, in river	"	S. 27° E.	
Holderness,—Mt. Prospect—summit	"	S. 37° E.	
" W. side	"	S. 35° E.	

Courses of Striæ—Continued.

LOCALITIES.	ROCK.	TRUE COURSE.	REMARKS.
Shepard's hill	Porph. gneiss	S. 62° E.	
Squam mountain—top	"	"	
Ashland,—near depot	"	S. 42° E.	
Village turn to lake, hill road	Ferrug. schist	S. 32° E.	
Waterville slide	Labradorite	N. 32° W.	Perhaps made in 1869.
Sandwich,—W. of vil., J. Goodwin's.	Gneiss	N. 78° E.	
M. Bean's	"	N. 83° E.	
West line	"	S. 82° E.	Down a valley depression.
N. E. corner of Squam lake	"	N. 85° E.	
North foot of Red hill	Sienite	N. 80° E.	
S. Dinsmore's	Gneiss	N. 78° & 83° E.	
At notch	"	S. 60° E.	Two places. W. Upham.
¼ mile north of Dinsmore pond.	"	East.	W. Upham.
Moultonborough,—near S. E. town line	"	S. 55° E.	
H. Smith's	"	S. 57° E.	
Red hill, near summit	"	S. 62° E.	
D. Vickery's	"	S. 72° E.	Obscure.
Center Harbor,—west of landing—Mrs. Sutton's	Lake gneiss	S. 72° E.	
Middle of township	"	S. 42° E.	
Common all through township	"	"	
Near M. Wade's, promontory of Squam lake	"	S. 57° E.	
West of Bear pond	"	S. 42° E.	
Tuftonborough,—"Corner"	Ferrug. schist	N. 68° E.	
Near Melvin hill	Gneiss	S. 25° E.	
Below Melvin village	"	S. 27° E.	Two last on hills west of Lower Beech pond.
2 miles south of "Corner"	"	N. 80° E.	
½ mile south of last	"	E.	
Wolfeborough,—west side of Trask hill (G. M. Garland's)	Lake gneiss	S. 85° E.	Rather obscure.
Top of Trask hill	"	S. 50° E.	
1 mile N. E. of Wolfeborough Centre (E. of L. Shotridge's).	"	S. 40° E. & E.	
Porcupine ledge	Quartz	S. 60° E.	
N. W. Tibbetts's	"	"	
R. H. Piper's, north side of Mt. Delight	"	S. 65° E. S. 50° E.	
Tumble-down Dick	"	S. 65° E.	
Brookfield,—north of Tumble-down Dick	"	S. 65° E.	
North corner of town	"	S. 55° E.	
2 miles south of last	"	S. 70° E.	
J. Perkins's	Mica schist	S. 52° E.	
D. F. Stoddard's	Gneiss	S. 72° E.	
Top of Moose mountain	Granite	S. 32° E.	
200 feet lower	"	S. 42° E.	
Wakefield,—L. C. Perry's	Gneiss	S. 52° E.	
South of Sanborn's, junction	"	S. 57° E.	
Top of hill near J. Copp's	"	S. 37° E.	
North of S. Cook's—high land	"	S. 57° E.	
Three Tibbetts' houses	"	S. 72° E.	
	....	S. 52° E.	
Near East pond	Mica schist	S. 42° E.	
Ossipee,—East of Leighton's corner.	"	S. 22° E.	
Hill south of I. L. Sanders's	"	S. 42° E.	
Freedom,—Small hill west of village.	Montalban	....	Towards village of Freedom.
E. Woods's	"	S. 22° E.	
Madison,—J. L. Frost's, near village.	"	S. 2°. E. x S. 22° E.	
R. Brown's, north of village	"	S. 12° W.	
1 mile west of Silver lake	"	S. 7° W.	
Gline mountain (road over)	"	S.	Excellent; broad floors.
Eaton,—hill, north-east corner	"	S. 30 E.	
Tamworth,—Chatham hill, near top.	"	S. 42° E.	
South of Chocorua house	"	S. 18° W.	G. L. Vose.
Top first rise towards Mt. Chocorua	"	S. 27° E.	"
Top of second do	"	S. 7° E.	
Side of Mt. Chocorua	"	S. 42° E.	C. T. Jackson.
Meredith Neck,—Rollins hill	Mica schist	"	Summit is one large embossment 30 feet long, 10 feet high, and 10 feet wide.
Advent church on Neck	Gneiss	"	
2 ms. N. of M. village—summit	"	"	5° less easterly 50 ft. below the summit.
East of Long pond	"	S. 37° E.	
East line, next Center Harbor	"	S. 40° E.	
Centre—hill to the south	"	S. 27° E.	
Village	"	S. 42° E.	

Courses of Striæ—Continued.

LOCALITIES.	ROCK.	TRUE COURSE.	REMARKS.
New Hampton,—N. W. part, clay deposit	Andalusite schist.	S. 37° E.	
Harper's hill	Porph. gneiss....	S. 52° E.	Plain, and running up hill.
Centre	“	S. 42° E.	Abundant ; embossed ledges numerous
Edge, next Meredith	“	S. 52° E.	
Beyond	....	S. 37° E.	Course with valley.
West edge of N. H. village	Gneiss	S. 57° E.	
North side Burleigh mountain	Montalban	S. 32° E.	Down valley ; many emb. ledges here.
North side White Oak hill	“	S. 37° E.	“ “ “
Laconia,—	“	S. 27° E.	
Dr. J. L. Perley's	“	about S. 27° E.	
Mrs. M. Gale's, top of hill	“	S. 14° E.	
Gilford,—near Weirs	Porph. gneiss....	S. 35° E.	
H. Hunt's	Ferrug. schist....	S. 37° E.	
E. of Lake Village—M. C. Dexter's	“	S. 42° E.	
Hill south of L. Gove's	Mica schist......	S. 35° E.	
Gilmanton line	“	S. 32° E.	
Top of Mt. Gunstock	Trap dyke......	S. 62° E.	A single scratch
Marks's island, Winn. lake	Gneiss	S. 42° E.	
Sanbornton,—Back of Sanbort'n Sq., 1 mile to the north-west	Mica schist......	S. 22° E.	
North part—T. B. French's	“	S. 24° E.	
Ridge in north part	“	S. 42° E.	
Further south	“	S. 32° E.	
“Gulf”	“	S. 22° E.	Two places. W. Upham.
Road west of Hopkinson hill	“	S. 15° E.	“
1 mile north “ “	“	S. 35° E.	
Belmont,—B. Chase's	“	S. 32° E.	
Line of B. & G	“	“	
K. Hall's	“	S. 42° E.	
Gilmanton,—hotel	“	“	
South-east from hotel	“	S. 52° E.	
C. Gilman's	“	S. 42° E.	
Lower Gilmanton village	“	“	
I. P. Hill's	“	S. 52° E.	
North-west part of town	“	S. 32° E.	Grooves.
C. A. Hackett's	“	S. 36° E.	
East part, top of hill	“	S. 47° E.	
Tannery, south edge of town	“	S. 42° E.	
North-east part	“	“	
Hall's hill, south-east part	Gneiss	S. 52° E.	
2 miles east of Peaked hill	....	S. 45° E.	W. Upham.
Tilton,—near village	....	S. 14° E.	
Alton,—east line	Montalban	S. 42° E.	
D. & J. Varney's	“	S. 37° E.	
J. Morrison's, west of lake	“	S. 42° E.	Also a few straggling to S.; all up hill.
N. S. Straw's	Gneiss	S. 57° E.	
W. of L. S. Nute's, top of ridge.	“	S. 52° E.	
H. Hunt's, north-east part	“	S. 17° E.	
New Durham,—B. F. Sawyer's and J. B. Burnham's	Montalban	S. 42° E.	
West part	“	“	
Brook in east part	“	S. 52° E.	
G. D. Savage's	“	“	
W. H. Tush's	“	“	Unusually fine.
“Ridge”	“	S. 67° E.	
Church on ridge and ¼ m. west.	“	S. E.	W. Upham.
Barnstead,—S. W. Young's	Gneiss	S. 52° E.	
Clark's corner	“	“	
Strafford,—Corner	Mica schist......	S. 72° E.	Obscure.
S. Young's	“	S. 52° E.	
Ridge north	“	S. 57° E.	
Top of ridge, north-west part	“	S. 42° E.	
South of D. Marsh's	“	S. 32° E.	
North end of Bow lake	Gneiss	S. 58° W.	
1 mile north	“	S. 31° W.	
2 or 3 miles north-east, in Paul Tasker's pasture	Quartz..........	S. 35° E.	
North-west corner	Mica schist......	“	
East of Isinglass river	“	S. 62° E.	
G. W. Foss's	“	“	
A. W. F	“	S. 35° E.	
½ mile S. W. from south corner.	“	S. 40° E.	Two places. W. Upham.
1 “ “ “	“	“	“
Farmington,—west side Hussey mt.	“	S. 52° E.	
O. K. Otis's	“	“	
South Farmington	“	S. 42° E.	

Courses of Striæ—Continued.

LOCALITIES.	ROCK.	TRUE COURSE.	REMARKS.
Milton,—top of Teneriffe mountain..	Mica schist......	S. 42° E.	Grooves seen 50 feet long.
N. H. Roberts's................	"	"	
Rochester,—north-west from village.	Andalusite schist.	....	Abundant; not measured.
2 miles south..................	"	S. 24° E.	
J. F. Young's....	Mica schist.... .	S. 27° E.	
Barrington,—Wheeler Foss's........	"	S. 42° E.	
Rollinsford,—E. S. Clement's.......	"	S. 12° E.	
Durham,—W. P. Sherburne's	"	S. 37° E.	
West of J. W. E. Thompson's...	"	S. 52° E.	
North-west part	Sienite..........	S. 57° E.	
Lee,—school-house No. 1............	Mica schist......	S. 42° E.	
Northwood,—centre	Montalban	S. 37° E.	
Top of Saddleback mountain....	"	S. 32° E.	Grooves.
Pittsfield,—Catamount hill—top.....	Mica schist......	S. 42° E.	
Chichester,—1 mile south-east from Kelley's corner..............	....	S. 20° E.	W. Upham.
Deerfield,—hill-top near J. Chase's..	Merrim'ck schist.	S. 40° E.	
Middle part	Gneiss	"	
North side of Pawtuckaway.....	"	S. 72° E.	
Epsom,—east line	"	S. 36° E.	
Canterbury,—south edge............	Montalban	S. 16° E.	
Further north..................	"	S. 20° E.	
Soapstone quarry..............	Soapstone.......	S. 26° E.	
1 mile N. E. from North Concord station........................	....	S. 15° E.	W. Upham.
1½ m. S. from Canterbury centre.	....	S. 25° E.	"
¼ m. N. of Crane Neck pond...	....	S. 40° E.	"
1 m. N. W. from Shaker Village.	....	S. 30° E.	"
Franklin,—west part of village.......	Montalban	S. 17° E.	
H. George's	"	S. 32° E.	
North of village................	"	S. 27° E.	
Near Hill	"	S. 42° E.	Bends with Merrimack valley.
Near north-east edge	"	S. 22° E.	Down a valley.
South-west corner	"	S. 42° E.	
1 mile north-east from falls......	"	S. 15° E.	W. Upham.
Hill,—near church	"	S. 22° E.	
Andover,—near centre.............	"	S. 62° E.	
Potter Place	"	S. 67° E.	
Top of hill south of centre village.	"	S. 38° E.	Also south-east on a wall, and down hill to the south.
Near J. Farnum's—high hill	"	S. 57° E.	
Salisbury,—S. part, top Bean's hill..	Porph. gneiss....	S. 22° E.	
South village	Montalban......	S. 12° E.	
J. S. Morrill's.................	"	S. 15° E.	
Boscawen,—near village	"	S. 27° E.	
Back of Fisherville.............	"	S. 17° E.	
Kearsarge mountain,—top	Andalusite schist.	S. 46°-51° E.	Remarkably fine.
Top of clearing, north-west side.	"	S. 36° E.	All the way up the mountain.
Above Winslow house..........	"	"	
At " "	"	"	
½ mile north of Winslow house..	"	S. 41° E.	
North side.....................	"	S. 76° E.	
....	"	S. 46° E.	
South side of "White house"....	"	S. 71° E.	
Toll-gate of turnpike..........	"	S. 51° E.	
West side, in Sutton...........	"	S. 11° E.	
Ragged mountain, Andover, top.....	"	S. 23° E.	
....	"	S. 36° E.	
....	"	"	
....		S. 56° E.	
Monadnock mountain.			
East edge of Jaffrey............	Mica schist......	S. 11° E.	
Jaffrey............................	"	"	
A. Baker's S. W. corner of Jaffrey.........................	Andalusite gro'p.	S. 31° E.	
Monadnock house	"	S. 46° E.	Also S. 75° E., or perhaps N. 75° W.; local.
East and south-east sides of top..	"	S. 21° E.	
South-east side, local sliding	"	S. 56° E.	
Top....	"	S. 21° E.	
South-west of top..............	"	S. 51° E.	
Somewhat lower down..	"	S. 61° E.	
Still lower	"	S. 51° E.	Slope to south.
New London,—near south line......	Gneiss	S. 31° E.	
George's mills.................	"	S. 46° E.	
Sutton,—south part................	Porph. gneiss....	S. 59° W. and S. 11° E.	
Mills..........................	"	S. 11° E.	
Nelson hill	"	S. 28° E.	
Newbury,—E. Nelson's.............	"	S. 11° E.	

Courses of Striæ—Continued.

LOCALITY.	ROCK.	TRUE COURSE.	REMARKS.
Bradford,—Baptist church	Porph. gneiss	S. 25° E.	
North-east corner	Gneiss	"	W. Upham.
"Joppa"	"	S. 25° and S. 20° E.	C. T. Jackson.
Warner,—south side of Mink hills	Porph. gneiss	S. 26° E.	
South of Levi Bartlett's	Gneiss	S. 21° E.	
Concord,—south foot of Horse hill	Montalban	S. 9° E.	
Mast Yard	"	S. 11° E.	
South of Rattlesnake hill	Granite	S. 21° E.	
Phenix quarry	"	S. 11° E.	
½ mile north of Snow's pond		S. 17° E.	W. Upham.
London,—1 mile N. E. from village		S. 15° E.	"
½ mile south-east from "Ridge"		S. 25° E.	"
North-east corner		S. 40° E.	"
Hopkinton,—east part	Ferrug. schist	S. 10° E.	
Henniker,—village	Gneiss	S. 11° E.	
Dunbarton,—Wedge—hill-top	Lake gneiss	S. 21° E.	
School-house east of Kimball pond and further east—high	Montalban	"	
S. H. Woodbury's	"	S. 10° E.	W. Upham.
Bow,—school-house, south corner	"	S. 38° E.	
S. H & J. H. Bartlett's	"	S. 21° E.	
L. White's	"	S. 38° E.	A downward slope.
Hooksett,—near village	Gneiss	S. 26° E.	
Back from village	"	S. 18° E.	
Campbell's hill	Quartzite	S. 21° E.	
1½ miles west Merrimack S. pt.	Gneiss	"	
Manchester line, E. side of river.	"	S. 16° E.	
Rowe's old station	"	S. 41° E.	
Manchester,—fair ground	"	S. 26° E.	
South-east part	"	S. 15° E.	
Methodist church, Hallsville	"	S. 16° E.	
Amoskeag quarry	Granite	"	
" " local	Mica schist	N. 40° W.	
Same neighborhood	Gneiss	S. 41° E.	
Bridge, Hanover street crossing.	"	S. 26° E.	
Outlet of Massabesic lake	"	S. 21° E.	
Candia,—top of hill, west part, J. Emerson's	"	S. 31° E.	
Store, H. M. Eaton's	"	S. 26° E.	
East line	"	S. 36° E.	
Patten's hill	"	S. 21° E.	
Raymond,—2 miles north of railroad (hill)	Mica schist	S. 28° E.	
Abbott & Smith's, further north.	"	S. 41° E.	Exposed 40 feet long.
Flint hill	Quartzite	S. 36° E.	
North of, at B. Dearborn's	Mica schist	S. 31° E.	
South part	"	S. 51° E.	
North of village	"	S. 31° E.	
Hill west of Flint	"	S. 41° E.	
W. Titcomb's	"	S. 26° E.	
Epping,—D. Kennard's	"	S. 28° E.	
North line	"	S. 21° E.	
A. Randlett's	"	S. 31° E.	
East of H. Bly's	"	S. 31° E.	
Nottingham	"	S. 31° E.	
West side of square, same hill	"	S. 56° E.	
¼ mile north-west from square	"	S. 20° E.	W. Upham.
¼ mile south-east from square	"	S. 20° E.	"
East of hotel	"	S. 31° x 41° x 46° E.	Intersecting.
Fremont,—B. Poor's	Gneiss	S. 31° E.	
I. Sanborn's	"	S. 36° E.	
Exeter,—south-west of village brook.	Merrima'k schist.	S. 52° E.	This is usually covered by water.
E. C. Sanborn's	Sienite	S. 24° E.	
Stratham,—near B. Howe's	Merrima'k schist.	S. 27° x 47° E.	Intersecting.
Greenland,—north of church	"	S. 27° E.	
Portsmouth,—powder magazine	"	S. 12° E.	
¼ mile west of Newcastle bridge (south end of town)	"	S. 37° E.	
School-house, N. part of houses (¼ mile from depot)	"	S. 32° E.	
Rye,—Sagamore house	"	S. 52° E.	At ocean level.
South of Sagamore river	"	S. 35° E.	
Hampton,—west part	"	S. 42° E.	
Seabrook,—north part of village	"	S. 52° E.	Same seen obscurely near post-office.
Newton,—N. Gould's	"	S. 32° E.	
Atkinson,—D. Noyes's	"	S. 42° E.	
South Kingston,—D. Collins's	Granite	S. 22° E.	

Courses of Striæ—Continued.

LOCALITIES.	ROCK.	TRUE COURSE.	REMARKS.
Danville,—Wm. Bagley's	Merrima'k schist.	S. 32° E.	
Hampstead,—J. E. Emerson's	“	S. 47° E.	
Salem,—village	Gneiss	S. 22° E.	
Granite quarry	“	S. 22° x 72° E.	Intersecting; the first the most common direction.
School-house	“	S. 32° E.	
Derry,—north part	Mica schist	S. 22° E.	
Below hotel	“	S. 24° E.	
South part	“	S. 22° E.	
Chester,—W. S. True's	“	S. 51° E.	
H. Hazeltine's, hill-top	Gneiss	S. 31° E.	
C. Chase's	Mica schist	S. 29° E.	Abundant.
Auburn,—west of village	Gneiss	S. 26° E.	
D. Ball's	Mica schist	S. 21° E.	
Pelham,—near west line	Gneiss	S. 21° E.	
Londonderry,—Mammoth road, N. part	Mica schist	S. 21° x 41° E.	Intersecting.
North-west part	“	S. 21° E.	
“	“	S. 11° E.	
Hudson,—Mrs. Barrett's, east part	Gneiss	S. 3° E. x S. 21° x 36° E.	Intersecting.
Nashua,—Merrimack river bridge	Merrima'k schist.	S. 11° E.	
Reservoir	“	S. 11° E.	
Merrimack,—Souhegan village	Gneiss	S. 16. E.	
Amherst	“	S. 14° E.	
Goffstown,—Centre	Granite	S. 21° E.	
N.E. part, near G. B. Blaisdell's		S. 20° E.	W. Upham.
New Boston	Gneiss	S. 23° E.	
West edge	“	S. 11° E.	
North of Joe English hill	“	S. 16° E.	
D. Todd's	“	S. 11° E.	
Near Leach's	“	S. 9° E.	
Francestown,—north-west part	“	S. 21° E.	
Weare,—top of Mt. Misery	Andalusite schist.	S. 16° E.	
50 feet down east side	“	S. 21° E.	
Two places at south base of do.	“	“	
Hodgdon's soapstone quarry		S. 31° E. x S.	Intersecting; the first course the most common.
⅔ mile south-east of So. Weare church—A. L. Hadley's		S. 10° E.	W. Upham.
Deering,—north-west part	Gneiss	S 19° E.	
West of village	“	S. 31° E.	
Hillsborough,—near north line	Porph. gneiss	S. 26° E.	
Antrim,—west part	“		Fine example; moved up hill in North Branch valley.
Peterborough		S. 16° E.	
J. Mace's, 3 miles east of village		S. 10° E.	W. Upham.
Lyndeborough,—near “hard” drift.	Mica schist	S. 41° E.	Both wall and floor surfaces striated.
Wilton,—north-east corner	Gneiss	S. 21° E.	
West Wilton	“	S. 31° E.	
Temple,—top of Temple mountain	Mica schist	S. 16° E.	
North of hotel	Quartzite	South.	
Mason,—north-east corner	“	S. 36° E.	
West of centre	Gneiss	S. 11° E.	Polished smooth.
Centre village	“	South.	
New Ipswich	Mica schist	S. 11° E.	
South end of Kidder mountain	“	S. 36° E.	
Barrett Mountain range, near W. Shattuck's	“	S. 16° E.	
W. Young's	“	S. 33° E.	
1 mile east of Wilder village	“	S. 25° E.	W. Upham.
Sharon		S. 21° E.	
Nelson,—¼ mile south of Munsonville	Gneiss	S. 20° E.	W. Upham.
Sullivan,—south-west corner	“	S. 30° E.	“
Marlborough,—⅔ mile west of Pottersville	“	S. 15° E.	“
D. Field's, 2 miles east of depot.	“	“	“
Troy,—village	Montalban	S. 21° E.	
Generally	“	S. 18°-25° E.	C. T. Jackson.
Surry,—Bald hill	“	S. 23° E.	
Gilsum,—near village	“	S. 21° E.	
Marlow,—3 miles north of village	Gneiss	S. 10° E.	W. Upham.
⅔ mile south of do.	“	“	“
Stoddard,—west line	“	S. 21° E.	
Near village	“	S. 16° E.	
East line	“	S. 21° E.	
1 mile west of village	“	S. 25° E.	W. Upham.
1½ miles west of Centre pond	“	S. 15° E.	“
1 mile south of last		S. 15° E.	“
South-west corner		S. 20° E.	“

Courses of Striæ—Continued.

LOCALITIES.	ROCK.	TRUE COURSE.	REMARKS.
Harrisville	Gneiss	S. 28° E.	
Dublin,—generally	Porph. gneiss	S. 27° E.	C. T. Jackson.
1 mile N.W. of Monadnock lake.		S. 50° E.	W. Upham.
¼ mile south-east of W. Spalding's		S. 50°-60° E.	“
Keene,—north edge	Gneiss	S. 15° E.	
Hill west of village—West mt		S. 20° E.	
West Keene, top of hill—Connecticut river water-shed		S. 15° E.	
Chesterfield,—Bear hill	Mica schist	S. 10° W.	
1 mile south of Factory village		S. 10° E.	W. Upham.
1 mile east of Centre	Mica schist	S. 20° W.	“
North of T. A. Stoddard's	“	S. 10° W.	“
Winchester,—4 miles N. N. W. from village	Porph. gneiss	S. 5° E.	“
Westmoreland,—“Hill” village	Mica schist	S. 5° W.	“
⅔ mile east of E. W. depot	Gneiss	S. 10° E.	“
Walpole,—½ mile south-east of S. H. No. 13		S. 15° E.	“
2 miles east of village	Mica schist	S. 15° W.	“
Alstead,—1 mile north of E. Alstead.		S. 10° E.	“
Hinsdale and neighborhood	Gneiss	S. 10° W.	
Depot	Mica schist	S. 10° E. x S. 60° E.	Intersecting.
North-west base of Stony mt	Mica schist	S. 2° E.	C. T. Jackson.
Richmond,—east part	Gneiss	S. 25° E.	
Soapstone bed		South.	
Fitzwilliam,—1 mile east of village	Gneiss	S. 20° E.	
Quarry hill, south of depot	Granite	S. 10° E.	Up hill.
Rindge,—East Rindge		S. 15° E.	W. Upham.
Washington,—north part	Porph. gneiss	S. 21° x 41° E.	Intersecting.
Lovell's mountain—top	“	S. 36° E.	End of ledge embossed.
1 mile south of Miller pond	Gneiss	S. 30° E.	W. Upham.
South of Ashuelot pond	“	“	“
West “ “	Porph. gneiss	S. 25° E.	“
Lempster,—Lempster mount'in—top.	Mica schist	S. 41° E.	Uncommonly fine.
West side do	“	S. 21° E.	
Acworth,—village	“	S. 8° E.	The same 1 mile west.
Charlestown,—village	Coös schists	South.	
East part	“	S. 11° E.	
Near north-west Acworth		S. 5° E.	W. Upham.
Unity,—south of Neal mine	Mica schist	S. 51° E.	
Centre	Gneiss	S. 10° E.	W. Upham.
East Unity	“	“	“
Claremont,—aqueduct, north slope of Bible hill	Slate	S. 17° E.	
Top of Bible hill	“	S. 6° E.	Noticed more fully in text.
Below top	“	S. 1° W.-S. 57° E.	
Most common about village	“	S. 41° E.	
1 mile south-east from Claremont village		S. 25° E.	W. Upham.
¼ mile north do		S. 15° E.	“
Barber mountain, south-west side, near J. Woodell's	Huronian	S. 12° W.	
Barber mountain—top	“	S. 16° W.	
A. Brown's, W. Clark's, and south of N. Stone's	Mica schist	S. 12° W.	
S. Nott's		S. 23° E.	
East of S. Nott's		S. 13° E. x S. 47° E.	Intersecting, and irregular below.
L. Farnsworth's		S. 11° E. x S. 76° E.	Intersecting; first cut by second.
West of C. Dean's		S. 46° E.	
Cornish,—west flank of Croydon mountain—Hilliard's	Slate	S. 19° E.	
4 miles south-west from “Flat”		S. 20° E.	W. Upham.
Goshen,—south part	Gneiss	S. 21° E.	
Croydon,—south end of Croydon mountain	Coös schists	S. 31° E.	Boulders in a line, S. 40° E.
Plainfield,—north end Croydon mt		S. 20° E.	W. Upham.
Grantham,—½ mile south-east from last		S. 30° E.	“
New London,—east end of Otter pond	Gneiss	S. 30° E.	“
1 mile east of do	“	S. 40° E.	“
Springfield,—Mud pond	Gneiss	S. 51° E.	Very fine.
J. Currier's—ridge	“	S. 21° E.	Numerous.

Courses of Striæ—Continued.

LOCALITIES.	ROCK.	TRUE COURSE.	REMARKS.
Ridge	Gneiss	S. 29° E.	
1½ miles north-west of West Springfield	"	S. 6° E.	
Station pond	"	S. 37° E.	
South line next George's mill	Andalusite schist.	S. 31° E.	
A. Melvin's	Gneiss	S. 26° E.	Top of hill near, S. 20° E., on quartz veins beautifully smooth.
Grafton,	"	S. 25° E.	
Mica quarry—Ruggles's	Mica schist	S. 31° E.	
Miners' house—Ruggles's	"	S. 21° E.	
Hill north	"	S. 31° E.	
Outlet of Tewsbury pond	"	S. 31° E.	Uncommonly fine embossment; valley movement.
North end of do	"	S. 36° E.	
Melvin's mica quarry	"	S. 34° E.	
Grafton,—school-house No. 3	Gneiss	S. 31° E.	
C. Prescott's—hill-top	"	S. 41° E.	Observed in two places.
Hill west of Prescott's	"	S. 46° E.	
V. W. Powell's, west side of hill.	"	S. 31° E.	Transversely up hill.
Near top of Alger hill	Granite	S. 41° E.	
Giles's pinnacle, west side	Gneiss	S. 25° E.	
Orange,—summit	Mica schist	S. 36° E.	Grooves.
Between school-house No. 1 and church	"	S. 21° E.	
Andrews's mill	"	S. 31° E.	Abundant.
Hoyt hill, south of quarry	Andalusite schist.	S. 31° E.	
" mica quarry, N. side	"	S. 31°–36° E.	Striæ visible for 50 feet and furrows.
Top of Shad hill		S. 17° E.	Very fine.
Canaan,—1 mile west of Orange summit	Gneiss "	S. 31° E.	
Hill north-west of East Canaan	"	S. 26° E.	
North-east of Hart's pond	"	"	
Sawyer's hill	"	S. 21° E.	
South edge	"	S. 24° E.	
North line	"	S. 11° E.	
Enfield,—1 mile east of village, on lake	Lake gneiss	S. 21° E.	
West side of ridge, near W. line.	Coös slates	S. 24° E.	
Lily pond	Quartzite	S. 21° E.	
West of do., ¼ mile	Mica schist	S. 16° E. and S. 61° E.	Intersecting.
South-west base of Choate hill	Gneiss	S. 26° E.	Up hill, and east side of rocky valley.
East hill, east side	"	S. 24° E.	
Lebanon,—east edge of village	"	S.	
West of East Lebanon	Quartzite	S. 21° E.	
West of B. Walker's	Slate	S. 51° E.	On ledges close by course is S. 7° E.
D. Hardy's	"	S.	
Near hill-top further north	"	S. x 21° E.	Intersecting.
East Lebanon	"	S.	
School-house by O. S. Martin's	Mica schist	S.	
Between A. Freeman's and H. Grant's	Coös slate	S. 7° E.	Abundant.
Hanover,—near S. H., Hayes's hill	Clay slate	S.	
West part of do	"	S. 31° E.	
North part of do	"	S.	
Hill south from S. Hayes's	"	"	
Near town line to south	"	"	Embossed ledges 40 feet long.
A knob west	Quartzite	S. & S. 21° E.	Latter on lee side of first; do not intersect.
Copper mine, "Rudsborough"	Mica schist	S. 9° W.	
Mink brook, near Held. conglomcrate	Slates	S. 51° E.	Unusual; local (?).
Enfield side of Moose mountain, near school-house	Gneiss	S. 19° E.	
W. K. Covell, hill-top, N. part	Mica schist	S. 11° E.	
Observatory hill	Hornblende sch't.	S.	Obscure.
Moose mountain		S. 38° E.	J. H. Huntington.
Lyme,—below I. P. Holt's, down valley from East Lyme to Canaan	Gneiss	S. 31° E.	
A. Blood's, down valley from East Lyme to Canaan	"	S. 26° E.	
West of I. F. Clark's	"	S. 26° E.	
L. Conant's, east part	"	S. 21° E.	
West of S. Ames's		S. 11° E.	
Orford,—top of Mt. Cuba	Quartzite	S. 28° E.	Abundant.
West side	Staurolite schist.	S. 37° E.	
Top of Sunday mountain	Mica schist	S. 11° W.	
Few rods on south slope	"	S. 3° W.	
Cheese factory	"	S. 2° E.	
Bass hill—top	"	S. 8° W.	
Near C. Albee's, north part	"	S. 14° E.	Very fine.

Courses of Striæ—Continued.

LOCALITIES.	ROCK.	TRUE COURSE.	REMARKS.
Bridgewater.	Montalban	S. 32° E.	Down valley.
Dorchester,—south part	Gneiss	S. 12° E.	
Wright's hotel	“	E.	
2 miles south of village	“	S. 17° E.	
Piermont,—east part	Hornb. schist	S. 42° E.	
½ mile west	“	S. 24° E.	
West part, near Conn. river	Huronian	S. 15° E.	
1 mile east of village	Mica schist	S. 18° W. x S. 22° E.	Intersecting.
Near whetstone quarry	“	S. 19° E.	On large hill.
East part of town	“	S. 20° E.	
North of Tarlton pond	Gneiss	S. 18° W.	Near foot of Webster Slide mountain.
Peaked Hill range to south	Mica schist	S. 16° E.	
Cross hill	Quartzite	S. 42° E.	C. T. Jackson.

STRIÆ IN STATES CONTIGUOUS TO NEW HAMPSHIRE.

LOCALITIES.	ROCK.	TRUE COURSE.	REMARKS.
VERMONT.			
Norwich, Vt.,—east of school-house No. 2, and also below Dutton's, a mile distant	Clay slate	S. 26° E.	Down a valley tributary to Conn.
D. H. Bragg's, Distict No. 2	“	S.	Normal course again, west of the local one above.
Gregg's hill	Calc. mica schist.	S. 8° E.	Numerous.
Weathersfield,—near Conn. river	Huronian	S. 4° W.	
South of do	Slate	S.	
Opposite North Charlestown	“	“	
Warren,—Summit to Roxbury	Huronian	S. 31°-41° E.	Intersecting.
Near do	“	S. 55° E. & S. 60° W.	“
Sherburne	Gneiss	N. 10° E.	Down hill.
Windsor,—top of Mt. Ascutney	Sienite	S. 20° W. S. & N. 80° E.	
¾ way down	“	S. 10° E.	
At dam near village	Mica schist	S. 30° E.	The common direction.
“ “	“	N. 70° E.	Unusual direction, and local.
Bradford,—south-east corner	Huronian	S.	
Peacham,—1 mile west of "Corner".	Granite	S. 13° E.	
Canaan,—2 miles west of Conn. river.	Mica schist	S. 34° E.	
OBSERVATIONS TAKEN BY GEOLOGICAL SURVEY.			
Waterbury,—east part	Huronian	S. 41° E.	
Stowe,—central parts	“	S. 35° E.	
Elmore	“	S. 24°-38° E.	
Woodbury	“	S. 12°-S. 42° E.	The observations taken in these several towns were abundant, and I have given the extremes, it being unnecessary to present all the details of locality and variability.
Barnet and Waterford	“	S. 7°-12° E.	
West Concord	“	S. 22° E.	
East Concord	“	S. 2° E.	
Kirby	Slate	S. 20° E.	
Lunenburg	Huronian	S. 13° E.-S. 28° E.	
Guildhall	“	S. 7° E.	
Granby	Mica schist	S. 13°-33° E.	
Victory	“	S. 23° E.	
Maidstone	Mica schist	S. 23°-41° E.	
Canaan	“	S. 13°-25° E.	
Sheffield	Calc. mica schist.	S. 4° E.	
Glover	“	S. 7° E.	
Greensborough	“	S.-S. 12° E.	
Craftsbury	“	S.	
Lowell	Huronian	S. 22° E.	
Wolcott	“	S. 57° E.	Runs up Lamoille valley.
Hyde Park	“	S. 4°-37° E.	
Morristown	“	S. 18° W.-S. 7° E.	
Johnson	“	S. 42°-82° E.	Up Lamoille valley.
“	“	S. 8° W.	Normal course.

Courses of Striæ—Continued.

LOCALITIES.	ROCK.	TRUE COURSE.	REMARKS.
Mansfield mountain	Gneiss	S. 22° E. and S. 57° E.	
Jay peak	“	S. 53° E.	
Camel's Hump	“	About S. E.	
Troy	Huronian	S. 28° E.	
Salem	Mica schist	S. 23° E.	
Brownington	“	S. 12° W.	
Brighton	“	S. 13° E.	
Randolph	Huronian	S. 8° W.-S. 52° E.	
Roxbury	Mica schist	S. 8° W.	
Newbury	Huronian	S. 15°-37° E.	
Bradford	“	S. 22°-32° E.	
Fairlee	Clay slate	S. 9°-17° E.	
Thetford	Mica schist	S. 12° E.	
Chester	Gneiss	S. 42° E.	
Rockingham	Clay slate	S. 2°-11° E.	
Putney	“	S. 10°-2° W.	
Dummerston	“	S. 10° E.	
Brattleborough	“	S. 10°-18° E.	
Vernon	“	S. 4°-22° E.	
Guilford	“	S. 10°-15° E.	
QUEBEC.			
Aukland	Argillac. schist	S. 24° E.	J. H. Huntington.
Gould	Mica schist	S. 60° E.	“ “
Newport	Calc. mica schist	S. 34° E.	
Sherbrooke	Huronian	S. 22° E.	
Sutton	“	S. 36° E.	W. E. Logan.
Sutton Flats	“	S. 26° E.	
Orford	“	S. 43° E.	“
Brome,—Canada mine	“	East.	
East Canada mine	“	S. 18° E.	
Jerry Davis's	“	S. 13° E.	
Potton,—top of ridge south of Owl's Head	“	About E.	
MAINE.			
Portland,—north-west from custom-house	Huronian	S. 23° E.	Very fine.
Portland hospital	“	S. 3° E.	
Saco	Cambrian	S. 16° E.	
Lebanon post-office	Andalusite schist.	S. 47°-52° E.	
East of Lord's	“	S. 47° E.	Very fine.
Springvale (Sanford)	Mica schist	S. 42° E.	
Denmark village	Gneiss	S. 12° E.	
1 m. north of Pinhook, Bridgeton	“	S. 32° E.	
Bridgeton, north-west of village	“	S. 20° E.	
Standish, railroad lake station	Mica schist	S. 22° W.	
Top of Mt. Pleasant	Granite	S. 41° W.	
West side, near top	“	S. 31°-33° E.	
Androscoggin valley, north part of Mt. Ephraim	Montalban	S. 64° E.	Androscoggin Valley marks more fully described in text.
Church in Gilead, north side	“	S. 73° E.	
Base of Tumbledown-Dick	“	S. 83° E.	
East line of Gilead	“	S. 58° E.	
Paradise hill, Bethel	Gneiss	S. 23° E.	
Newry	Montalban	S. 33° E.	Down Bear River valley.
Falls near Poplar tavern	“	S. 19° E.	
Just above do	“	S. 34° E.	
East line of Grafton		S. 84° E.	
Grafton notch—highest point	Mica schist	S. 14° E.	
Upton,—D. C. Brooks's	“	E. of S.	
O. H. Abbott's	“	S. 59° E.	
Near East B. hill	“	S. 47° E.	
Opposite Dartmouth College grant	“	S. 4° E.	Valley movement down the Magalloway.
Andover N. surplus, n'r Dunn's notch.	Granite	S. 64° E.	
A. Pratt's	Gneiss	S. 64° E.	
South line	Mica schist	S. 34° E.	Valley movement.
N. S. Lufkin's	“	S. 24° E.	
J. Howe's	“	S. 34° E.	Curving with valley.
Rangely,—top of Bald mountain	Granite	S. 64° E.	J. H. Huntington.
Bethel,—opposite Hanover	Gneiss	S. 4° E. and S. 14° E.	
Near Songo pond	“	S. 44° E.	
Lovell,—No. 4 Corners	“	S. 8° E.	
Fryeburg,—Near Mt. Tom	Granite	S. 32° E.	

Courses of Striæ—Continued.

LOCALITIES.	ROCK.	TRUE COURSE.	REMARKS.
Broomfield,—M. McLucas's	Granite	S. 18° W.	
Hiram,—north west of Spectacle pond	Gneiss	S. 12° E.	
Cornish,—Ossipee river, above village	Montalban	S. 22° E.	
Standish,—west edge	"	S.	
Limington,—W. Chick's, east base of hill	Andalusite schist	S. 52° E.	
F. Strout's, top of hill	"	S. 33° W.	Several examples of this remarkable direction occur for ½ mile.
Limerick village	"	S. 22° E.	
Alfred,—½ mile north of N. Alfred	"	S. 32° E.	
J. Roberts's		S. 32° E.	
South Berwick		S. 32° E.	
Danville junction, G. T. R.		W. of S.	On wall—well shown.
Saco slate quarry	Cambrian	S. 15°-20° E.	
Cape Elizabeth,—T. Seavey's	Huronian	S. 8° W. and S. 22° E.	S. 8° W. course the most common.
Edge of	"	S. 27° E.	
Peak's id.,—Evergreen landing	"	S. 22° E.	
East side	"	S. 37° E.	
Cape Elizabeth,—Rail schist locality.	"	S. 12° E.	
Deering,—hospital		S. 2° E.	
MASSACHUSETTS.			
Northfield,—very near New Hamp.	Mica schist	S. 8° W.	
New Salem,—top of hill	Gneiss	S. 12° W.	
South Royalston	"	S. 10° E.	
Salisbury,—Eastern Railroad crossing north of village	Sienite	S. 51° E.	
Bernardston,—top of West mountain.	Slate	S. 5° E. x S. 10° E.	
Newbury,—several places	Sienite	S. E.	According to Massachusetts report.

Remarks. The table contains everything needful for explanation, save where more than one set of striæ is mentioned. When two or more sets occur in immediate contiguity, not crossing each other, the fact is indicated by the use of the conjunction *and;* when two or more intersect each other, the letter *x* is employed, and the fact is usually stated in the column of remarks.

The embossment of certain ledges in Pittsburg and Shelburne is peculiar, in that the lower part of the rock below the smoothed surface is rough. The ice may not have struck the lower part of the ledge; or, in some cases, the subsequent disintegration may have removed the lower part, leaving it as rough as the lee side. The Pittsburg examples may be eight or ten feet high, with a roughness of three feet, partly to be accounted for by the easy removal of rock on account of the presence of easterly dipping jointed planes. The Shelburne example is more striking. It is about a mile below the station. The ledge is about 30 feet high and 75 long, and the roughness below the striated part as much as 6 feet. The irregularities upon the lee side begin at the very top of the eminence. The end struck is 40 feet wide, tapering to a blunt point, where the smoothed appearance disappears; and the inclination of the stoss slope towards the north-west is about 50°.

Wall and floor surfaces are alluded to. This is because some writers insist that the former method of sculpture is never seen with iceberg action, being produced only by a glacier. As noted above, this species of moulding is very common.

The striæ about Bible hill in Claremont need further mention. This hill rises about 350 feet above the plain of the village at its northern base. What is supposed to be the normal direction is about S. 12° W., which occurs commonly west of the summit of the hill for two or three miles, reaching beyond the Connecticut. North of the village, it is S. 15° E.; among the houses, S. 41° E.; and on the east side of the hill, S. 23°–25° E., in a valley leading to Unity. On the south slope of Green mountain, east of the village, are intersections of the almost east course with that of about S. 12° E. On the westerly side of the top of Bible hill the most common course is S. 6° E. with S. 25° E. This is half a mile east from Brown's, Clark's, and Stone's, where the westerly course has been noted. We now proceed three fourths of a mile north-east to the "Flat Top," a spur of the hill, with scarcely any depression between. At the commencement, where the north-east slope begins, are striæ S. 57° E. pointing back to Little Ascutney, and crossing others S. 1° W. Next are some S. 46° E., pointing to Ascutney, apparently marked on the lee side of striæ pointing S. 1° W. to S. 1° E. Another ledge has striæ S. 46° E. crossed by others S. 1° E.; then S. 16° E. crossed by S. 41° E. and S. 51° E., the middle one the most common. Another ledge shows, in a narrow compass, the courses S. 21°, 36° 41°, and 57° E. Where the courses are so numerous, there is a marked tendency to irregularity; the striæ do not preserve their parallelism. A change of ten or fifteen degrees in direction will occur in a distance of less than a yard. Flat Top hill shows more of the irregularities than the highest summit to the south-west. Near the aqueduct, at the base of Flat Top, the course is S. 17° E. The impression was acquired at our visit that the south-east course cut those running southerly.

This is the most remarkable mingling of striæ I have ever met with. It is obvious that the field was crossed by the ice proceeding south-east and south, or from Ascutney, and down the Connecticut. The first were also occasionally deflected still more to the east by the large valley of Sugar river leading easterly to Sunapee lake. Some of the intermediate courses might have been caused by the meeting of the two masses of ice struggling to advance in different directions. Boulders from Mt. Ascutney are common to the north-east and east of Bible hill. The locality needs further exploration.

A few other interesting localities will be mentioned next before we attempt to draw the legitimate conclusions authorized by the list of striæ.

Mt. Monadnock.

This mountain possesses a conical shape, rising about 2,000 feet from a comparatively level country, the elevation of the plain being 1,000 feet above the sea. Its composition causes the striæ and embossment to be well preserved, while its isolated position illustrates one peculiarity of the drift-action. My father first described it in the *Proceedings of the American Association of Geologists and Naturalists,* in 1842, in the geology of Massachusetts, and in his text-book. He says of it,—"From top to bottom it has been scarified on its northern and western sides. On its lower parts, especially on the south-west side, the striæ run about N. W. and S. E., by the magnetic needle, as they do in the country around the mountain; but, when we approach its top, the course changes to N. 10° W. and S. 10° E. Other striæ are seen here on steeper slopes, both northern and southern, than I have found elsewhere."

The observations given in the table were mostly taken in 1871. It would appear that the common direction in the vicinity of Monadnock is about S. 12° E., the towns north showing a few degrees additional of easting, while the mountain itself, from the lake to the south-west corner of Jaffrey, about eight miles, exhibits, on its north-west flank and southern edge, the south-east course. After looking over the whole area, one sees that the ice coming from the north and west of north struck the mountain and clung to it closely, so much so as to run much more easterly on the south edge than elsewhere. Over the region to the south-east all trace of this easting is lost, the striæ in Jaffrey running S. 11° E., much like those of Troy and Marlborough. I have not explored the east side of the mountain; it is mostly covered by trees. Hence it is impossible to decide upon the value of Mr. Wheelock's theory, from present explorations. I understand his view to be, that Monadnock was an island in a sea full of icebergs, which struck equally strong upon both the north-west and south-east sides. There is certainly a dearth of striated ledges upon the south-east side, while even the earth has been largely removed from the north-west flank, so mighty has been the planishment of the rock. The striæ on the south-east side should all point south-westerly, if the summit were an island scarified on both sides by icebergs. Mr. Wheelock's paper is a very valuable one; and that part which relates to striæ is herewith reproduced.

*Striæ on Mt. Monadnock.** Having, in the last three years, spent many days in studying the striæ upon Mt. Monadnock, the writer is unwilling that the results of his observations should be lost for want of record, especially as they seem to have an important bearing upon unsettled questions of surface geology. This mountain is peculiarly favorable to such study. Its long spurs radiating from a central elevation, though

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* *American Naturalist*, vol. vii, 1873.

less regular than the points of a star, yet present to four points of the compass long ranges of bare rocks, which have recorded the markings of the ice-period, with all their variations of direction, and furnish a lesson not to be found, perhaps, in any other locality. To understand fully the meaning of the evidence herein detailed, it is necessary to have a clear idea of the relative bearing and position of these radiating ridges or spurs.

For the sake of clearness of description, we will suppose the principal ridge, which runs N. 25° E., to be straight, and to be four miles long. This ridge was an uplift, sloping towards the west, and presenting its broken and precipitous face towards the east. It is like a dam set obliquely across the current of the northern drift, and its serrated edge rises from 1,500 to 2,000 feet above the surrounding country, growing higher from each end to its central parts. If we suppose a section of this range near the centre to be pushed some fifty rods further west, and elevated to the height of 3,280 feet, we shall have the summit of Monadnock. A short spur projects west of the summit about a mile, and divides into two branches. These we will call the west and north-west spurs. The two ends of the dam we will call the north and south spurs; these, with the western spur and its north-west fork, complete the outline of the mountain, making four radii.

Numerous observations of the direction of drift striæ made in the adjoining towns show very general uniformity. They have a range of not more than 15°, varying 15° west of north to north and south. On the summit of Monadnock the direction varies within the same limits. Only one set of striæ was noted there as 5° east of north. So, too, following along the north-east spur, there is no change in the striæ so long as the altitude remains the same. The crest is all naked rock for two and a half or three miles, and frequent observations can be made. Just as fast as the ridge falls off in height, the striæ gain a more westerly direction, becoming 15°, 20°, and 25° west of north; where the rocky ridge terminates and is succeeded by open pastures, 30°, and in many places 40°, were noted as common. Appearances indicated a local deflection of a current around the northern end of this long dam.

Although a special expedition was made to what was called the north-west spur, the lower portion of it was so much covered with drift that few exposed places could be found. Some five or six, however, and all that were noted, showed striæ N. 25° E. All the higher portions of the ridge were striated like the summit and the ridge before described.

Another day's expedition was made to the west spur. Standing on the crest of this lofty ridge, and looking towards the south, the view is unobstructed to the horizon. The striæ all along this ridge are innumerable, and all north and south. There is no opposing ridge near, to lead one to expect south of this a change in the striæ. On the contrary, there is every facility for the drift current after passing this ridge to continue on in a straight course. The southern spur is a mile or more off on our left, and presents a high opposing barrier towards the south-east, but none towards the south. Why should the drift current, after passing this ridge, suddenly turn towards the east and climb the steep and lofty barrier of the south spur? Nevertheless, there are indications of just such a change as this.

If we place one foot of a pair of imaginary compasses on the summit of Mt. Monadnock, and with the other strike a curve from the west spur to the south spur, we shall hardly have made a more complete change of direction from one spur to the other than is indicated by the striæ in the short space of a mile and a half. It is difficult to pass over all parts of the valley between these two spurs, the upper portion of it being extremely craggy or uneven. It is better to go down to the open pastures at the base of the mountain. Beginning at the foot of the western spur, and skirting the base of the mountain towards the east, the first thing to excite attention is the immense number of boulders. They exceed in multitude any other deposit about the mountain, but form no part of its talus, which does not fall on this side. They seem to be in some way connected with the change of the drift current, which began at this place, and with the position of the ridge, under the lee side of which they lie. Passing through these boulders, which continue for half a mile or more, we come to the first bare ledges. These are marked with striæ N. 20° W. These are soon succeeded by others, 30°, 40°, and 50° west of north. They may not all occur in regular order. On some ledges there are two or three sets of striæ of different angles. Proceeding a mile and a half, we arrive at the easterly slope of the south spur, near the Mountain house. The road to this house was built north and south on sloping ground; and for half a mile the fresh surface of the rock was in many places exposed to view. It is everywhere scratched and polished. These scratches vary from 50° to 60°, and 70° west of north. Climbing the slope of the ridge, everywhere the exposed prominences of rock are embossed in the same direction. Arriving at the crest of the ridge, it is everywhere serrated and uneven.

On this height we again overlook the whole country. Here, on the narrow crest of the ridge, the striæ are very generally N. 40° or 45° W. In one place an angular trough, perhaps 20 feet long and 6 feet deep, runs across the crest. In this are long, continuous striæ due east and west. They appear to be exceptional, and suggest the idea that this shallow trough had been able to control and change the direction of the striating force. Standing on this ridge, and looking towards the east, we see that the mountain on this side is very precipitous, and that probably there are no striæ on its broken surface. Higher up the mountain, within a thousand feet of the summit, the striæ are 35° and 30° west of north; lower down, at the extremity of the south spur, the end of the long dam, they vary from 40° to 25° west of north. What kind of striæ should we expect to find under the lee of this four-mile breakwater? Another expedition and another day were required to answer this question. The country east of the four-mile ridge is mostly wooded and difficult to traverse. The rock is mostly covered by drift. Beginning at the south end, and travelling north, no striæ were found until two thirds of the distance had been passed over. Curiosity was at last gratified by finding large, flat surfaces of naked rock, scored all over with long parallel lines much better preserved than those on less wooded and more exposed parts of the mountain.

It would be difficult to decide what was their prevailing direction. Multitudes ran due east and west; some few, north and south; some, N. 10° W.; some, N. 10° E.; many, N. 70° and 80° W.; many, N. 70° and 80° E. No theory of mountain slides could explain this remarkable scratching: the situation seemed to forbid such an explanation. These observations were made on many different ledges, but all of them within half a mile of each other, and within a mile of the north end of the ridge. When a rapid stream, with a current of three miles an hour, passes a rock in its bed, water will flow around the rock and meet on its lower side. Do not these irregular striæ indicate a changeable and eddying current inconsistent with the motion of a glacier?

Mts. Kearsarge and Ragged.

Mts. Kearsarge and Ragged rise abruptly from a comparatively level country, like Monadnock, but, being situated near each other, not quite six miles apart, the conditions gave rise to a different motion of the ice. Ragged is not so completely isolated as Kearsarge, being connected with mountains in the north part of Andover. Sutton, Salisbury, and Hill have the average direction for striæ of about S. 12° E., while in Warner there are several degrees more of easting. The parts of Wilmot and New London next to Kearsarge do not show striated ledges. Starting from Warner, on the south, the table shows the change from S. 20° E. to as high as S. 76° E., it being nearly south-east on the summit. On following down the north side, the easting falls off to S. 36° E. at the Winslow house, but reaches N. 67° E. in the valley by Potter Place. Similar figures continue all the way to the top of Ragged mountain from the southern base. At the last house,—1,100 feet (450 feet above Potter Place),—the striæ run S. 71° E.; at 1,340 feet elevation, S. 31° E.; at 1,650 feet, S. 46° E.; at 1,775 feet, S. 23° E.; the same for 200 feet further; at 2,000 feet, S. 36° E.; at 2,100 feet, S. 23° E. and S. 51° E. Here the embossed ledges are numerous, while the striæ are much worn. The S. 50° E. course appears higher up, but not on the summit or at the signal, 2,256 feet, where the direction S. 23° E. is to be seen. We have, therefore, two well marked directions, very much as on Monadnock, the S. 23° E. course appearing by itself on the summit, while the south-east lines show themselves all the way down the south slope.

Considerations will be presented soon, showing that there was somewhat of a local or valley movement of ice down the Blackwater river. It may be that the greater eastings of the striæ about Potter Place are due to other causes than the mere influence of the two mountains, so that we cannot strongly insist that the easterly movement of the striæ from Hill to Warner is entirely due to the presence of the two mountains. The only feature where this case is unlike Monadnock, is the easting at the base of the mountain, which we see may have been produced by an independent movement.

Other Mountains similarly Striated. Of other mountains similarly situated, some exhibit the same kind of ice-action. Mt. Gunstock has S. 62° E. striæ on top, and the S. 32°–35° E. course on the east side, bordering Lake Winnipiseogee. Mt. Lovell in Washington shows the direction S. 36° E. on the summit, while it is commonly S. 21° E. in the north part of the town, though crossed by a set running S. 41° E. Lempster mountain summit shows the direction S. 41° E., and it is S. 21° E. on the west side. On Mt. Cuba we find S. 28° E. and S. 37° E., while it is commonly west of south in Orford on the west, and S. 22° E. in Wentworth. Moose mountain in Hanover shows S. 38° E. on its summit, while the course is south on the western side, and S. 19° E. on the Enfield side. There is a south-east course in the middle and south-east part of Hanover, which may have some connection with these movements on the elevated summits. Sunapee mountain would be expected to agree with its neighbors, but no observations of striæ have been made there. Mt. Ascutney, just out of the state, exhibits phenomena worthy of mention here. This has the same altitude with Mt. Monadnock, while the land about it is more uneven, averaging less than around the Cheshire peak. Owing to the rapid disintegration of the rock, striæ are scarce, and perhaps the few examples discovered should not be taken as truthfully representing the general courses. The very summit showed a due south course. About 300 feet lower down, on the north-east side of the mountain, following the Windsor path, are striæ running due east, or N. 80° E. They rest upon a wall inclined 70° N., and point down the mountain towards the south part of Cornish. Others in the neighborhood run S. 20° W. About two thirds of the way down are other distinct striæ running S. 10° E.; and no others were seen on the mountain proper. On reaching the dam over Mill brook, west of Windsor village, the course S. 30° E. is seen, and a few N. 70° E., a very unusual direction, supposed to have been the result of some local disturbance. In Weathersfield and Claremont, along the river, the usual course is west of south. Observations west of Ascutney are wanting. It appears, therefore, that the observations are not ample enough to say positively, though it is probable, that the striation of Ascutney is like that of Monadnock.

Mt. Pleasant, in Denmark, Me., may also be mentioned as allied to Monadnock. South of the mountain the course is S. 12° E.; east, it is S. 20° E.; north, it is S. 8° E., while one observation in Fryeburg, to the west, reaches S. 32° E. On the summit the striæ run S. 41° E. On the north-west side, following down the path, good examples occur of the course S. 31°–33° E. Lower down are others less satisfactory, running S. 52° E. Not far from the Half-way house are some seemingly local, running west down the hill.

Certain other elevations in the state, with topographical surroundings like Monadnock, show little difference in the direction on the summit and the neighboring plain. Such are the Moose mountains in Brookfield and Middleton, Teneriffe in Milton, New Durham ridge, Catamount hill in Pittsfield, Blue hills in Strafford, Saddleback in Northwood, Temple mountain, Barrett mountain in New Ipswich, etc. Crotched mountain in Francestown, Ossipee in Carroll county, and Pawtuckaway in Nottingham, have not been studied, while Green mountain, Effingham, is too thoroughly disintegrated to preserve any markings.

PREDOMINANT COURSES OF STRIÆ.

The Vermont geological report states that the striæ may be classed in three divisions,—those pointing to the south-west, south, and south-east, the first being the least common. The south-west course is much more infrequent in New Hampshire, while the south-east direction is more prevalent than in Vermont. A sketch map in Volume I (p. 542) shows the general relations of these three kinds of movement for both states. Many of the striæ are so disposed that they may be believed to be the result of valley movements. In our researches we have constantly asked, How much do topographical features influence the course of the striæ? The replies forced upon us insist that a portion of the directions is due to topographical features, while others—the majority—pursue a fixed course, in total disregard for all obstacles. The first we have styled valley movements. A part of these are distinguishable from the others where the course of the valley corresponds with that of the neighboring striæ.

The south-east courses commonly occur upon the most elevated mountains, both in New Hampshire and Vermont. The whole Green Mountain range, and the loftier Presidential line of White Mountain summits, show this direction of marking. Scarcely any other course is known in Coös county, and it is common all through the Lake and Coast districts, including Essex county, Mass., and all the mountains of the Monadnock type. On comparing these courses over so much of New England with the customary south-east course of the valley of the St. Lawrence, one perceives a very striking contrast, and has the difficult problem of the course of the south-east current set sharply before him. How could the ice-sheet climb the highest New England mountains from the low St. Lawrence valley, and then press onward to the sea? I will not attempt the answer at present, but offer, in the first place, our reasons in full for believing the ice current passed over the summit of Mt. Washington.

Evidences of Glacial Action upon Mt. Washington.

As this is the highest summit in the whole glaciated area of North America, geologists have been greatly interested in examining its sides, to note how far the ice-marks could be found. The most important visit in that regard was that of my father in 1841, and the observations then made universally accepted. Most other geologists have visited the mountain, but have had no occasion to publish anything about the phenomena. My father, in 1841, became greatly interested in drift phenomena, and visited the White Mountains for the purpose of determining the limits of the ice-action. He came from Conway through the Notch, passing up the Crawford bridle-path. "Along the whole course of the valley," he says, "I noticed rather fewer of the phenomena of drift than in most of the mountain valleys of New England." After describing the route of the path, he says,—

> All the peaks which I ascended are made up of broken fragments of this slate, which have been entirely removed from their original position by frost, and form sometimes a coating of loose angular blocks several feet thick. This is particularly the case upon the summit of Mt. Washington, and downward about 1,000 feet [see frontispiece, vol. i]; but in all the valleys between these peaks more or less of the rocks appear in place,

and here I discovered many examples of embossed rocks. They are, as we might expect, much less distinct than in many other places less exposed to decomposing agencies, and I should probably have passed by them without recognition, had I not previously examined many other more distinct examples. So far as Mt. Clinton has been uncovered, it seems one huge boss more or less rounded. As we begin to ascend Mt. Pleasant, the embossed rocks are quite distinct; and here, too, are boulders most evidently transported. Here, too, I discovered striæ running N. 30° W., S. 30° E., corresponding essentially with the general course of striæ on the mountains of New Hampshire and Massachusetts. * * Near the south foot of Mt. Franklin is another example of the embossed rocks with boulders. * * Finally, at the south foot of Mt. Washington, near a small pond called *Lake of the Clouds*, is a third example of the *Roches moutonnes*. It is less distinct than at the other localities, as the rock here is more broken up by frost; still it is impossible for a practised eye not to recognize them. And it ought to be stated that here it is the north-west exposure of the rocks that has been most powerfully acted upon, proving conclusively that the force was exerted from that direction. * * Can there be any reasonable doubt that the rocks on the summits of all these peaks were once abraded by the same agency, and that, were they in place, they would still exhibit traces of it?

Conclusions. In the first place, the same glacio-aqueous agency that has operated in a south-easterly direction over the northern parts of the continent, at the lowest and at intermediary levels, has acted in the same manner and in the same direction upon the summits of the White Mountains. * * Hence, thirdly, we have no reason to suppose that the White Mountains have ever been a centre from which boulders have been dispersed; and no evidence has been discovered on the sides of the mountain of the former existence of glaciers. * * * * * *

But as no ice-marks were discovered on the highest summit, my father and others could not affirm what they seemed to have believed, that the glacier did move over the summit. Every geological text-book in the land has followed the leading of the facts just stated; and it has seemed an established dictum, that no ice marks could occur above about five thousand feet.

In 1870 I traversed Mt. Washington, following the usual paths, and discovered small transported stones of a nature foreign to the mountain, at an altitude of 5,800 feet. The locality was at the then upper tank of the railway. Not much search was made, as it seemed preposterous to question the conclusions of my predecessors, though my notebook stated that the ledges above these pebbles exhibit the usual appearance of embossment produced by glacial agency, the force having come from a north-westerly direction, but no striæ were seen upon them. In the years following scarcely any thought was bestowed upon the subject; and it was almost by accident that, in 1875, I found decisive evidence to prove the passage of the glacial sheet over the summit of Mt. Washington. Very shortly afterwards the story of the discovery was communicated to the public, as follows, at the Detroit meeting of the American Association for the Advancement of Science:

> The first suggestion of this novel proposition came to me the last day of July, 1875, from an examination of the somewhat rounded stones of small size lying along the carriage-road upon the north-east side of the mountain, about two hundred and fifty feet below the summit. I stumbled upon two boulders of granitic gneiss foreign to the mountain, one nearly ten and the other six inches long. This raised the altitude at which transported materials existed to above 6,000 feet. Observation showed that these boulders came invariably from the earth underlying the conspicuous angular débris common all over the peak above the line of trees. In repairing the road, the workmen usually dug beneath the surface blocks before obtaining a material suitable for their purposes, and there always seemed to be a plenty of it. This earth proves to be the ordinary *ground moraine* of modern glacialists, full of the worn angular and roundish stones, which have been fashioned peculiarly by being shoved along. Large boulders are not common in it, though abundant elsewhere. These stones are usually of the same mica schist and gneissic rocks that compose the adjacent ledges; and this kind of ledge extends to Israel river, five or six miles distant from the top of Mt. Washington in a north-westerly direction. Were these deposits situated in the lowlands, they would be pronounced at first sight by any one to be the common drift heaps of the neighborhood. I did not discover satisfactory evidences of striation upon the few stones picked up near the two boulders of granite just mentioned, but they possess the characteristic shapes of those that are covered with scratches elsewhere. Some are pointed at both ends, being either flattened or round along the middle. Others are squarish or trapezoidal, with rounded corners. Many resemble perfectly the shapes figured by Geikie in his recent work on *The Great Ice Age;* and, in fact, they are of the constantly occurring forms familiar to all glacialists. The rock is quite soft, and that fact may explain the absence of striation.
>
> The question naturally arose, as I lifted up these stones, Are these the shapes resulting from the cleavage of ledges by frost? No, it could not be; some agency of transportation other than the falling down a slope has worn off the edges, smoothed their surfaces, and mixed them with earth. The glacial ice must have transported them, though they cannot have travelled more than five or six miles, or the limit of the extent of this kind of rock. If this were so, then the whole of Mt. Washington was covered by the glacier ice. Thus I reasoned with myself, and began to look further. Remembering that these glaciated stones came from below the surface, I sought for localities where the lower earth had been excavated. The first case examined was the founda-

tion of the Mt. Washington hotel. In laying the foundation of this edifice,—nearly two hundred feet long,—the angular débris was first taken up and placed in the cellar walls. When this had been used up, the workmen reached the same moraine mass which occurs below, along the carriage-road. Some of the earth was sandy, and went into the composition of the mortar used on the walls. There was scarcely any ledge requiring removal. I examined such of the stones as remained in the cellar as well as possible with a dim lantern, and found everything in agreement with the character of the materials seen two hundred and fifty feet lower along the carriage-road. The stones assumed the ordinary glaciated shapes, but I did not discover any material foreign to the mountain. One of the quartz fragments seemed to show traces of smoothing or incipient striation.

Next, I examined the excavations made for the road between the house and stables, and obtained several small boulders, four or five inches long, corresponding in mineral structure with the ledges in Randolph and Jefferson, twelve or fifteen miles away. The general color of the rock is so like that of the mountain that one would not perceive the difference between them without close inspection. The mica is arranged differently in it; the white parts are more abundant, though in fine grains, and the rock is evidently the same with the upper member of what I call the "Bethlehem gneiss" in the New Hampshire reports. The highest point at which stones of foreign origin were obtainable may be twenty or twenty-five feet below the very pinnacle of the mountain. Hence it is fair to conclude that every part has been covered by the glacial ice. The glaciated stones, composed of the same material with that of the mountain, are common all along this road to the stables, and elsewhere in excavations over the summit.

Being unexpectedly called away, I had not time to search carefully for striæ upon the ledges. Just beyond the signal station dwelling I found a flat ledge sloping a little north-westerly but precipitous on the south-east. Atmospheric agencies have marred the surface so much that no striæ are visible, even if they ever existed. I had proposed to scrutinize every harder projection of quartz with a lens, as this course sometimes reveals striation where other inspection is unavailing. Were this ledge situated near the Lake of the Clouds, where embossment is common, I should point it out unhesitatingly as an example of ice-sculpture, though much degraded by weathering. The shape agrees with that of thousands of glaciated ledges in other parts of the state. Other ledges on the mountain further north resemble this one. Inasmuch as the transportation of materials is clearly proved by the presence of the Jefferson rock upon the summit a few rods away, it will not be unreasonable to believe that this apparent embossment is real. The altitude of the ledge is the same with that of the site of the travelled stones.

The disposition of the large blocks upon the summit is noteworthy. Several acres of surface are covered by them far away from visible ledges. As you approach a ledge, it is easy to see what fragments have been separated by frost action, as the projections match the indentations; and a very few feet of distance represent the extreme amount of removal, save on a steep slope. Since the surface covered by the large angular blocks is quite extensive and comparatively level, it is fair to conclude that the transportation has been affected by the glacier and not by frost. The latter agency, however, has very industriously operated upon both ledges and boulders in post-glacial times, so that the shattered ledges, their fragments, and the fractured boulders form a continuous field of angular débris over the whole upper cone of the mountain.

From these facts, the following conclusions seem legitimate:

1. The glacial ice completely covered and passed over the summit of Mt. Washington in a south-easterly direction.

2. It brought along a large amount of moraine rubbish and glaciated stones, which were disposed in various hollows and convenient locations about the mountain, in the same way that the ground moraine is distributed in the lowlands.

3. Subsequently an immense number of large blocks of stone, taken from the northern slope of the mountains, were transported to the summit (as well as beyond), and left overlying the finer earth débris of a previous transport.

4. Frost and gravity have been acting upon the boulders thus transported and the ledges, so that every large block has been split up into smaller ones; and this angular débris entirely conceals from view the previously formed moraine, and the summit is apparently destitute of soil.

After the announcement of this discovery, it was objected by some that these transported foreign stones might have been brought by teamsters or by the railroad. It was said to be a common custom for the men to place canvas over articles in their vehicles for protection, and to fasten down the cloth by stones. On reaching the summit, the stones would be thrown away, and perhaps the glaciated bits might be some of the fragments thus transported. The boulders I found were not over two pounds in weight. These would hardly be sufficient to hold canvas down in a wagon in the teeth of the formidable winds often blowing at the summit. Still, I thought it best to search further in localities not reached by débris. About fifty feet below the summit, midway between the railway and carriage-road, I soon found a rounded block of light gray Bethlehem gneiss weighing ninety-one pounds, evidently the rock that is common about Jefferson, but very different from the material composing the mountain. It lay beneath other fragments of stone, partly embedded in earth, and showed patches of the common yellow lichen of the summit growing upon it, older than the date of the building of either road. I therefore concluded that no human agency ever brought this heavy stone and planted lichens upon it; nor is it probable the ones first discovered reached the summit except as borne by ice. Hence the proof of the presence of glaciated foreign transported boulders upon the summit of Mt. Washington is indisputable. These consist of two different members of the Bethlehem group, together with a trap rock of unknown origin. The larger boulder is preserved in the state museum at Hanover.

Further examination of the smoothed ledge west of the signal office confirms the impression of ice-action mentioned above. Faint markings indicate the course of S. 43° E., while the smoothing is very obvious to the touch, and is best seen where some of the ledge had been recently exposed, and especially upon a finer-grained stratum than usually occurs. The weather roughens every exposed surface in a very short time, so that this smoothness cannot be expected to continue a great while. This example was shown to Mr. E. Lewis, Jr., of Brooklyn, N. Y., a geologist familiar with glacial phenomena, who agreed with me as to its nature and origin. The course of the striæ and dispersion of the boulders both indicate the movement of the ice to have been from the north-west to the south-east, a direction in unison with corresponding phenomena upon the neighboring summits. It is therefore clear that the ice moved south-easterly from the St. Lawrence valley towards and over the highest ranges and peaks of New England (6,291 feet), in the direction of the Atlantic ocean. Our discoveries may increase the difficulty of explaining glacial phenomena in New Hampshire; but it is better to meet the truth, though formidable, than to adopt errors. All speculations, claiming that Mt. Washington rose above the ice, or constituted the central peak from which local glaciers radiated in the height of the glacial period, are false. It will be shown soon, however, that local glaciers occupied the flanks of the White Mountains during the decline of the ice period. This does not interfere with the fact of the earlier mightier movements.

Directions West of South.

A few examples of a current west of south have been observed. The first of importance occurs upon the east side of Mt. Washington, passing from Gorham up the Peabody valley to the Glen house, thence to the height of land and down the Ellis valley past Jackson. The course is S. 15° W. near the Glen house; S. 3° W., half a mile south; and perhaps a little east of south into Jackson. The valley must have been filled certainly as high as the Half-way house on the carriage-road, where the course is S. 8° W. Perhaps the most natural way to explain this case is, to say that ice from the north entered the mouth of the valley at Gorham, and, being powerfully urged onwards, followed up the Peabody river, because that lay in the direction of least resistance. Whether this action was coeval with the motion on Mt. Washington, is doubtful; most likely the intensity of that force had somewhat abated before this culminated. The valley is on the lee side of the mountains, and might possibly have been moving at the same time with that on the summits without inteference. Dr. Packard has cited this valley movement as an illustration of a local glacier passing northerly down the Peabody river to join the Androscoggin.* In this he is followed by Vose.† The latter thus states the case:

> The Peabody river rises upon the eastern slopes of Madison, Adams, Jefferson, Clay, and Washington, and upon the western slopes of the opposite range of the Carter mountains,—the Imp and Mt. Moriah, and flows about N. N. E. to Gorham, where it joins the Androscoggin. The surface geology of this valley is exceedingly interesting. It has been carefully studied by Dr. Packard, and, from the arrangement of its terraces and the other forms of the unconsolidated material, he concluded that a large glacier once occupied this valley, extending as far down as to Gorham. His conclusion is somewhat confirmed by the following facts: About 150 yards north of the Glen house, just south of a large boulder upon the west side of the road, the surface has been cut open, and has exposed a portion of a ledge, perhaps a dozen feet in length and a yard wide, on which, at right angles to the contorted lamination of the rock, faint lines, or, rather, furrows, are seen, running N. 35° E. or S. 35° W. This ledge was covered several feet deep by the material of the terrace in front of the Glen house. Just across the valley from the hotel, where the carriage-road commences to ascend, the upper part of the large exposure on the right hand is well polished and furrowed in a south-west direction. Half a mile further up the road, furrows upon the right side, close to the road, are seen running S. 40° W. or N. 40° E.; and, again, a short distance above the path leading to Tuckerman's Ravine, upon a surface somewhat inclined towards the road, may be seen lines running S. 30° W. or N. 30° E. Many more traces would doubtless be found in this neighborhood, if sought for with care, as the few recorded were noted without stepping out of the common road.

These and other examples given in the table have been carefully examined; but I am satisfied the force proceeded up instead of down the valley. If the facts about stoss and lee sides of ledges declare truth,

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* *American Naturalist*, vol. i, p. 267.

† I'd, vol. ii, p. 287.

there can be little doubt as to the south-west direction. Some of the examples given require scrutiny to decide which is the stoss and which the lee side, but all present the same appearances. Perhaps the most satisfactory cases are recently exposed by a clearing midway between the Glen house and the saw-mill, not seen by either Packard or Vose. The rounding on the north sides of the domes here is very conspicuous, while the south sides are rough and uneven, though not so much so as in the most perfect examples of stoss and lee action. At the lower end of the carriage-road the smoothing occupies a broad face of rock 200 feet long and 40 wide, with the north-east end the most worn. Two miles up this road the markings are on a vertical wall exhibiting a well defined example of the north-east force. A short distance south from the Glen house, where a tributary enters from the south-east, the greatest amount of wearing appears at the angle of the fork, and not upon its sides. All these cases show clearly that the principal force, or that making the striæ and producing the embossment, proceeded west of south, and not northerly. There may have been a later current down the valley in the decline of the period, but this did not have strength enough to score the ledges. This later current explains the origin of the immense thickness of stratified deposits near the mouth of the Peabody river, called moraines by Packard and Vose. They are relics of the ancient flood plain, produced by the glacial river after the ice had been melted, certainly as far up as the Glen house. These terraces are very conspicuous as far south as the mouth of Miss Barnes's brook, and show differences in coloration like those between the upper and lower till. Mr. Upham agrees with me in this view (see p. 141), without any conference or suggestion whatever from me.

The next examples of the movement west of south occur on the west side of the Presidential range, and seem to connect with the Connecticut Valley movement. It has not been observed in Carroll, probably because of the scarcity of ledges. Observations are also wanting for Whitefield. Bethlehem abounds with them. The north-west slope of the Mt. Agassiz eminence has been powerfully struck and smoothed by it. This current passed over the summit of Mt. Agassiz, and followed some portions of its southern slope. From here southerly the current is merged with that of the Connecticut Valley movement. That seems to commence with the Passumpsic. The great westerly bend of this valley below Dalton, and the sudden fall of the land, may have prevented the ice of the upper Coös flats from descending to Barnet. Certain striæ in West Littleton, near Milliken's saw-mill, cross the Connecticut, and ascend Gardner mountain in preference to following around the lowland. Our numerous observations in Littleton, Lyman, and Monroe show that the prevailing course was a little west of south, conforming both to the longer axis of the Gardner range and the Connecticut valley. The whole area of this westerly course may be readily referred to the Connecticut Valley movement, of which more will be said beyond.

Another area, showing a course west of south, is in the Lake District. We have on the south slope of Pequawket, S. 6° W. (misprinted in the table); Madison, S. 7° and 12° W., besides S. and S. 2° E.; Brownfield, Me., S. 18° W.; Eaton, S. 3° E. This area is essentially a valley sloping southerly; but there are no indications of this direction in its continuation in Ossipee or Wakefield, nor in the broad opening to the south-west between the Chocorua and Ossipee mountains. The striæ point south-east in both these localities. Hence the reason for this course in the Lake District is not obvious. Probably extensive explorations in Maine will be required for the solution of this problem.

Those nearer the coast might be referred possibly to iceberg agency, or to some connection with the ocean. They are at Cape Elizabeth, close to salt water, S. 8° W.; at Limington, Me., S. 33° W., numerous and well marked for half a mile's distance, seen in crossing a hill; at Danville Junction, Me., a little west of south; and at Bow lake in Strafford, S. 31° and 58° W. The usual direction in this neighborhood is fairly at right angles with these. Is it possible that these are scanty relics of a once abundant south-west glaciation? Some of the lenticular hills, about to be described, are arranged in a line suggestive of a connection with a south-westerly current, much more extensive than is indicated by the striæ. The course of S. 59° W. in Sutton cannot easily be classed with either of the foregoing.

We cannot properly appreciate the importance of this movement without reference to other observed examples obtained outside of New Hampshire. In Maine they are S. 8° W. at Saco, and about the same at Rockport. In Vermont they are S. 50° W. at Halfax centre; S. 28° W.

at Marlborough. In Massachusetts they are S. 20° W. on the summit of Mt. Pocumtuc, 1,888 feet above the sea; S. 50° W. at Granville, 1,240 feet. In Connecticut, according to Prof. Dana, there are striæ proceeding S. 30° W. on Mt. Carmel, and S. 33° W. half a mile west of Allingtown on the Milford turnpike, a few miles west of New Haven.

SOUTH-EAST DIRECTION.

The south-east course is well-nigh universal. All over Coös county and about the White Mountains there is scarcely any variation from it upon the high ground. It is the most common in the lower part of Carroll, Strafford, east part of Merrimack, east part of Rockingham, and on the isolated mountains of the Monadnock type everywhere. In Belknap and the west part of Rockingham the course averages a little less easterly than south-east. The Winnipiseogee Lake neighborhood is much the same. In all the regions showing a west of south course are many cases of this south-east grooving. About Madison we have noted S. 22° E. The Strafford hills indicate S. 35°–78° E. In the Connecticut valley numerous examples are given. We find in Lancaster, S. 23° E.; at Haverhill, S. 21° E.; at Newbury, Vt., S. 23° E.; at East Lisbon, S. 28° E.; in Bethlehem, S. 28° E.; in Piermont, S. 42° E.; in Lyme, as high as S. 31° E.; in Hanover, S. 38° and 51° E.; in Lebanon, S. 51° E.; in Enfield, S. 16°–61° E., but most commonly about S. 22° E. A full description has been given already of the remarkable eastings in Claremont. At Unity the course S. 51° E. occurs, and S. 61° E. at Hinsdale. Along the Connecticut-Merrimack water-shed the direction is commonly between S. 20° and 40° E. These south-east courses in this valley must not be confounded with those conforming to the direction of its contour, about to be mentioned.

The universality of a south-east course among the striæ shows that this was the most common direction taken by the ice in its southerly movement. All other directions are exceptional, and probably produced subsequently by an action differently directed.

VALLEY MOVEMENTS.

To this class I refer all those examples of striation where the ice seems to have followed the topographical contour of the country, including all the local glaciers. In most glaciated countries it has been found practicable to refer all the ice-action to this class of movement; but in New Hampshire the most characteristic phenomena have resulted from a motion made in total disregard of all topographical obstacles or allurements. On the supposition that ice moves up hill only when forced by a flow starting from an eminence higher than what is being surmounted, we must believe that, to the north of the St. Lawrence valley, the land was elevated several thousand feet higher than at present. This is Prof. Dana's view. It must be adopted, unless we can show that reasons exist why the ice can move up hills higher than the source of the flow.

The most important valley movements in New Hampshire are those in the Connecticut, Merrimack, Blackwater, Baker's river and Winnipiseogee lake, the Androscoggin, Saco, and others. I will describe each in turn.

Connecticut Glacier. None are better marked than this. It starts with the Passumpsic and the Lower Ammonoosuc valleys, and, below Haverhill, occupies commonly the width of two townships, one on each side of the river, into Massachusetts. It continues across Massachusetts, with a course a little west of south, as has been described in my father's publications. On both sides the course is east of south. It follows, therefore, that this movement must have been entirely independent of all others. As it conforms to the valley, while here and there a few remnants of the south-east course remain as relics, its existence was probably subsequent to the other, and in the decline of the period. By observing the present heights of the striated ledges, we can determine the minimum thickness of this glacier. It covered Mt. Agassiz in Bethlehem, the higher parts of Lisbon and Landaff, the Gardner mountains, or over 2,000 feet of altitude. Lower down the valley it attained the height of 1,100 feet at the Haverhill soapstone ledge; 1,400 feet near Tarlton pond in Piermont and Warren; 1,500 feet upon Sunday mountain in Orford; 1,600 feet in the south-east part of Hanover; and it may have reached the summit of Mt. Ascutney, or over 3,000 feet. South of this mountain, none of the recorded observations exceed 1,000 feet,—most fall below it. On Bear hill, Hinsdale, they stand at 700 feet. In Massachusetts we found one example, at New Salem, on the east rim of the valley, certainly as much as 1,200 feet high. Similar marks have been found at the same height over the Holyoke range, or upon Mt. Tom. Allowing for the elevation of the river bed, this glacier must have exceeded 1500 feet in thickness in the Ammonoosuc valley, and probably 2500 feet at Windsor. From Prof. Dana's paper,[*] it is obvious that the ice continued a little west of south to New Haven, Conn., thus following the depression of the valley to Long Island sound. The breadth of the area showing striæ conforming to the river's course is greater in Massachusetts and Connecticut than in New Hampshire and Vermont, as might be expected where the valley itself is broader. So far as can be conjectured, the heights are less in the more southern states; and it is bounded by the east of south course on both sides as sharply as further north.

It would be repeating observations uselessly to print again the numerous statements about the course of the striæ along this valley given in our table. That may be consulted to understand how fully the river towns abound with groovings following the general course of the valley.

Prof. Dana argues that the Connecticut valley ice moved towards the sea at the same time that the great ice movement was in progress south-easterly upon both sides, and explains it as the necessary result of a natural law. "It moves just as thick pitch poured over a sloping surface, in which there are a few large groovings, would move, the mass following the general surface, and the portions in the grooves nearly or quite the course of the grooves. The thickness of the ice that followed the course of the valley was at least 2,000 feet." Three considerations are presented in favor of this view:—first, in Massachusetts and Connecticut only the course with the valley has been observed; second, if the glacier were local, 2,000 or 3,000 feet thick, the southerly scratches ought to be found further west than they now are; third, there is more easting in the course north of Massachusetts, as if produced by some part of the general movement. I think it much better to believe the Connecticut Valley movement was confined exactly to the limits where its evidences are found, and to say that the south-east courses found here and there within it are the relics of an earlier and grander glaciation. In fact, when different parts of the same ledge, as in Hinsdale, show the courses S. 10° E. and S. 60° E., no amount of argument can convince one that the ice moved in both these directions at the same time. It is impossible.

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[*] *Am. Jour. Science*, iii, vol. 2, p. 233.

The phenomena agree best with the theory that the south-east course originally covered both the valley and the adjacent borders for scores of miles, but that, after the ice ceased to be furnished abundantly from the St. Lawrence, the residue followed its natural way down the several river depressions to the sea, and, being of considerable thickness, was able to leave abundant evidences of its passage.

Prof. J. D. Dana was the first to insist upon the existence of a Connecticut glacier separate from the general mass of drift. My father was the first of American geologists to point out the fact in any publication of the existence of local glaciers radiating from high ridges.* He was led to this conclusion from a comparison of the ancient glacial drift in Wales and Switzerland with the drift generally, and with the local examples seen by him in western Massachusetts and Vermont. As the common phenomena of the drift seemed to him best explicable upon the iceberg theory, his ready recognition of the real glacial markings in the Westfield and Deerfield River valleys shows how ready he was to accept truth, even against his judgment of the proper interpretation of the phenomena of nature. His suggestion of a movement down the Connecticut valley is not to be regarded as a claim that he understood the whole depression to be scored like the few examples he had seen.† The fact established clearly by him was, that the Hoosac and Green Mountains supported the *mer de glace* in the last part of the ice period, from which local glaciers flowed down, both towards the Connecticut on the east, and to the Champlain valley on the west. We can now extend this deduction eastwardly, and say that there was a Connecticut Valley glacier in the latter part of the ice period, with branches both from the west and the east.

The branch glaciers on the west that have been described are these: Upon Westfield river, with its tributaries, especially Little river; Deerfield river, both in Massachusetts and Vermont; West river, joining the

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* *Report Geology of Massachusetts*, 1853. *Smithsonian Contributions*, vol. ix.

† The following is the passage referred to (*Smithsonian Contributions*, vol. ix, p. 136): On examination, I did find, on the west side of the Connecticut valley, that what I called drift striæ, instead of running north and south, as they usually do, turn southerly south of South Hampton as much, in some places, as S. 65° W. I suspected at first, either that these markings were produced by the [Westfield] glacier, after it reached the Connecticut valley, or that the supposed glacier scratches were the result of drift agency operating up hill. But when I found that the stoss of the glacier striæ was the west side, and that of the drift striæ was the north-east, both these suppositions were shown to be untenable; and I accounted for the south-west direction of the drift striæ by the expansion to the right of the Connecticut valley south of South Hampton. I think this the right interpretation of the facts, but I could wish to give them further examination.

Connecticut just above Brattleborough; Saxton's river; Black river in Ludlow and Cavendish; Otta Quechee river; White river. Those farther north have not been particularly explored. On the east side, the branches of this glacier are not well marked. This may be explained partly from lack of attention directed to their discovery, but chiefly because the east side of the basin is very narrow. There is not sufficient room for the glaciers to form, and to make much sign of their existence. In Massachusetts, Miller's and the tributaries of the Chicopee river might furnish some indications of the former presence of the ice. In New Hampshire, the Ashuelot is the first valley where we could search for these relics. They may be expected in Winchester, where the river changes its course to pass between hills, and in the towns of Surry and Gilsum. It will be singular if these localities do not afford striæ or other indications of the tributary ice-sheets. We have no observations for Cold river; and all that has been noted in the Sugar River valley indicates the passage of the ice up instead of down the stream. The marks of the older south-east current were so pronounced that any action of a force in the opposite direction might be unnoticed. The Mascomy valley is rather short; and ledges between Enfield and Hartford, Vt., are rare. There is a moraine-like accumulation of till about a quarter of a mile below the outlet of the lake, whose origin may be explained either by supposing it to be the frontal rubbish of a local glacier, or the filling up of the valley by the south-east current from Hayes hill. The existence of the projecting hill is very marked; and it is spoken of by the residents of East Lebanon as a former barrier to the progress of the water, so that the lake must once have had a much greater extension, leaving its shore marks forty or fifty feet above the present level of the water in beaches of sand. Excavations in this barrier show both the lower and upper till with great distinctness. Next come Mink brook, Hanover; Great brook, Lyme; Jacob's brook, Orford; Bean's and Eastman's brooks, Piermont,—none of which afford marked glacial features, that is, we have not noted any. On the north branch of Jacob's brook, between S. H. Sargent's and the water, are many large blocks of Bethlehem gneiss, the rock which is in place a mile higher up, and not at the place of crossing. I did not follow down the stream to search further for these boulders. But the evidence is clear of the transportation of rocks down the stream in a westerly direction; and this may indicate what sort of phenomena should be looked for, in the other westerly descending valleys mentioned, to satisfy us of the existence of tributary glaciers. No pains have been taken to observe this class of facts. Oliverian brook in Haverhill may be expected to show some signs of a local glacier descending the west flank of Moosilauke. On page 30, considerations are presented to show that unusually abundant gravel and sand deposits in Haverhill must have been derived from such a source as this local glacier would be. We have also a barrier-like ridge of till lying across the Oliverian valley suggestive of a former terminal moraine. There are many boulders of Bethlehem and porphyritic gneiss in the Oliverian valley, seemingly of eastern origin. If not from the Moosilauke pile, they must have been brought down by the main Connecticut Valley ice. The numerous marks between Haverhill and Carroll may be regarded as made by one branch of the Connecticut glacier. These are very abundant, and satisfactorily illustrate the local movement. Those down the Passumpsic valley are less common and convincing.

Above the Ammonoosuc district the Connecticut Valley movement seems to have been interrupted in consequence of the presence of the Gardner Mountain barrier. The markings in this part of the valley do not conform to the topography, and must therefore be regarded as made by the older movement. The map (Pl. II) illustrates the nature of the ground over this space. Above Lancaster there are well marked signs of a local glacier, probably the last movement in the region, separate from and later than that just described. Its existence is manifested by moraines and not by striæ, and may be classed with the Bethlehem glacier, to be described presently in the words of the late Prof. Agassiz.

Midway between Stratford Hollow and North Stratford is a pile of granite boulders so conspicuous as to arrest the attention of the most careless. They occupy several acres of ground, and seem to form a terminal moraine. It is represented in Fig. 53. The exact location is indicated by the word Moraine on Pl. I; and a section crossing the valley is shown in Fig. 2. Mr. Clough's stereoscopic view of the same is entitled "New Hampshire Cow Pasture." The name indicates the use to which the field is put, while the abundance of boulders seems to have discouraged the owner from attempting to make a stone wall of the material. A dozen walls would so slightly exhaust the supply that none of the boulders would be missed. The largest boulder represented weighs about 1,300 tons. On looking across the valley, similar boulders, but less abundant, can be seen on the Vermont side. I suppose they extend beneath the intervening meadow the whole distance, and therefore present us with an admirable example of a terminal or frontal moraine. The material corresponds closely with the granite quarried a few miles up the Nulhegan river by the side of the Grand Trunk Railroad. The ice there seems to have descended the Nulhegan river before joining the frozen stream of the Upper Connecticut. Pl. I shows a projection of glacial drift into the valley, at Horseshoe pond, in Northumberland. This promontory is suggestive of other terminal moraines farther to the south. I do not recall their nature, so as to say definitely whether the resemblance is only accidental. It might be added, that the drift hills on Israel's river approach each other closely, just above Lancaster village, in the manner of a frontal moraine.

Fig. 53. Moraine in Stratford.

The Merrimack Movement. The limits of this particular ice mass would be naturally the east and west water-sheds, while the northern boundary does not extend beyond New Hampton on the main stream, passing instead to Newfound lake. The movement north of New Hampton belongs to another area quite distinct. It is thus like the Connecticut glaciers, divided by a barrier above Monroe. As thus limited, the Merrimack glacier is with difficulty separated from the general southeasterly movement. The country is almost flat below Concord, so that there is little opportunity for a local glacier to exist for want of inclination; and the western sloping valleys on the east side rarely show any marks pointing westerly. From Winnipiseogee lake to Franklin the descent is sufficiently great to induce motion, 225 feet in fifteen miles, but the ledges are covered, and no topographical feature suggests glaciation. Any special striation or embossment in the lower part of the Suncook and Soucook rivers would be concealed by the immense piles of alluvium of later origin. The upper Souhegan valleys are better adapted to show these evidences; and no situation could be better than that of the upper Contoocook for exhibiting traces of the glacial action distinct from that of the general drift. Warner river valley is much like the Souhegan. Three of the more northern tributaries of the Merrimack show good evidences of the valley movement,—Smith's, Blackwater, and the Pemigewasset rivers. I will describe these first.

Smith's River. This stream rises at Orange summit, follows the Northern railroad through Grafton and Danbury, and thence turns easterly between Alexandria and Hill. The course of the valley usually corresponds with that of the general movement, but the phenomena of embossment are like those of local glaciers. In the Orange summit notch, the course is S. 36° E., a few more degrees easterly than is common in Canaan and the north part of Orange. It is the same at the north end of Tewkesbury pond, but 5° less at the outlet. The rock for several miles about is admirably adapted to exhibit striation and embossment, and the phenomena at the outlet of the pond where the railroad passes can hardly be excelled for perfection in any part of the state. Any one familiar with glacial phenomena would instantly recognize them while passing in a train. At the mica quarries on the west side of Grafton valley, the course is about the same; also, at a school-house between the two Grafton stations. We should expect somewhat more easting at this point, as the course of the valley has commenced to change. Two tributary valleys from the north, Mill and Whittier brooks, may show striation coursing more southerly; but these, and all the rest of the Smith's brook region, have not been specially examined with the object of noting the glaciation. The lower part of Smith's river changes its course so much that if a mass of ice followed it, the variation in the direction of the striæ would be very observable. Between Alexandria and Hill there has been considerable excavation since the ice period, so that the markings may be looked for away from the stream. We have good reason to expect to find evidence of local action all along Smith's river, provided the ledges are not too much covered up.

Blackwater Valley. The map of local glaciers in Volume I represents the movement of the ice as continuous from Grafton and Danbury along the railroad, to connect with that in Andover along the Blackwater. I have separated them now, because it seems more natural for the ice to flow down Smith's river to join the Pemigewasset, than to cross the Danbury water-shed, where the necessary rise is not far from a hundred feet. The course in the south part of Grafton, on the highlands, is such that the continental sheet points directly to Andover, or to the valley between Mts. Ragged and Kearsarge. It is not therefore certain that the ice going down the Blackwater, whose marks remain, should be classed with the later movements. But it is certain that the course was modified by the valley, so that it belongs to the category of those motions whose course did not proceed in defiance of elevations and depressions of the surface. Several ledges at Potter Place and Andover show that the course was much more easterly than the very east directions upon Kearsarge and Ragged [see page 200]. It has 20° more easting than on Kearsarge, and 40° more than upon Ragged. This course would naturally turn at Andover Centre, and proceed southerly through Salisbury, if it continues to conform to the valley, and not climb the hill at East Andover like the railroad. Such facts as are reported confirm this view. The East Andover ridge is occupied by drift, perhaps lenticular moraines; and the striæ in West Franklin run S. 32° E., and therefore belong to a different movement. The top of a hill west of the Blackwater, on the south town line, shows the course S. 38° E., and on its south slope are striæ running down hill towards Salisbury. And in this last named town the courses are S. 12°, 15°, and 22° E., the greatest easting being in the valley on Bean's hill, near the south boundary line. The courses in Webster would not vary essentially from those in Salisbury.

The Pemigewasset below Ashland. Local glaciation probably reaches from the mouth of this stream at Franklin all the way to Newfound lake and up Cockermouth brook in Hebron and Groton. At the outlet of Webster lake the course is S. 32° E., which may represent the normal direction to the west of the Pemigewasset. North of Franklin village the direction is S. 27° E. This continues uniform for three miles; and the grooves and embossment are remarkably well developed near J. W. Simonds's. At this point there is a conspicuous bend in the course of the valley; and the striæ are observed to change their direction to conform with the topography. At S. Pike's, a mile beyond Simonds's, the striæ point S. 42° E. From here to Hill the valley broadens, and the ledges are covered by sand. At the east side of the river, in the north-east edge of Franklin, the course is S. 22° E. down the valley, and the accompanying embossments are admirable. This locality is opposite to the first named examples below the prominent bend in the river.

On the Sanbornton side of the valley, between Hill and Bristol, there are ledges which have their stoss sides marked from the north, and they probably present other illustrations of the local action. Our table contains several observations of south-east striæ down the valley of Cockermouth brook in Groton. The east side of the lake shows other striæ, however, pointing up hill, and therefore having no connection with the local glacier.

There are examples of a local sliding in New Hampton and Bridgewater. These are all connected with the Pemigewasset movement, and are mentioned in the tabular list.

The Lower Merrimack. Several points may be made about the lower Merrimack movement. The general direction of the valley is S. 15° E., so that striæ varying ten degrees from this on either side may be regarded as belonging to this special glacier. From Franklin to Massachusetts we have, in order, S. 15°–27° E.; Canterbury, 15°–40°; Boscawen, 17°–27°; Concord, 9°–11°–21°; Hooksett, 16°–26°; Manchester, 15°–26°; Londonderry, 11°–21°; Souhegan village, 16°; Nashua, 11°; and in Hudson an interesting case of intersection, S. 3° x 21° x 36° E. On the east rim of the basin are higher figures. Belmont, 32°–42°; Gilmanton, 32°–52°; Loudon, 40°; Pittsfield, 42°; Deerfield, 40°; Northwood, 32°–37°; east part of Hooksett, 41°; ridge east of Manchester (quarries), 40°; Candia, 21°–41°; Londonderry, 41°. It would seem as if these observations might be interpreted as indicating a difference between the direction of the forces down the valley and over the eastern rim. There are a few strongly marked south-east courses on the west rim, as through Washington and Springfield, that are between 20° and 30°. Hence there is not that definiteness of demarcation between the rims and the valley courses that we found in the Connecticut. The three courses in Hudson may perhaps be regarded as typical of as many different movements. The unusual direction of S. 72° E. in Deerfield, on the north side of Mt. Pawtuckaway, may have been due to the presence of the mountain mass.

There is one example of striæ sliding N. 40° W. on the east side of the valley. It is at the Amoskeag granite quarry in Manchester. Its existence would not be known save for the removal of the earth for quarrying. Who knows how many more such cases may exist under these loose materials, sufficient to make sure the presence of the glacier in the Merrimack valley!

In the Contoocook valley we find no evidence from striæ to suggest the northward motion of the ice. Unusual accumulations of till at Hillsborough Bridge and in the west edge of Henniker are suggestive of terminal moraines pushed forward by such a movement. The striæ in Antrim follow the course of the valley, but may have gone southerly. The North Branch valley, in the same town, is deep and narrow, and hence well fitted for the passage of a glacier. We find marks indicating that it was crossed by the main ice-sheet without regard to the depression.

Our final conclusion, from all the facts, must be, that the Merrimack movement was largely a topographical modification of the course of the main ice-sheet. As occasional remnants of the genuine south-east current occur, it may be proper to say that the modification would naturally take place in the interval of time between the predominance of the south-east current and the local glaciers. And in the latter period the Merrimack ice became still more restricted, and feebly imitated the local action elsewhere.

Baker's River and Winnipiseogee Movement. This is an interesting example of a movement seemingly both local and hardly separable from the action of the continental sheet. It starts with a south valley in Benton, curves to the east with Baker's River valley in Rumney, extends nearly due east over Squam lake and Sandwich, and then enters the valley of Winnipiseogee lake, merging into the normal south-east course after leaving this hydrographic basin. Allusion has been already made to the latter part of its course (p. 121 *et seq.*). The movement down the upper Pemigewasset may be regarded as a branch of this.

On the summit of Moosilauke the striæ run S. 22° E., a course less easterly than is common over the high mountains of the state. This corresponds with the direction through Warren and Wentworth, save a few local tributaries in Warren mentioned in the table. The easting seems greater than the proper course of the valley; but a correspondence was noted between the direction of the striæ and of the depression when the observation was recorded. The numerous observations in Rumney indicate a gradual bending of the scratches in complete agreement with the change in the course of the valley. On the south side, the south-east course does not reach the top of the rim, as the directions in Groton on the ridge between Baker's river and Cockermouth brook are S. 22° and 32° E. The glacier was certainly 500 feet thick, and probably not much more at this point. In the west part of Plymouth and the south-east corner of Rumney are remarkably fine examples of striation and embossment of the ledges. I hardly think a finer place could be found for a photographic representation of these phenomena than of the east base of Hawks mountain in Rumney. A spur of the hill projects into the valley, which was struck powerfully by the ice as it descended, beautifully embossing the schists and scoring the domes with striæ. One ledge has numerous large blocks of stone on top, some measuring as much as 20 feet long, 10 wide, and 8 high. Further west the mural striated surfaces are common, as between A. Kelley's and J. Davis's houses. On the north side of the valley two elevated ranges come close to the river,—Rattlesnake and Stinson mountains,—which are precipitous for two hundred feet. On these steep sides striæ are often visible, though much of the rock containing them has fallen to the base of the hill. Wolf hill in Plymouth, a solitary bunch of granite in the midst of a low country, has been passed over by this glacier as if it were of no consequence.

The Pemigewasset valley turns to the south below Plymouth; but the striæ continue on in the direction observed in Rumney, just as if the ice could not stop after it began to slide. The smallest easting in Holderness is S. 37° E., on top of Mt. Prospect; the ridge of Squam mountain shows S. 62° E.; and there are others equally pronounced. Sandwich, however, shows the greatest amount of easting. At several places it travelled a little north of east, and the east course is frequent. The movement did not continue further east into Tamworth on the north side of the Ossipee mountains, since the marks there are quite southerly, though Chatham hill shows the course S. 42° E. The mass seems rather to have gone south-easterly to the lake through Moultonborough, and over Red hill, S. 62° E. On reaching Winnipiseogee lake the striæ on the east side average a more easterly course than on the west side in the towns of Meredith, Gilford, and Alton. The occurrence of the Moose mountains directly in the path of the Winnipiseogee ice suggests whether the course was not changed on account of this obstacle in its way. It is a fact, that the course on the summit of these mountains is that of the longer axis of the lake, while there is a much greater easting to the north-east. The striæ at Tuftonborough Corner run N. 68° E., as if crowded closely upon the flank of the Ossipee mountains. Nearly all the observations in Tuftonborough, Wolfeborough, Brookfield, and Wakefield run between south-east and east. Mr. W. Upham explains this condition of things, by supposing the ice of the Ossipee basin melted earlier than that over Winnipiseogee, and hence the ice from the latter area moved towards the vacancy left on the east side. If most of the ice were forced to pass out between Ossipee and Moose mountains, a part of it might emerge through Alton. The striæ there have a much less easting than on the other side of Moose.

Thus it would appear that the topography of the country between Warren and Wakefield, along the valley of Baker's river and Winnipiseogee lake, determined somewhat the direction of the motion of the ice, whether it be regarded as a part of the continental sheet or a local movement.

Upper Pemigewasset Movement. The observations of the striæ in the upper Pemigewasset valley are grouped together in the table (p. 185). The valley runs southerly, and the striæ mostly conform to it; at the very entrance, high up, we have the course S. 8° W., above the Eagle lakes on Mt. Lafayette. On the summit of Bald mountain, in the Franconia Notch, the course is S. 2° E., with a large boulder of Bethlehem gneiss on its summit. The same force went over Mt. Profile, leaving many boulders of the same kind. It appears from these circumstances that a large body of ice entered the valley from above, which must have been a portion of the larger and older sheet. This and the later local masses scored the vertical east side of Mt. Pemigewasset, with the course S. 12° E., working southerly. Other examples occur through Lincoln and Woodstock, following the valley. Were the forests cleared upon both sides of the stream, many other interesting examples would be found. At North Woodstock, the hills upon the west side display a magnificent embossment on a large scale, as worthy of photographic reproduction as those in Rumney. There seems to be more easting in lower Woodstock and Thornton than is needful to conform to the valley. This may be explained partly by the fact of local turns in the course, not obvious, except on the ground. On the rim of the valley to the south-east is the course S. 70° E., which may have influenced somewhat the direction of the ice lower down, yet is sufficiently different to satisfy us that the marks in the valley were not produced by the same movement. Through Campton the scratches essentially follow the valley. A single case is reported from Mad river, high up, of a descent N. 32° W., or down one of its tributaries. This will be an example of the local movement, or possibly the result of a recent slide, described in Volume I. Below Campton, the Pemigewasset glacier joined the ice movement down Baker's river, and went with that over to Lake Winnipiseogee.

Androscoggin Movement. Should a glacier start from the Rangely lakes and follow down the whole Androscoggin river, the course would be to the south-west, then south, and then a turn to the east as far as Bethel, in Maine. We have evidence of a strong south-east current over Rangely lake, and in Upton on the east side of Umbagog lake,—a movement not of a local character. Down the Magalloway river, close by the College Grant, there was a well defined valley movement, S. 4° E., towards Umbagog lake. There is a pretty lateral moraine of granite blocks at the uppermost landing of the steamboat in Wentworth's Location, resting upon Huronian schists. The rocks for several miles up the Magalloway are finely embossed. The numerous striæ in Errol, S. 73° E., have no connection with the Androscoggin, and we have no further observations from this valley till we reach Gorham. The rocks here are much weathered, but have the aspect of ledges struck from above, with a few south-east striæ. According to Vose, the striæ upon the top of Mt. Hayes, directly opposite the opening of the Peabody valley, run S. 40° E., or nearly at right angles to the direction up the river towards the Glen house. The Androscoggin valley, with its low, broad terraces, is very different from the high sand-banks near the mouth of its Peabody tributary, suggesting the origin of the former under very unlike circumstances. The utter absence of all material transported down the Peabody at Gorham would indicate its removal by the powerful current of the Androscoggin, for certainly such deposits could not fail to have been brought, and seemingly at a later date than the existence of the Androscoggin glacial river. These facts suggest either extensive freshets in post-glacial times, or the longer continuance of the Androscoggin glacier. The valley below Gorham village, for two miles or more, consists chiefly of rubbish from the sides, moved by the rains and frost, not in the terrace form. No particular signs of glacial action are seen before reaching the middle part of Shelburne, near the most northerly course of the river. Here, at the height of 150 feet above the railroad, upon a projecting ridge, are grooves pointing down the valley, S. 88°, N. 88° E. The east side is a rough cliff, never touched by ice action. At the extreme north point of the hill, the course is S. 63° E. On this lee side of the dome are many rough granite blocks, each from five to twenty feet in length. They have been transported only a short distance, and are properly a moraine caught behind the projecting ledge. These markings are those of a well defined local glacier.

On reaching Clement's brook are other fine embossments, with striæ S. 73° E. The former have been described upon page 195. Local moraines appear upon the projecting side of these ledges. Similar embossments occur on the north side of the river, opposite Clement's brook. About a mile below Clement's brook, opposite the first house with a conspicuous tower, is a rough ledge, protecting moraine material. A similar ledge further east has the west side rounded by ice. Near the state line is an outcrop of white gneiss, scored S. 58° E., and an enormous quantity of boulders, torn off the light colored ledges, follow for a short distance. These several examples of blocks torn from the ledges, but not carried far, illustrate the beginnings of glacial transportation.

For about half a mile into Maine, in the town of Gilead, glacial marks are wanting. In the middle of the valley is a long rocky hill athwart its course, behind which moraine material is gathered. At the north foot of Mt. Ephraim are striæ S. 65° E., where the road and railroad draw close together.

Grooving is well shown here. Above Mt. Ephraim the rounding looks as if it had been produced by a mass of ice coming down Ingalls river from the north. On the east side of Wild river the rocks have been well planed and embossed by the force down the Androscoggin. No explorations have been made up this tributary to ascertain whether ice-marks from the south-west may not exist there. At Gilead station, just north of the railroad and ten miles from Bethel, are furrows upon polished quartz running S. 40° E. A mile further east, where the road bends around a mountain spur, are striæ S. 80° E. On the west side of Peaked hill, where the high land crowds closely upon the river, about 300 feet above the water, is a large, steeply inclined, magnificently polished surface, very plainly seen from the road below, a mile and a half distant, with faint lines and well defined furrows, S. 55°-60° E. The embossment and planishment show even better from the north side of the river. On this north side, by the bridge at Gilead station and at the mouth of Peabody brook, are grooves following the course of the valley, and also large rough blocks removed only a short distance. At a church, the markings occur almost at the water's edge, with the direction S. 75° E. On the precipitous south side of Tumble-down Dick are many examples of striæ on vertical surfaces; but the greatest force of the ice struck the ledges on the south side. At the base of the precipice, where floor surfaces are exposed, are grooved areas 150 feet long, thoroughly planed down the whole distance. It would be difficult to find more beautiful examples of ice-sculpture in New Hampshire. The striæ run S. 85° E. Near White brook are other striæ and bosses, with rough south-east lee sides.

At the east line of Gilead, on the north side, the striæ run S. 60° E. No further marks were seen on the north side of the river from this point to Bethel hill. Ledges are scarce, and covered by drift.

The observations mentioned above, between Peaked hill and Gilead, on the south side of the river, are taken from Prof. Vose's account of this interesting glacier.* I will quote his own words for the facts between Peaked hill and Bethel. His course was up the valley from Bethel.

> Where glacial furrows are found upon the tops of the Bethel hills, they run nearly north and south. Proceeding up the valley towards Gorham upon the south bank, at a point about two and a half miles above Bethel, before we really enter the close valley, and perhaps one hundred feet above the river, a small exposure of rock is seen directly in the common road, being about six feet square, with a long, gently sloping polished surface towards the north, and a steep and rough face towards the south. The furrows upon the smooth northern surface run north and south; and the hills, upon the summits of which the furrows run north and south, lie exactly north of this rock upon the opposite side of the river. This furrowing had evidently no connection with the Androscoggin, as the grooves point almost directly across it. Continuing up the valley just above Pleasant river, five miles above Bethel, about a quarter of a mile south of the road and perhaps two hundred feet above the river, the rocks are well polished; and, from faint lines upon masses of quartz, the direction of the ice is seen to have been S. 50° E. Six miles above Bethel, where the river, railway, and road draw closely together and sweep around the base of Peaked hill, there is a steep ledge, about twenty feet high, close to the track, which is polished and furrowed, both upon the nearly vertical face towards the river, and also upon a narrow horizontal shelf part way up on the ledge. The lines upon the horizontal shelf run S. 20° E., the vertical face standing S. 25°–30° E. It is necessary, however, to be guarded in drawing conclusions from glacial traces left upon vertical or steeply inclined surfaces, as the movement of ice, jamming through a narrow passage, may be locally disturbed, so as to give a direction to the furrows quite different from that of the general movement of the glacier. This was most likely the case at the point referred to, as the furrows on the opposite side of the hill—*i. e.*, the south side—ran S. 80° E., thus according much more nearly with the traces, both above and below this point, than the furrows upon the steep face towards the river do. The ice would seem to have passed around both sides of this hill; and we can readily conceive that this might be, since the depression in the rear, south of the elevation, is quite low. Indeed, in the fine view from Sunset Rock in Bethel, Peaked hill seems to rise in a very isolated manner from the middle of the valley, which makes it a very prominent feature in that magnificent picture.

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* *American Naturalist*, vol. ii, p. 284.

There are no indications of the passage of this glacier below Bethel, so far as I had time to search for them. I did not follow down the Androscoggin on the south side, and the north side only to Bear river, though I crossed it at Rumford Point. I found evidences of local action down Bear river, in Grafton and Newry, and upon Ellis river in Andover and Rumford, as well marked as those along the Blackwater in Andover, N. H. On the east town line of Bethel, the striæ run S. 4° E., and S. 24° E. On Paradise hill, south of the village, the course is S. 23° E. These all correspond to the common course of the drift in this part of the state.

Saco Valley. A few points of interest manifest themselves through the valley of the White Mountain Notch, which may be regarded as a local movement. The mountain east, Webster, shows the course S. 30°–37° E. On the west, Tom, S. 57° E., Field, S. 50° E., Willey, S. 42° E., corresponding well with the usual south-east course on the highest summits. Mt. Willard, which is really the head of the valley, shows distinct striæ, more abundant on the slate towards Field, running S. 23° E. In the very Notch, by the railroad, the course is S. 20° E. Under the Butterwort flume, close by the railroad, at a small house, are glacial lines on a mural surface running with the valley; and on the south side of Mt. Willard the course S. 15° E. was measured. On the railroad, by the Willey brook, the striæ may be seen from the train on both sides, and is thought to be southerly, as it certainly occurs parallel to the valley. Other markings down the valley directed more easterly, occur upon the north side of Frankenstein cliff. Below Bemis a mural surface shows similar scratches over a limited area. No other markings have been seen. Mt. Washington river shows an immense cliff of rudely stratified material near its mouth, comparable with the similar deposit on Peabody river produced by the melting of a local glacier. The immense amount of boulders and coarse moraine material just below Sawyer's Rock suggests detritus brought down by a local glacier. The tributary Duck Pond stream, west of Bemis, shows striæ upon a mural surface, pointing S. 18° E., which may have been connected with the Saco glacier. The nature of the rocks, readily disintegrating, and their obscurement by débris and forests, render it difficult to accumulate many facts about drift phenomena in it; but enough has been seen to indicate the probability of the existence in it of an ancient local glacier.

The Latest Glaciers.

Having now described the various phases of glacial motion in the state, referring all our observations of direction to their various classes, it may be proper to introduce a related topic, upon which much might be offered. I will content myself with the briefest mention possible.

The examination of various isolated hills in the south part of the state indicates that, as the closing up of glacial action, there has probably been a sliding on all sides from the summit, not sufficient to score ledges, but enough to push boulders to the base. It is common to find a dome-shaped hill, of not necessarily large dimensions, nearly encircled by a ring of boulders. The explanation of their presence, as suggested by a friend, is, that the ice moved from the summit down the various sides precisely like the radiation of local glaciers from lofty mountain ranges. The materials transported are what have once been acted upon by the ordinary glacial agency. Attention has not been called to this reärrangement by other authors, as there is nothing striking about it to suggest anything different from accumulations brought in the ordinary way. This action is akin to that of the local glacier, and where the hills are large would be classed with them.

I had commenced a careful study of this class of hills, when the singularity of the presence and arrangement of the lenticular moraines began to be developed, and led me to devote what time remained to that more important subject. I have therefore no well digested facts to present upon the later phenomena. I will only point out a few examples of them. To properly set forth this subject would require a thorough topographical survey, wherein elevations of ten feet would be indicated, as well as the character of the surface in all its variations of ledge, peat, meadow, forest, cleared and cultivated fields, rocky pastures, etc.

After beginning to look at our hills in the light of this suggestion, I have been surprised to discover how frequent the examples are. Such as can be readily recalled will be enumerated. One particular must first be specified, wherein these phenomena are scarcely distinguishable from others of equal importance. They are like lateral moraines. In fact, it is conceivable that the rubbish sliding down the side of a valley may fall upon the edge of a moving glacier, and be pushed along afterwards so as to constitute a true moraine. The observer will call a particular example a lateral moraine, or one derived by the later sliding, according to his prepossession. For example: in Moultonborough, between Long and Round ponds, is a long drift ridge in the middle of the valley parallel with Red hill. This may be called the local frontal moraine, sliding from the whole western slope of Red hill, or else a lateral moraine of ice from the north pushing towards Lake Winnipiseogee. I think this example, as it lies fairly in the middle of the valley, is properly a case of sliding from Red hill; but Prof. Agassiz refers to this, or one like it, in a paper cited a few pages ahead, as a lateral moraine. At the south-west end of Red hill, this same moraine changes its direction, conforming to the slope of the hill. Other illustrations are in the Wildcat valley of Jackson, which seem to be the lateral moraines of the ice filling the whole valley.

Near the town lines of Moultonborough and Tuftonborough, next Ossipee mountain, are several ridges, mostly gravelly, that seem to have been turned up by ice sliding down the elevation. By Mrs. Brian's they are large and conspicuous, with a south-east course. Further south, they begin to trend a little more southerly than is required for perfect parallelism with the mountain, and often are a mile long. Near G. Hartford's in Moultonborough is a small ridge of drift parallel with the mountain. In the south-east corner of Sandwich are quite extensive ridges of till parallel with the Ossipee mountains, and having a course about north-east and south-west. On the east side of the same mountains, from Moultonville nearly to West Ossipee station, is a nearly continuous fringe of large, angular blocks of porphyritic granite, such as occurs at the east part of the elevation, underlying the granitic breccias. These probably underlie the broad sand plain of the Bear Camp river. Green mountain in Effingham is an isolated elevation; and I thought at first these granitic blocks at the base of Ossipee came from it, having been transported northerly. Rock of similar character occurs on Green mountain, but it does not seem to have been carried so far to the north. There are many large blocks of granite close by Ossipee pond, at the cross-roads about three miles north-west from Green mountain, which probably came from the Ossipee mountains, moving east or south-east. The largest one seen is 21 feet long, from 7 to 14 high, and 16 wide. Green mountain has a great thickness of hard, compressed till upon its northern flank, extending more than half-way up. At its base are some small ridges turned up parallel to the mountain, with the steep slope against the mountain, as would naturally be the case if their origin were what is here indicated. The till has usually a smooth surface, the loose blocks having been removed from it by the sliding. Some of the striated blocks, as at James S. Smith's, have been deposited in stratified sand. A boulder of Ossipee granite over the sand near here is 12 feet in diameter. The thick deposit of till is wanting on the south side.

Between Greenfield and Bennington are rows of boulders on the south-west side of a large lenticular hill.

Crotched mountain in Francestown and Bennington may be taken as a good example to illustrate the presence or absence of this class of deposits. An attempt to make a thorough examination of this elevation was frustrated; but evidences of the moraines were seen on the south-west side, consisting of many large, rough blocks and ridges on the north-east side of Whittemore pond. Similar blocks occur on the road nearest the mountain on its south side. The north-east slope of this elevation is smoothed, as if there had been a sliding over the till; but I have not seen the nature of the ground at the very base. As it appears uncultivated when seen from a distance, it is probable that so much rubbish has been pushed into it from Crotched as to make the land difficult of tillage.

The north side of the New Durham and Brookfield Moose mountain is thickly strown with large boulders of granite and schist, obscuring the ledges.

Various evidences of local sliding appear in the city of Manchester. One is at the corner above Brook street. Three layers appear in an excavation, the two lowest apparently resembling the upper and lower till. The uppermost—of a lighter color—may have slid down the hill about the time of the termination of ice action. It is a material that runs like porridge when wet. Other similar cases have been removed in grading for new streets. The north-west side of Company hill for over a mile shows many moraine-like windrows parallel with the ridge. These contain more or less boulders, and are properly referable to this latest action. Perhaps these moraines should have some connection with the north-west course across the rock near the Amoskeag granite quarry. On the south-east side of this hill, back of the granite quarries, as we pass the pest-house on Bridge street, is another local moraine. Bald hill, near the east line of the city limits, furnishes other illustrations, there being two north and south lines of moraines upon its east side. On the south slope of this hill are numerous blocks of granitic gneiss, situated in a north and south course, reaching nearly to the railroad. One of them is 20 feet square. These seem to have been derived from Bald hill. Other lines of moraines occur at the south-east base of the Reservoir hill, where the fragments are angular.

In Grafton are high hills extending from Prescott's easterly along the Springfield line. A brook flows easterly along their base, turning at an acute angle by a small pond, and entering Smith's river at Grafton station. Within this acute angle are piles of drift parallel with the easterly hills south. These may be the rubbish sliding down from the south across the brook.

In Chester, two hills near each other seem to have crowded this loose detritus into the valley between. First is the gneiss hill in the north part of the town; and we find a line of blocks on its south-east side from Wm. S. True's round to near North pond, a distance of two or three miles. There may have been additions to the moraines from the smooth hill south, upon which Chester village is situated.

In Deerfield, the direct road from Candia to the Centre across a long ridge in the south part of Deerfield descends to a large branch of the Lamprey river, and then rises much towards the Centre. On both sides of this stream are lines of moraines parallel with the brook, and also with the valley. These are excellent illustrations of this class of moraines. How far these moraines would extend along the valley, can be known only by further search. Our traverse is simply one section across them. Other examples occur in crossing the parallel tributary one mile south from the Centre.

The hill north of Pawtuckaway pond in Nottingham, on the road nearest to and around the mountain, shows lines of moraines parallel to the hill south-west from Quincy pond. Some of the blocks are 12 or 15 feet in length.

In the north part of Fremont is a round hill less than 200 feet above the plain, around which are local moraines, especially upon the north-west side. There is a large field of big blocks near the Baptist church on the east side. The east and west road in the north parts of Fremont and Brentwood lies over numerous drift ridges and moraines essentially parallel with the stream and the higher land to the south. These may not be local.

In Kensington, the lenticular hills in the north-west part of the town show good illustrations of the local moraines in the form of many rough blocks and small mounds on the north-east side near M. Hobbs's. Some of the blocks are 20 feet long. This example is of a large moraine deposit by the oldest drift, serving for the centre of dispersion of blocks at the close of glacial work.

South of the railroad at Raymond for two miles, chiefly east from the village, are many moraines of all sizes, referred to local action, in case the high land to the north is regarded as the locality from which they have come. They are as conspicuous as most moraines left by the older drift.

The foregoing are sufficiently numerous to call attention to the subject of these late movements of earth analogous to glaciers. In this same connection, I desire to describe certain other glacial phenomena of more consequence, but which usually do not prove themselves by any striæ or embossment. They are better examples of ice action than what has just been described, but like them, move down valleys and hillsides, smoothing the ancient hill, and pushing along boulders. It is the action of glaciers upon material that had already been moved by the continental ice, and which belong to a later period still than the valley movements and local glaciers. All these glacial movements are described here before speaking of the boulders and moraines, so that the subject of glaciers may be treated as a unity. This class of facts was first brought out by the late Prof. L. Agassiz, who spent much time in their study about Bethlehem. I had the pleasure of seeing the phenomena he describes, under his guidance, and can testify to the fidelity of his statements. He communicated to me many other speculations concerning the existence of glaciers in the neighborhood, some that I could not indorse; but it is very gratifying to see that he published only what would stand the test of the most rigid scrutiny. It is to be regretted that he was unable to make other further publications, as intimated in the following paper. I subsequently searched the mountains, and other parts of the state, for facts confirmatory of Agassiz's views, both as to the special case described and to the further development of similar classes of facts in other localities. These facts I will present after reproducing the original paper referred to. I find evidence of a local glaciation in the White Mountains, not in the style of sculpture and moraine advocated by Packard and Vose, but in the peculiar form of evidence first suggested by Agassiz. It required a genius like his to point out the proper method of investigation.

Twenty-three years ago, when I first visited the White Mountains, in the summer of 1847, I noticed unmistakable evidences of the former existence of local glaciers. They were the more clear and impressive to me because I was then fresh from my investigations of the glaciers in Switzerland. And yet, beyond the mere statement of the fact that such glaciers once existed here, I have never published a detailed account of my observations, for the simple reason that I could not then find any limit or any definite relation between the northern drift and the phenomena indicative of local White Mountain glaciers; nor have I ever been able since to revisit the region for more careful examination. This year, a prolonged stay among these hills has enabled me to study this difficult problem more closely, and I am now prepared to show that the drift, so-called, has the same general characteristics on the northern and southern sides of the White Mountains. Whatever, therefore, may have been the number of its higher peaks which, at any given time during the glacial period, rose above the great ice sheet which then covered the country, this mountain range offered no obstacle to the southward movement and progress of the northern ice fields. To the north of the White Mountains, as well as to the south, the northern drift consists of a paste more or less clayey or sandy, containing abraded fragments of a great variety of rocks, so impacted into the minutely comminuted materials as to indicate neither stratification nor arrangement or sorting, determined by the form, size, or weight of these fragments. Large boulders and pebbles of all sizes are found in it throughout its thickness, and these coarser materials have evidently been ground together with the clay and sand under great pressure, beneath heavy masses of ice, for they have all the characteristic marks so unmistakable now to those who are familiar with glacial action,—scratches, grooves, furrows, etc. These marks are rectilinear, but they cross each other at various angles, thus showing by the change in their direction that the fragments on which they occur, though held for a time in one and the same position while these straight lines were engraved upon their surface, nevertheless changed that position more or less frequently. A few flatter fragments with more angular outlines show only one kind of scratches, having evidently been held for a longer time in the same position. This drift, however it may vary in its mineralogical components in different localities, exhibits everywhere the same characteristic treatment over the whole country, from the shores of the Atlantic to the Rocky Mountains, and beyond. In the White Mountain region it has the same mineralogical character north and south of the range, and rests everywhere upon the well known *roches moutonnées*,—in one word, upon the planed, grooved, polished, and scratched surfaces of the rocks underlying it.

Observation has taught us that materials such as those described above, so combined, exhibiting the same characters in their surfaces, and having the same diversity of composition and absence of all sorting or regular arrangement, occur now at the bottom of the great glaciers of our time, and nowhere else, being found between the ice and the rocks over which it moves,—the result, in fact, of the grinding action of advancing glaciers. On account of their unvarying position, I have called these deposits "ground moraines," because they are always resting upon the rocky floor of the country, between it and the under surface of the ice. Our typical unaltered so-called *northern* drift is synonymous with the ground moraines of the present day, differing only in its greater extension. It is in fact a ground moraine spreading over the greatest part of the continent. All its characteristics, identical in every detail with those of the deposits underlying the present glaciers, show that it can only have been formed under a moving body of ice, held between it and the underlying mass of rock. The great ice sheet of the glacial period which fashioned the drift must therefore have been coëxtensive with the distribution of the latter. It is very important to distinguish this drift from the moraines formed under other circumstances, and from the so-called erratics and perched blocks. Moraines, as commonly understood, that is, lateral and frontal moraines, consisting of loose materials collected along the sides and at the terminus of a glacier, always indicate, and, where undisturbed, actually define the margins of a moving mass of ice; whereas, the so-called median moraines formed along the line of junction of the glaciers are carried upon the back or upper surface of the ice, and always consist of angular materials, the shape and arrangement of which are determined by their mode of accumulation. Just as among the glaciers of the present day we discriminate between ground moraines, lateral, frontal, and median moraines, so must we also distinguish between the same phenomena in past times. The glacial period had also its ground moraines, its lateral, its frontal, and its median moraines, its erratics and perched boulders. But the huge ground moraine of the earlier ice time stretched continuously, like the ice sheet under which it was formed, over the whole country, from the arctics to the Southern states, and from the Atlantic to the Rocky Mountains. I do not speak of the western slope of the continent, because I have not examined it personally. The great angular erratics of that period were scattered irregularly over the country, as the few large boulders are scattered on the upper surface of a glacier now. It is the contact of the more limited phenomena of the local glaciers which succeeded this all-embracing winter (their lateral, frontal, median, and limited ground moraines and their erratics), with the more wide-spread and general features of the drift that I have been able to trace in the White Mountains this summer. The limits of this paper will not allow me to do more than record the general facts, but I hope to give them hereafter more in detail, and with fuller illustrations. The most difficult part of the investigation is the tracing of the erratics to their origin; it is far more intricate than the identification of the origin of ordinary drift, or of continuous moraines, because the solution of the problem can only be reached under favorable circumstances, where boulders of the same kind of rock can be followed from distance to distance, to the ledge *in situ* from which they were detached. Now, in the neighborhood of the White Mountains, we find, beside the typical or northern drift, large erratic boulders, as well as lateral, frontal, and median moraines. A careful examination of these shows beyond a doubt that they came from the White Mountains, and not from the northern regions, since they overlie the typical drift which they have only here and there removed and modified. A short description of the facts will leave no doubt upon this point.

The finest lateral moraines in these regions may be seen along the hillsides flanking the bed of the south branch of the Ammonoosuc, north of the village of Franconia. The best median moraines are to the east of Picket hill* and Round hill. These latter moraines were formed by the confluence of the glaciers which occupied the depression between Haystack and Mt. Lafayette, and that which descended from the northern face of Lafayette itself. These longitudinal moraines are particularly interesting as connecting the erratic boulders on the north side of the Franconia range with that mountain mass, and showing that they are not northern boulders transported southward, but boulders from a southern range transported northward. But by far the most significant facts showing the great extent of the local glaciers of the White Mountain range, as well as the most accessible and easily recognized, even by travellers not very familiar with glacial phenomena, are the terminal moraines to the north of Bethlehem village, between it and the northern bend of the Ammonoosuc river. The lane starting from Bethlehem street, following the cemetery for a short distance, and hence trending northward, cuts sixteen terminal moraines in a tract of about two miles. Some of these moraines are as distinct as any I know in Switzerland. They show unmistakably by their form that they were produced by the pressure of a glacier moving from south, northward. This is indicated by their abrupt southward slope, facing, that is, toward the Franconia range, while their northern face has a much gentler descent. The steeper slope of a moraine is always resting against the glacier, while the outer side is comparatively little inclined. The form of these moraines, therefore, as well as their position, shows that they have come down the Franconia mountains. A few details concerning their location may not be out of place, in order that any visitor

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* Since called Mt. Agassiz.—C. H. H.

interested in the facts may readily find them without a guide. The ground to the north of Bethlehem slopes gently northward, and is not wooded for about half a mile from the street. Following the lane above mentioned, the first moraine reached skirts the edge of the wood, and is near the houses of Mr. Phillips; there are four others more or less distinct before reaching a little trout brook called "Barrett's brook." The lane descends more rapidly towards the brook than before, and where the descent begins to be steep the eye commands the space between the brook and a higher ground on which stands a house owned by Henry McCulloch. Over that interval six very fine moraines may be counted, one of which is perhaps the finest specimen of a terminal moraine I have ever seen. Beyond McCulloch's there are five more, not quite as distinct. The ground beyond the termination of the glacier of the Rhone in Switzerland is celebrated for its many distinct concentric terminal moraines; but here we have a field over which, within the same area, a larger number of such moraines may be seen, and I believe that a pilgrimage to this spot would convert many a skeptic to the true faith concerning the transportation of erratic boulders, especially if he has seen the glacier of the Rhone, and can compare the phenomena of the two localities.

The Littleton road from Bethlehem, and the roads to Franconia Notch from both these towns, frequently intersect terminal moraines. Those familiar with the topography of the Franconia range, and its relation to Picket hill and the slope of Bethlehem, will at once perceive that the glacier which deposited the front moraine to the north of Bethlehem village must have filled the valley of Franconia to and above the level of the saddle of Picket hill, making it at least fifteen hundred feet thick, if not more; thicker, in short, than any of the present glaciers of Switzerland. It will be observed, also, that as soon as the northern portion of that glacier had retreated to the wall which encircles the Franconia valley on the north, the glacier occupying henceforth a more protected valley within the ranges must have made a halt, and accumulated at this point, that is, south and west of the saddle of Picket hill, a very large terminal moraine. This moraine actually exists to the present day, and is one of the most characteristic features of the distribution of erratics in these regions. From the moment the glacier was reduced to the level of Franconia bottom, it must suddenly have vanished entirely from the whole valley; and thus it happens that no other large terminal moraines are seen between that just mentioned and the higher range of Franconia.

Moraines similar to those observed on the northern side of the White Mountains exist also on their southern side in the vicinity of Center Harbor. Lateral moraines may be traced at the foot of Red hill, a little above Long pond; also, along Squam lake. Median moraines are very distinct near Center Harbor hotel. Terminal moraines are also numerous near Center Harbor, and in the neighborhood of Meredith. At the southern end of Red hill the lateral moraines trend westward, and show their connection with the terminal moraines. These facts, taken in their relation with those enumerated above, show that there were local glaciers on the southern as well as the northern slopes of the White Mountain ranges, moving in opposite directions,—those on the northern slope moving northward, and those on the southern slope moving southward. I have seen no evidence thus far of these northern glaciers extending beyond the range of hills which separates the Ammonoosuc river from the Connecticut river valley west of Lancaster, nor have I traced the southern glaciers beyond Lake Winnipiseogee. Traces of an eastern glacier moving westward may be seen near the Twin Mountain house; but I have not examined that region with sufficient care to give minute particulars.

All these moraines and traces of local glaciers overlie the typical or northern drift, so-called, wherever the latter has not been swept away by the local glaciers themselves; thus showing that the great ice sheet was anterior to the local glaciers, and not formed by a spreading of preëxisting glaciers. At least, wherever I have recognized traces of circumscribed glaciers in regions where they no longer exist, it has always appeared to me that the minor areas covered by ice were remnants of a waning sheet of greater extent. If the glacial period set in by the enlargement of limited glaciers already formed and gradually spreading more and more widely, as Lyell and the geologists of his school suppose, the facts which would justify such a view are still to be made known. I have not seen a trace of them anywhere. On the contrary, throughout the ranges of the Alps, in the Black Forest, the Vosges, as well as in the British islands, in Scotland, Wales, and Ireland, I have everywhere satisfied myself that the more extensive the glaciated areas indicated by polished surfaces and moraines, in any given locality, the older they are when compared with glacial phenomena circumscribed within narrower limits.

It therefore follows from the facts enumerated above, as well as from a general consideration of the subject, that the local glaciers of the White Mountains are of more recent date than the great ice sheet which fashioned the typical drift. On another occasion, I hope to show that the action of the local glaciers of the White Mountains began to be circumscribed within the areas they covered, after the typical drift had, in consequence of the melting of the northern ice sheet, been laid bare in the Middle states, in Massachusetts and Connecticut, after even the southern portions of Vermont, New Hampshire, and Maine had been freed, and when the White Mountains, the Adirondacks, and the Katahdin range were the only ice clad peaks in this part of the continent.

When in their turn the glaciers of the White Mountain region began to melt away, the freshets occasioned by the sudden large accumulation of water remodelled many of these moraines, and carried off the minute materials they contained to deposit them lower down in the shape of river terraces. I have recently satisfied myself, by a careful examination, that all the river terraces of the Connecticut river valley and its tributaries, as well as those of the Merrimack and its tributaries, are deposits formed by the floods descending from the melting glaciers. What President Hitchcock has described as sea-beaches and ocean bottoms near the White Mountain and Franconia Notches, as well as in the Connecticut river valley and along the Merrimack, have all the same origin. The ocean never was in contact with these deposits, which nowhere contain any trace of marine organic remains.—*American Naturalist*, vol. iv, p. 550.

LOCAL GLACIERS IN THE WHITE MOUNTAINS.

I will now present whatever additional facts may be known respecting the existence of former glaciers radiating from the White Mountain highlands. We have seen that my father and Prof. Agassiz agreed as to the nature of the glacial markings upon the mountains,—that they belonged to the older and continental sheet, a south-east movement proceeding up hill whenever obstacles made it necessary. The markings described by Packard and Vose, claimed to have been the result of local glaciation in the Peabody valley, have been shown to belong to the older movement. The others mentioned by Packard in Jackson are properly local, and will be described presently.

In order to prove that glaciers have radiated in all directions from the White Mountains, it is necessary to find evidences of northerly or northwest motion. Evidences of valley movements towards the south-east can easily be referred to the general south-east movement, modified slightly by the topography. If nothing else could be found, the doctrine of the existence of local glaciers would depend upon unreliable evidence. The researches of Agassiz about Bethlehem were the first in this direction in New Hampshire. He found evidence of a movement opposite to that of the general drift. Hence this must have been different from the common drift, and, taken in connection with the other features described, it was found to have been local, and existed in the decline of the ice period after the continental sheet had mostly disappeared. The action was rarely sufficiently energetic to score the ledges. Agassiz does not rely upon that class of evidence in maintaining his position. The ice of this Franconia-Bethlehem movement has passed over ledges, but has not smoothed or striated them. The boulders which went southerly in obedience to the south-east movement were simply pushed back towards their source; and we find very few cases of their protrusion beyond their starting-point. I will first add whatever observations I can in elucidation of this specific example, and then describe the other observed facts seen nearer the mountains.

The starting-point of this glacier was in the prominent valley back of Eagle Cliff, on the north-west flank of Mt. Lafayette. This was visited by my father in 1851, and a sketch of the phenomena seen described soon afterwards.* It appears that in 1850 a powerful rain soaked the débris in this valley so that it slid a considerable distance downwards, and left deposits analogous to moraines, but did not materially engrave the ledges.

At the head of the slide we saw a mass of naked gneiss rock many rods wide, mostly denuded of soil, and much of it also of several layers of the rock, which had slid downwards, and were strown along the sides of the ravine for at least two miles. This naked surface, at its upper part, had a slope of about 38°. Lower down, however, it was much less, for the most part, and at its termination the descent was slight. * * * It was just such an example as I had long wished to find. An enormous mass of detritus, probably from ten to twenty feet thick, and in some places two or three rods wide, composed of irregular fragments of all sizes, from twenty feet in diameter down to sand, had been driven forward over a rocky surface two miles long. What, now, was the effect upon the rocky floor? Did it score and striate the floor, as was done by the drift agency, as some suppose would be done by the crowding forward of detritus by the power of water? I found it was not so. The rock in place was smoothed but not striated, except in a few places, perhaps in the slightest manner. The fundamental rock passed over is gneiss, but it is traversed occasionally by veins of granite, and towards the upper part by dykes of trap several rods wide. They are such rocks as in various places retain distinct markings of the drift action. The beds of detritus produced along this slide are so closely like those of glacial origin that we may call them *moraines*. They are larger and more distinct than I have seen on any other slide. All along the borders of the ravine are ridges of blocks, gravel, and sand, sometimes twenty feet high, lying in as much confusion as is possible, and making it difficult and even dangerous to go into or out of the ravine over the loose and crumbling ridges. At the lower end of the slide is a large terminal moraine, by which the river has been forced to seek a new channel. This terminal moraine is, in fact, double; that is, an old moraine lies in advance of that produced by the slide of 1850, the blocks of the two being easily distinguished by the appearance of recent or more ancient erosion. In short, the appearances along this gulf are almost precisely what they would be if a glacier in one of the valleys of the Alps should melt away. And when examining it, I had no doubt that the slide was produced by the advance of a mass of ice; yet I noticed that, in some places, the lateral moraine was driven in among the trees without affecting them. In some places near the bed of the slide I noticed the stumps of trees, perhaps six inches in diameter, that had been broken off by the descending mass.

This valley was regarded by Agassiz as the source of that glacier. In confirmation of it, boulders of Franconia breccia like the ledge composing Eagle cliff, have been found near J. McDonald's, in Franconia, at

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* *Am. Jour. Science*, ii, vol. xiv, p. 73.

the end of a road on the direct line between the cliff and Bethlehem street. The distance of their transportation is about two miles, and no locality of this rock is known to exist nearer McDonald's than Eagle cliff. Many of these blocks are four feet in length. The ledge near here does not show any ice marks from the local glacier, but there are appearances upon it of the usual south-west movement of the neighborhood (page 211). North of McDonald's, towards Gale river, the surface of the drift is smooth and nearly flat. This is to be explained by the passage of the ice over it, as in Bethlehem. Near the western edge of this flat expanse is a moraine running N. 27° W., about 20 feet high and 40 rods long. It is thought to have been connected with this Bethlehem glacier, as a medial or lateral moraine. The hill slopes rapidly just west of the moraine, and has many quite large boulders scattered over it.

Between Bethlehem street and Littleton is a Baptist church, near which I observed boulders 15 feet long, 10 wide, and 10 high, whose source is estimated to be from 300 to 500 feet to the south up hill. Their transportation down this slope I ascribe to the same local glacier.

There are numerous moraines commencing a few rods east of Littleton railroad station, probably put in their present position by ice of this or a related glacier. The eastern slope of the hill between Bethlehem street and station is thickly strewn with large boulders, of material similar to the nearest ledges. Their position is suggestive of transportation down the Ammonoosuc from the east. As similar rocks occur as far as the Twin Mountain house, it is not unlikely that the Ammonoosuc glacier brought them there; but further study is required to demonstrate the proposition.

Ammonoosuc Glacier. We have a few facts in regard to the movement of rocks down the Ammonoosuc valley, probably caused by a local glacier. The ice transported boulders far below Bethlehem station, so that abundant proof exists of the existence of a glacier close by the gneissic blocks just mentioned, on the east slope of the Bethlehem hill. The source of this movement was in the large valley occupied by Concord granite, between Fabyan's and the Presidential range. Many large blocks of a coarser-grained granite than ordinary lie upon the slope of Mt. Deception, just opposite the Fabyan house, and along the turnpike for a mile easterly. These have not travelled far, having been derived from the south base of Mt. Deception. One piece is 22 feet long, 14 high, and 10 thick. Those 6 feet in length are common. The fragments are too far removed from the mountain to have accumulated merely by gravity. A similar moraine is cut by the railroad just below the White Mountain house at the head of the falls in the Ammonoosuc.

The recent clearings disclose a sharp, conical moraine south of the Mt. Pleasant house, perhaps 20 feet high, and very different in character from the neighboring mounds of esker and river gravel. The many large granite blocks, where the railroad approaches near the Ammonoosuc river, above Mt. Pleasant and near the upper falls, are also like a local moraine.

In the fields east of the Twin Mountain house there are hundreds of boulders of Mt. Deception granite, often 12 feet in length. The underlying rocks, for the four or five miles distance between the Twin Mountain house and Fabyan's, are of very different material. Hence this is an example of materials transported westerly a distance of four miles. This cannot have been done by water,—the blocks are too large. A local glacier sliding over the more ancient drift must have been the agent of transportation. This lateral moraine east of the Twin Mountain house is quite conspicuous, and the most readily accessible of any examples known. It may be seen from the train, a short distance east of the station.

Just west of Rounsevel & Colburn's saw-mill, midway between the Twin and White Mountain houses, I found a large block of granite, in 1871, nearly 12 feet in diameter, and about square, closely resembling a handsome variety of granite occuring on Mt. Willey, and further south. A second smaller one exists in the neighborhood. I have never found this particular kind of granite north of the Notch in ledges, and as it occurs with the Conway granite near Mt. Willey, it is probable that these blocks descended the New Zealand valley, starting from the west side of the same mountain. Other boulders, seemingly from the south, are a few of Chocorua granite near the Crawford house, in which Prof. Dana discovered grains of chrysolite. I know of no ledge to the north of their present situation from which they could have been derived, while similar ledges abound farther south.

Examples of transported boulders of Albany granite are more decisive of a glacial movement down the stream. From the mouth of New Zealand river nearly to Bethlehem station are numerous blocks of this granite, six feet in length. This rock is in place on the New Zealand river, but not on the Ammonoosuc. Hence the fragments must have moved down the stream (also Little river, in Carroll), and being too large for water transportation, require the agency of a glacier. Rude striæ, supposed to have been made at this period, occur near the Wing road in the river. The boulders are found as far south as North Lisbon. I obtained a specimen there weighing about eight pounds. No search has been made for them lower down. Their location in the river, and angular shape, indicate transportation by a local glacier. About half a mile above Bethlehem station the valley is almost closed by a large hill of till, with some stratified layers on the outside. This eminence resembles a moraine.

On Little river, about four miles above its mouth, is a slide worthy of mention. For a distance of 50 rods the ledges are bare, where they have been exposed by the sliding, commencing at a point and expanding to 20 rods width. At the base of the hill are 10 rods space as long as the width of the slide, full of fallen trees with their trunks mostly arranged in convex order, opposite the direction of transportation. No other features of local motion were apparent in the Little River valleys, largely because a dense forest prevents them from being seen, or else the power exerted in this slide was not sufficient to score the exposed ledges. It is probable that the Bethlehem and Ammonoosuc glaciers united and flowed down the latter stream several miles below their junction.

River Moraines. In the Saco valley the tributary streams have brought down immense masses of large boulders that would be called moraines elsewhere. They cross the main valley like terminal moraines. The larger the tributary the more important the deposit. They are particularly conspicuous at the mouths of Bemis and Davis brooks, Nancy and Sawyer's rivers. The latter deposit has been cut through by a railroad excavation. This is the most conspicuous example. On descending the valley by the carriage-road, we approach a broad expanse of the terrace where are one or two farms, and also the turning off of the branch railroad to Livermore. The highway ascends a sort of terrace, and the railroad cuts into it, rising somewhat. At the excavation, the nature of the material is well shown, consisting of smooth boulders, from pebbles to boulders two and three feet in diameter. The bed of the river shows similar detritus. The stream is so violent in high water that these boulders are pushed downwards, and as the force of the current abates the detritus accumulates by the sides. The amount brought down is so great that it rises higher than the meadow, and thus we have a deposit analogous to that of the levee near the mouth of the Mississippi. The tributary stream causes this very coarse deposit to form a ridge reaching nearly across the Saco valley, and at right angles to it. Hence it simulates the terminal moraine of a glacier, and might easily be mistaken for one, if the connection between its presence with the tributary were not noticed.

Below Sawyer's rock this coarse material exists in such amount that it is difficult to decide whether it should be called a glacial or a river moraine. The rubbish has accumulated in the eddy behind the ledge, and can be called by either name. It must be 50 feet thick, and cover half a square mile of surface. It seems to have been excavated at Stillings's old hotel stand by Albany brook from the south, and the moraine between this stream and Upper Bartlett station is of large size. The railroad cuts through a similar bank on the north side of the Saco, about opposite the mouth of Stony brook in Hart's Location.

I have already mentioned a few examples of striæ on the ledges in the valley of Saco river and its tributary, Duck pond, which are referable to a local glacier. Through most of Bartlett the land is flat, as if all the rubbish that usually occurs in the form of terraces had been washed out. The soil is sufficiently good to enable farmers to cultivate it extensively. For a mile and a half along Burbank and Cow brooks, there is a ridge of coarse material comparable with a lateral moraine. It is where detritus would be naturally deposited, as the river begins to bend northwardly. Where the Saco runs northerly to meet Rocky branch is another moraine pile, at the angle formed by the meeting of these two streams. Below this point the valley widens into the broad gravelly meadows of Lower Bartlett and Conway, which have been previously described (p. 143). Dr. Bemis points out at the base of Mt. Crawford a granite block, as much as 12 feet in cubical dimensions, now in the middle of the meadow. This came from the cliff 500 feet above the plain a few years since, and after striking the meadow bounded a distance of 10 rods to the spot where it now lies. A series of moraines occurs at the saw-mill on Rocky branch, and for half a mile above.

Ellis River Glaciers. A recent visit to the main Ellis river and the Wildcat Branch in Jackson enables us to describe the markings left by the ice in its descent. Dr. Packard has called attention to them in a paper cited above. He gives scarcely any details, and relies upon the course of the striæ, mainly, for the proof of the existence of the local glaciers. These have been credited to him in the table of striæ. One remark is of importance: "Riding up the Conway valley, up through Bartlett to Jackson, we observe moraines innumerable rising high up the sides of the valley, and, covered with boulders, revealed more distinctly in all the cleared lands. Above these moraines rise rounded and embossed rocks, while the evenly terraced valley shows that the river, then a series of broad lakes, reärranged and re-sorted the compressed materials composing the mounds left by the melting glacier into finely, evenly stratified fresh water deposits." I noted some of these moraines in Bartlett, or the edge of Conway, in the woods south of the Interval station. Mr. Bigelow's fine summer residence is upon one of these moraines; and the blocks are quite numerous among the pine trees further south. The striæ S. 60° W., observed by Vose on the south side of Mt. Pequawket, must have been made by a branch from the east. After reaching the Ellis valley, there is a proper moraine of a local glacier just below Goodrich falls. In the edge of Jackson is a ridge in the middle of the valley, about an eighth of a mile long, with many large boulders upon its surface. Small cuts in it show the presence of some boulder clay. This reaches nearly to the bridge across the Ellis river, shortly below the entrance of the Wildcat Branch, and in a proper medial moraine. On reaching the village of Jackson, the valley divides; and I will first refer to the glacial traces seen on the main stream. There are large moraines upon both sides of the valley north and south of a large boarding-house, perhaps an eighth of a mile west of the falls. Those south are at the base of Cobb's hill, and are less important than those on the other side. About two miles up the valley are lateral moraines. About opposite the mouth of Miles brook the ledges show striæ running down stream, and have been abundantly rounded, producing the phenomena of embossment. Better examples occur higher up. The last notable example of the same is to be seen close by N. H. Cook's, or the last farm-house in Jackson. There is here somewhat of an expanse, while above the descent is greater, and no intervals can be seen. A careful examination of this valley will disclose many more facts, both in the settled and forest portions. On reaching the height of land in Pinkham Notch, we approach the Peabody valley, and find marks of a movement up the valley towards Ellis river. The ice travelled a little west of south, north of the water-shed, but east of south in the Ellis valley. It is difficult to say that the movement in the Ellis valley was disconnected with that in the Peabody. It is likely that, in the earlier glacial times, the course was first west and then east of south, while in the decline of the period the ice ceased to flow from the Peabody into the Ellis valley. There may have been a local northerly movement in the Peabody valley, also, as suggested by the enormous terrace, in the south part of Gorham (p. 210).

The marks upon the Wildcat Branch have been more carefully examined, although the scoring of ledges is less common than on the main stream. At the top of Jackson falls are many moraines supposed to be terminal, and of the last valley movement. An examination of their composition shows them to be a miscellaneous accumulation of ferruginous earth and rough stones of granite and schist. There has been no arrangement of the different sorts by aqueous deposition; it is an unstratified pile. Its red color arises from the extreme oxidation and hydration of the mass. The material corresponds closely with that of the upper till of the older drift, which we shall describe more fully presently. The origin of the two deposits is believed to be the same. These moraines cross the valley, and are about 140 feet above the bridge between the hotels. The next set of terminals jut out into the valley half a mile beyond, and probably once stretched across it. Near J. Gale's is another set, 215 feet above the bridge. On the west side of the valley, large, rough blocks of stone are common, while the east is smooth. A fourth moraine appears at the two Elkins's houses, a mile and a quarter from the bridge. The fifth example is near D. Gray's, shortly before coming to the road leading towards Black mountain. These moraines are lateral, and there is a slight depression between them and the hill west. There are many rough blocks near the road on the east side of the valley, on the south flank of Black mountain, which are to be regarded as lateral moraines, opposite to those mentioned at Gray's, but higher up.

A sixth set of moraines crosses the valley at a new saw-mill near Mrs. E. Gray's, two and a quarter miles north of the bridge, and 255 feet higher. Above this point the valley keeps the same contour as far as Johnson's mill, 150 feet higher, and more than a mile distant. No well marked local phenomena display themselves here, nor higher up, along the carriage-road. Possibly a search in the wooded tract adjacent to the stream might reveal something interesting above Johnson's. A cut in the drift here shows it to belong to the lower till. Opposite L. Wentworth's, nearly a mile above Johnson's, is an esker, or kame, 1,000 feet long, which may have originated during the melting of this glacier, and is thus one of its evidences. On reaching Grant's (Breck, on map) the present road ceases, but the valley might be followed further to the north-west. Here are striæ quite varied in direction. The face of the rock is smoothed in the direction of the valley a trifle west of south, crossed by faint irregular lines S. 33° and S. 83° E. These would be explained by calling the smoothing the direction of the ice down the valley, and the striæ caused by a local tributary sliding from the western flank. The top of the ledge, where there is freedom from local currents, displays the course S. 44° E., the normal direction of the ancient drift, pointing nearly to Mt. Washington. The Wildcat shows other interesting phenomena of local action further north, but I have not been able to examine them. I will add notices of them from Nowell and Sweetser. The slide described by the first properly belongs to one of the tributaries of the Peabody river glacier.

W. G. Nowell has given estimates of the position and dimensions of a slide upon the west side of Carter Dome, Vol. I, *Appalachia*, p. 83. I condense his account. The date was the same with that described upon the west side of Tripyramid. Mr. Thompson, the proprietor of the Glen house, lost his life in this freshet, while managing affairs at his saw-mill. The top of the "hopper," where the sliding commenced, is 1200 metres from the summit. It descended N. N. W. 300 metres, dropping 110 metres; then fell 140 metres in a course of 400 metres due north; next moved 500 metres W. N. W., descending 110 metres, and continues only 100 metres further. For the principal part of the last 700 metres the ledge is perfectly bare from 30 to 60 metres in breadth, and has piled up at its base about twenty square acres of rubbish that had come down the mountain. The greatest angle of descent, 42°, occurs in the upper and lower of the four sections, and the least angle of 18° is in the third section from the top. The minimum widths of the four sections are 10, 15, 20, and 30 metres; the maximum 15, 20, 30, and 90 metres. The minimum depths of the excavation were 15, 10, 5, and 3 metres; the maximum 18, 15, 10, and 10 metres.

Mr. Sweetser, in his guide-book, speaks of a line of boulders in the Carter Notch which may have had some connection with glacial action. At the south entrance of the Notch is a lofty line of immense boulders, piled on each other in inextricable confusion, and affording some of the most remarkable rock scenery in the mountains. They are rugged and deeply pitted, like the rocks on the cone of Mt. Washington, and may have been derived from the crests of the adjacent peaks. One or two of these boulders are near seventy feet long each.

Returning to Jackson, we find a tributary of the Wildcat coming from the north-east, and uniting with it about a mile above the falls, which ought to show a few glacial traces. I found nothing very characteristic, unless it were a few boulders of a peculiar porphyritic granite. I think these must have been derived from the north, as nothing like them is known in ledges west of Mt. Baldface, or "Peaked," a summit so called by Packard, and not named upon our map. The striæ upon these mountains do not point towards Jackson, as they belong to the older set. Mr. Packard says,—"On the summit [of Baldface, where the striæ run S. 23°–28° E.] rest several angular boulders of a peculiar porphyritic sienite, containing curious oblong crystals of albitic feldspar. Our guide to their source—the trusty ice grooves—points to Peaked mountain;" and, by investigation, he found the rock *in situ* upon that eminence. The porphyritic boulders found by me did not come from the mountains mentioned by Packard, as the rubbish derived from them would have gone down the east branch of the Saco, joining the main stream in Lower Bartlett. Further search will develop evidences of the existence of this glacier in the east branch. Packard speaks of staurolite mica schist boulders on the north flank of Mt. Pequawket, saying "they must have been borne down on the back of the glacier from Mt. Washington." This is hardly probable, since the rock occurs on both the north and south sides of Pequawket, and the boulders are even more abundant on the south side of the mountain. Jackson Falls village is situated in a hopper-shaped depression considerably open on the west side. Pickett, Thorn, and Tin mountains constitute the north and east rims, Black and

Eagle the north and west sides, while Copp's hill on the west very nearly completes the circle, with rifts for the entrance of the ice from Wildcat and Ellis rivers. On nearly every side the material low down consists of an immense thickness of till, cut deeply by small streams. This deposit gives an evenness of slope to the hills about Jackson that is uncommon among the mountains. It is believed that the till is mainly of ancient glacial origin brought from the north-west, and that the latest ice movement smoothed it over and left many large blocks of stone and small moraines. The north slope of Pickett hill shows several examples of what appear to be local moraines. Packard speaks of a block of many tons' weight upon a hill near Goodrich falls brought in this way only a few rods. In the neighborhood are striæ pointing S. 17° W., as if connected with the valley movement just mentioned down the tributary of the Wildcat river.*

Pot-holes. In northern New England there are many examples of pot-holes worn in ledges far away from existing streams. These are believed to have been formed by currents of water derived from the melting ice-sheet, passing down the crevasses of the glacier. Those on the summit between different valleys were formerly referred to the agency of one of the rivers pouring over the divide into the other depression. Many of our examples are so situated that such a theory would not explain them. I append a list of the principal pot-holes that have come to my notice:

One 4 feet deep on top of Swett's mountain, Gilmanton.

One of large size in Wentworth. It is on the south-west side of Carr's mountain, from 300 to 500 feet above Baker's river.

In the "Flume," Dixville, I saw one, 4 feet in diameter and 7 feet deep, in the process of formation.

On a ledge exposed for 200 feet, near its south end, a conical one, 2 feet in diameter at the top, and about 2 feet deep. It is 125 feet above the river at East Weare, and in the edge of Dunbarton. It is called "Indian mortar" by the people living in the neighborhood.

The same name is applied to a pot-hole near the top of Beech hill in New Hampton, about 600 feet above the valley of Lake Wukawan. It is situated on the south-western peak, not quite so high as the other, and perhaps 15 rods south of and 40 feet lower than the highest point. There are no other evidences of water action on the ledges of

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* I have assumed that Packard's observations were not corrected for the variation of the compass, as he does not say anything about it.

porphyritic gneiss than this, and they fall off precipitously for 200 feet. The mortar is 2½ feet from the edge of the rock. It is not perfect, as a notch is gone on the south side, so that the cavity is shaped like a pitcher with the nose broken off. The width across the top is 1 foot 3 inches; depth, on the north side, 2½ feet; depth below the notch on the south side, 1½ feet. The bottom is rounded, and it is frequently filled with water.

Mr. Upham has described the pot-holes of the Orange and Newbury summits, and Warwick, Mass., on pages 63–66.

At Amoskeag falls, Manchester, on the Merrimack, are several pot-holes; one of them is 12 feet in diameter and 25 deep.

The "Purgatory," on the line of Lyndeborough and Mont Vernon, shows other pot-holes. The stream—10 feet wide—winds spirally through a narrow chasm, and then falls 15 or 20 feet into a large pool. Both the spiral course and the pool are to be classed with pot-holes, and there are several small examples above the main cataract. A cave below is thought to have originated from ordinary disintegration through freezing.

Local Movements in Vermont. Besides the tributaries of the Connecticut glacier already mentioned, I will speak briefly of the other valley movements occurring in the area of our map. There has been an easterly movement up the valleys of the Lamoille, Missisco, and Winooski, perfectly distinct from the general south-east progress of the continental sheet. It seems to have been a modification of the south-east current, caused by the contour of the country, and in no sense a local glacier. They are to be compared with the movement of the ice up the valley of the Peabody river (p. 208).

I found excellent local glacier phenomena in the valley of Lincoln brook, a tributary of Mad river in Warren. In Plainfield, boulders of granite seem to have been transported north-westerly to the main village from Harris and Goshen gores. Other cases are probably Trout brook in Montgomery, and near Lake Memphremagog from the west.

Lake Basins.

One of the evidences of glacial action is seen in the hollowing out of basins in the solid rock, which are now occupied by lakes or ponds of fresh water. If one travels around the border of certain lakes, he will discover that it is everywhere rock-bound. In considering the possible methods of excavation of such a basin, some cannot be accounted for except by glacial action. We should consider, first, whether it might be a synclinal basin; second, whether it might result from the removal of a soluble mineral like limestone. Running water excavates rocks only where a descending current can act; hence it could never remove anything from beneath its level. Ordinary lake ice cannot excavate beyond a few inches below water level. Nor could the ocean, if it were present, excavate any deeper. There is no other agent left for us to employ, except the glacier. When this starts, having a strong force to urge it onwards, it will plough out rocks in its descent, and then move up hill. This sort of denudation is fitted to excavate lake basins.

There are numerous examples of these basins excavated out of the rock for lakes and ponds in our state. I purposed to make a catalogue of them, to be presented here, specifying all whose outlet flowed over ledges, and those where till or modified drift constitute the barrier. I found, on studying the subject, that a barrier of lower till would keep in the water as well as a ledge, so that the enumeration of ponds kept in by barriers of rock or till made little practical difference as to the stability of the water. Furthermore, a lake may be essentially kept in by a rock barrier, while the drift spreads an additional obstacle to the flowage outwards; and, as scarcely any examples could be found of ponds kept in by barriers of loose materials, it may not be necessary to present a formal catalogue of the nature of outlets, citing, instead, a few familiar examples.

Geological treatises make mention of Runaway pond in Glover, Vt., where a sandy barrier led to the sudden outrush of the water, after an attempt made to increase the size of the outlet by excavation. Similar floods have occurred recently by the removal of artificial dams, as in the well-known Mill River disaster near Northampton, Mass. We have a record of a similar flood on the Mascomy river, occasioned by the bursting of the original barrier of the lake at East Lebanon. The loose material was not abundant, so that little damage resulted. The Northern Railroad company have since renewed the barrier with better material. It is an interesting circumstance to recall the ancient barrier of till about a quarter of a mile below the present outlet (p. 216), whose removal in pre-historic times may have caused a great freshet. In Warren, the signs of the bursting of a barrier in ancient times are very distinct. A gravel ridge like a kame crossed the valley of Black brook, damming the stream and producing a pond. What circumstances destroyed this barrier are not known, but the former existence of the pond attracts universal belief. Another case is in the edge of Lyman below Young's pond. A new road follows the stream above the saw-mill, and the gravel hills on both sides for a quarter of a mile look as if they had been cut apart within the memory of the inhabitants. An old shore line, marking the former height of the pond, is still quite conspicuous. As one passes the south end of Station pond in Springfield, he is at a loss to see why the water does not immediately make an opening for itself towards New London. Upper Beech pond in Wolfeborough is an example of an existing pond kept in by a deposit of loose gravel (p. 128). There are many instances of ponds in gravel plains kept in by loose materials when the amount of water is not sufficient to lead to a sudden removal of the barrier. Such are indicated on the general map by the absence of any outlet.

Our largest lake,—Winnipiseogee,—must be a rock basin, although no ledges appear at its outlet (p. 121). The land falls off abruptly for about 1400 feet at the Weirs, in slopes say 600 feet long on the north-west, and 800 on the south-east of the middle of the channel, the amount of the fall being nearly 80 feet. As one looks at this from the east it resembles a gorge excavated by running water, and it would not be strange if the till had once been continuous across the present outlet. In that case the outlet would have been from Alton bay towards the Cochecho river. The present channel has been deepened about a yard by the Lake company. About 25 feet of till has been removed by erosion at the outlet of Newfound lake.

The majority of our ponds have ledges at their outlets. Those who are interested in the subject can ascertain whether a given example has been excavated from the ledges by observing the nature of the outlet. It is very often the case that no ledge is visible about a pond, save where the water discharges itself. If any dams are constructed upon loose gravel or sand, it will be well for those interested in the integrity of the works to examine them from time to time.

DISPERSION OF BOULDERS.

The second part of our subject relates to the removal of fragments of stone from their original ledges, and to any peculiarities that may be observed in their position, shape, size, distance and direction of transportation, etc., including the various kinds of moraines. The striation is believed to correspond in direction with the course taken by the fragments in their travels. The stones usually proceed in right lines from their sources, at first in large rough blocks, then showing more abrasion and less size, till they have been reduced to pebbles or coarse gravel, and finally no traces can be seen of them.

This method of dispersion shows miners how to search for veins of valuable ores. If blocks of copper or lead ore show themselves temptingly, the country may be searched in the direction of the drift common to the neighborhood, usually visible on ledges near by in striæ. Let the country be carefully explored in the direction whence the stones have proceeded, and when no more can be found, the soil may be removed, and the veins will show themselves. This method of search, both for veins and beds of rock, has been constantly employed in the conduct of the geological survey, and the principle has never been found incorrect. The existence of many peculiar ledges would never have been discovered had not attention been first drawn to certain singular boulders.

If we were to take up the drift deposits one by one, or town by town, and specify what kind of boulders occurred, and what seem to have been their sources, much labor would be required, and the details would not be interesting. When the geology of the state is perfectly understood, those conversant with it will be able to say whence every stone found anywhere within our limits has been derived. The general law of the dispersion of the fragments may be thus stated: the boulders have been transported in the direction in which the ice of the glacier period moved, as indicated by striæ. By consulting our table of striæ, where nearly every town is represented, those seeking to learn the origin of interesting stones in their neighborhood may learn the probable point of compass in which to travel to find the source of their specimens. I will endeavor to state presently any exceptions to the above rule known to exist.

The teachers of the institute at New Hampton have interested their classes in this subject, and the young people have left behind monuments to themselves in the form of large boulders transported by the drift, found in their neighborhood, and presenting some strange or unique feature. I noticed a large block of the handsome porphyritic gneiss found in the east part of the town, and two boulders of andalusite schist, with coarse and fine crystals, one of them apparently from Carr's mountain. These specimens ornament the grounds of the institute, while other minerals are exhibited under glass.

In order to give some idea of the distribution of boulders in the state, I will select a few examples, and describe carefully the kinds of rock found, their size, probable origin, and distance of transportation. In the same connection, other interesting features illustrating the general subject may be mentioned incidentally. Some generalizations may follow the description of localities.

Boar's Head.

In the middle of Hampton Beach, a mound of drift about 1300 feet long and 45 feet high, rises very conspicuously to view. It is the well known *Great Boar's Head*, visited every summer by thousands of people for the enjoyment of sea air and bathing. Though small, it may be regarded as a true lenticular moraine, isolated from all visible connection with any other mass of till, by a distance of nearly two miles between the nearest points. It has been exposed to the wearing action of the sea from time immemorial, and consequently has lost a considerable portion of its mass. The clayey portion of the till is washed out, leaving the stones, and consequently the former size and shape of the mound is clearly indicated at low tide by the remnants. From the extreme point of the cliff these boulders extend south-east for 400 feet. Their northern limit is about a quarter of a mile north of the Boar's Head hotel; opposite the middle of the cliff the boulders are continuous 120 feet to the fucus growth, and a single stone projects out of the water as far again. If the hill were restored to its original dimensions, it would probably be 1800 feet in length by 350 in width, with a course about N. 35° W. It was steepest on the south side. Mr. S. H. Dumas, the proprietor of the hotel, thinks there has been no wearing away of the hill of any consequence for many years. The landing-place for boats on the south side has been constructed as it is now for the past forty years. If a new one were desired, no change of position would be required; so that the erosion on that side has been very inconsiderable. The present slight curve in the beach north of the hotel he remembers to have been straight once.

Mr. Joseph Dow, of Hampton, says a measurement of the bluff in 1875 showed that a length of one rod at the point had disappeared since 1826; and his impression is that a prominent stone, called Gunning Rock, near the end of the boulders, is farther removed from the bluff now than it was forty years since.

A view of this bluff from either side near the end shows finely the distinction insisted upon in this report between the lower and upper till. The sides of the bluff meet at the end, making a sharp edge, which dips towards the east at an angle of 60°. Fig. 54 is copied from a photograph, which shows the line between these divisions as plainly as in nature. The upper part has been broken away near its end, but its depth is nearly uniform over the whole plain, about ten feet, or a little less, at the end. This has its usual reddish-yellow in distinction from the bluish cast of the lower till. It is ferruginous, comparatively loose in texture, and contains rough stones, rarely any that have been striated, and the material is chiefly the slates found in place two or three miles distant. Being easily crushed, the upper till contains an unusual proportion of earth. Its resemblance to the upper till of Portland, Me., is obvious. The lower thirty-five feet of till is composed of very compact, gritty earth, slightly clayey, containing numerous smoothed and striated boulders, from grains of sand to fifteen feet in length. Many of the stones are in the condition of unstable equilibrium. The uncovering of the boulders by washing enables us to learn their nature, and refer them to their probable source. A careful description of the different kinds observed here will illustrate the origin and dispersion of all the boulders along the sea-shore. The most abundant rock is sienite, boulders 12 and 15 feet in length occurring occasionally. Those 6 feet long are common. They are all glaciated, but many have been smoothed since falling out of the bank by the waves. It is gray with a considerable sprinkling of white. I will group the boulders according to size. Of those about six feet in length are sienite, gneiss, trap, Pawtuckaway sienite, granite with blue feldspar, such as occurs in ledges at Frost's Point in Rye, crumpled

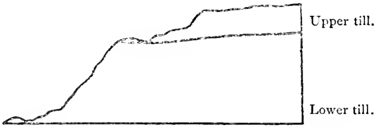


Fig. 54.—Section of Boar's Head.

gneiss of the Manchester and Deerfield range. We found the following in pieces from three to four feet long: Sienite of Exeter, the most abundant as usual, and twelve different varieties; well defined gneiss, flinty slate, ferruginous mica schist, porphyritic gneiss (some blocks like that of East Concord, others like the New Hampton rock, the feldspar very abundant in double crystals), breccia of flint or indurated slates, sienite with black patches, dolerite, gneisses like the Laurentian, green augite rock, Concord gneiss, porphyritic gneiss with large garnets, saccharoid quartz, gabbro like that of Gilford, sienite with feldspar,—perhaps labradorite and fine gray granite. The following were found of less dimensions than three feet, down to pebbles: Montalban schist with blotchy mica, trap of various textures, granite like that of Barre, Vt., clay slate, andalusite mica slate, jaspery quartz, slates like those of Portland, Me., fine-grained reddish whetstone slate, Manchester gneiss, greenish sienite with porphyritic like parallel spots of gray quartzite, argillo-mica schist, reddish porphyritic rock or sienite, gray garnet rock, Albany granite, red porphyry, white breciated quartz porphyry, and Tripyramid sienite or diorite; also, reddish weathering limestone, such as occurs in eastern Maine.

The most conspicuous and abundant of these materials came from the sienite range extending between Dover and Exeter, and travelled from nine to fifteen miles. A few of this class may have originated in a range three miles nearer. Many of the slates came from the ledges inside of the sienite. No andalusite slate is known to exist within twenty-five miles. The Manchester gneisses have travelled certainly twenty miles; the others may have come from either a greater or a less distance. I know of no porphyritic gneisses, like those occurring here, nearer than forty-five miles in a north-west direction, while ledges sixty miles distant agree with them exactly. The gabbro found at Gilford is in boulders, so that I cannot certainly refer to their source. I find nothing that seems to have come from a greater distance than the Tripyramid sienite, at 77 miles. The porphyries may have come from greater or less distances, possibly from the Ossipee mountains. Others of the pieces are like rocks further north, but I cannot claim anything but the minimum distances. I do not specify many other distances that might be mentioned.

I have assumed the north-west to be the proper direction of dispersion, and nearly all the boulders seem to have come from that direction. The schists like those at Portland, Me., cannot be indisputably proved to have come from that quarter; but if there were evidence of a south-west current, I should refer to that locality for their origin. The most difficult fragment to explain is the piece of limestone about a foot through, found at the eastern edge of the cliff. It is drab colored, weathering reddish, and tarnishes quickly after exposure. There is nothing like it in New Hampshire, nor in western Maine. It is like some limestones from the vicinity of Machias, 190 miles distant north-east in an air line, or New Brunswick, much farther. I inquired whether ballast from schooners might not have been thrown out upon the beach; but those who have lived here for many years thought the stone could not have been brought in that way. Our conclusion is, that the stone came from the bank, more likely the upper than the lower division, and that its original source was towards the north-east. We need, however, confirmatory observations before throwing down the gauntlet in favor of this proposition.

Dover.

The locality examined is the excavation in the kame half a mile north-west from the post-office, made by the Dover & Winnipiseogee Railroad, figured and described upon page 158. The previous example was in till; this is in material derived from the modification of the upper till, and the stones have travelled somewhat further than to their place of deposit from the glacier. The largest stone I have seen in any gravel deposit in the state occurs here, weighing sixteen tons. There are others two thirds the size of this, all of mica schist, with rough edges, showing only a short carriage. It is the rock of the neighborhood, and consequently the most abundantly represented among the pebbles. Others are fine-grained granites, Montalban schists, Concord granite, trap rocks, White Mountain porphyry, red porphyry (like that occurring upon Mt. Lowell), Albany granite, Tripyramid diorite, sienite (like that on Red hill), sienite with two kinds of feldspar, and the granite of Hart's Location, such as has been quarried on Sawyer's river. Probably ten per cent. of these stones came from the White Mountains, some of which can be shown to have been carried more than sixty-five miles. Perhaps most of them might have been derived from the Ossipee group, within forty miles.

Supposing the course of the striæ about S. 20° E., the Concord granite would have come from Farmington, 15 miles distant; the sienite from Gunstock, from 25 to 35 miles; the Montalban rocks about the same distance, or a little more.

MANCHESTER.

The city authorities have made numerous cuttings on various kinds of material within their limits, which can afford the most abundant information respecting the different kinds of material present in the drift. I searched for rocks transported a great distance rather than for the entire variety, so that my list is small. On Wilson's hill, at Lowell street, excavations have been made to the depth of from 12 to 15 feet, the finer sandy and gravelly portions separated by screens and carted away, leaving the stones and boulders, none of which exceed two or three feet in diameter. The excavation shows several features concerning the nature of the till better than anything seen elsewhere, and deserves to be shown in photographic illustrations. The examination was made before our decision to distinguish between the lower and upper till. The excavation probably exhibits both kinds of till, the upper a coarse, yellow gravel, from two to three feet thick. The surface of the hill is smooth, with scarcely any large boulders visible. There is a layer several inches thick of a sand overlying the gravel. Roots of pine trees have penetrated the earth to the depth of six feet. The lower till here contains many glaciated stones, including those that have come from the greatest distances. The material resembles clay, but, when pulverized between the thumb and fingers, is seen to be gritty, composed of siliceous rather than aluminous particles. This remark is applicable to very much of the drift deposits of southern New Hampshire, and explains our preference for the name *till*, adopted in this report for these accumulations, rather than *boulder clay*. The till here presents a laminated appearance, with horizontal partings, and iron oxide in the seams, evidently derived from water soaking down from the soil above. This laminated aspect is very common in the lower till, and is believed to result from the enormous pressure exerted by the presence of the ice-sheet. Two thousand or three thousand feet thickness of ice are adequate to induce these cleavage planes in the moist and slightly plastic earth. They cannot have come from deposition, as there has been no sorting of the material. Possibly some authors have mistaken these lines for stratification.

An uncommon feature is the presence of cracks and cavities, or what seem like such openings, one or two inches wide, filled with the upper gravel. Some masses of the lower till are entirely encompassed by them, so that in a section they appear like imbedded, irregular patches. The till occupies most of the area, the gravel occurring mainly in the veins. The section suggests the possibility of ice occupying the present position of the veins at first, and the subsequent infiltration of gravel after the melting of the frozen material. There are cases on record of large fragments of boulder clay transported by ice as if they were rocks. There might have been disturbances in the till, and the interspaces subsequently filled with gravel. This gravel does not show any cleavage structure like that of the lower till.

The larger of the boulders here are of granite, such as occurs within two miles. Those next in size are of the Manchester or Hooksett quartz, and mica schists of Andover and Franklin. Stones four inches long are composed of the Albany granite, and there are also two kinds of White Mountain porphyry. Similar White Mountain boulders occur in a railroad cut very near Massabesic lake, in a compact, elongated moraine, different from anything else in the vicinity.

The greatest distance of carriage indicated by these boulders is 68 miles. The mica schists travelled about 35 miles. The great bulk of the stones on Wilson's hill has come, therefore, from 35 miles and less.

A pebble of White Mountain porphyry has been shown to me by a resident of Nashua, who found it near his home. This must have travelled as much as 86 miles.

CONCORD.

An examination of the Concord kame showed many stones 8 to 10 and 12 inches in diameter, more than three fourths consisting of the Concord granite and associated rocks. I found, also, white quartz, ferruginous schists, porphyritic gneiss, trap, blue quartzite, hornblende schist, gneiss, and a possible example of Huronian schist from the Connecticut valley. Careful search failed to discover any rocks from the White Mountains. This indicates that the locality is too far west to receive contributions from the mountains. It suggests the probability of the transportation of those at Manchester and Nashua by the local Merrimack glacier. The ice from the White Mountains would meet the tributary glaciers from the west, and be compelled to slide upon the east side of the valley exclusively. Hence, whatever boulders came from the White Mountains would be found upon the East Concord or Manchester side of the valley.

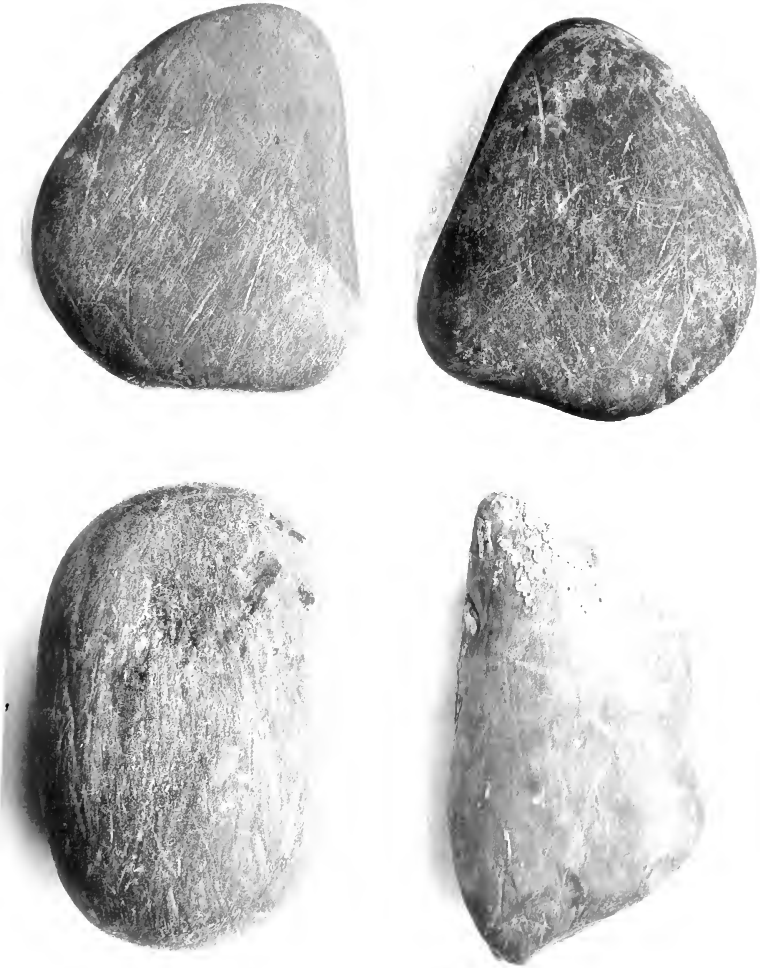
As the continental glacial sheet moved to the south-east, it follows that whatever White Mountain blocks are found in the lower till of the Merrimack basin must have been transported by a valley movement, unless the natural radial divergence from the mountains could have spread as far west as Manchester.

Hanover and vicinity.

Passing over to the Connecticut valley, boulders of a different class present themselves to view, or those derived from Vermont. We also find a large proportion of them brought by the south-east current, although the striæ close by run west of south. This confirms our previous suggestions of the existence of both movements in this valley.

About two miles north of Dartmouth college the kame furnishes the following pebbles, the largest 10 inches in diameter: Barre granite, Bethlehem gneiss—both varieties, Huronian diorite, quartz schists with decayed layers, calciferous mica schist—several varieties, clay slates, hornblende schist, jaspery quartz, quartzite, decayed limestone. Elsewhere this ridge furnishes handsome pieces of red jasper, thought to have been derived from ledges west of the Green Mountains, a distance of 70 miles. The Barre granite has been carried 32 miles. The Bethlehem gneisses are in place one mile east of this kame for four miles, but they more probably came from Haverhill, 40 miles distant, unless transported down from the Jacob's brook glacier in Orford, on the east side of the valley. These pieces travelled on the Connecticut glacier. The various Huronian and the calciferous schists, and the slates, mostly came from the north-west, involving from a few rods to several miles of carriage.

Further east are heavy deposits of till composed of long travelled and much glaciated stones. Three of them are represented in the accompa-



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THE HELIOTYPE PRINTING CO. BOSTON

nying heliotype. The two upper figures show the opposite sides of the same pebble—nearly of the natural size—of a mica slate, not of remote origin. On one side the striæ run at a small angle with the longer axis of the pebble. On the reverse side the lines are irregularly disposed. The lower left-hand view shows an argillaceous schist, derived from ledges five or six miles distant, of oblong shape, three inches long, and the striæ on both sides are approximately parallel to the longer axis. The whole surface on every side has been glaciated, some of the depressions being deeper than the others. The other view is of a Huronian schist, derivable from ledges three to twenty miles away, 12 inches long, 7 wide, and 3 thick. The upper end has been partially encrusted with carbonate of lime of more recent origin than the striæ. The opposite flat sides are scratched parallel to each other, and the longer axis of the stone. The ends are rough. This represents the shape and peculiarity of the striation of a majority of glaciated boulders.

The following varieties of material have been found in company with these heliotyped boulders upon the north side of Mink brook, about a mile east of the brick church at Mill Village: Hornblende schist, diabase, blue and gray quartzite, clay slate, serpentine, red quartz, red sandstone, and gneiss. The cliff is 40 feet high, the upper ten feet of upper till containing limestone.

These boulders must have been brought by the south-east current, some of them 65 or 70 miles. I think there is a notable absence of the Bethlehem gneiss among them. In the north part of the town the drift is very thick on the northern slopes. On following Mink brook to its source, in the south-east corner of the town, other similar ground-moraines occur. The same are more abundant south of Hayes hill in the edge of Lebanon. A tributary of the Mascomy has cut through this deposit, producing by erosion terraces of till. The surfaces of all these moraines are smooth, indicating the sliding of a glacier over them. Between Prospect and Corey hills is a smooth depression rising gradually to the curved water-shed between the stream flowing west and Mink brook. Scarcely any boulders occur on this basin; but after beginning the descent to Mill Village, coarse moraines and large rough boulders, twelve and fifteen feet through, abound. It would seem that the glacier broke off the fragments from the ledges of the smooth area, carried them to the brink of the declivity, pushed them over, and left them on the lee side of the hill. The contrast between the smooth fields south of Prospect hill and the rough pastures towards Mill Village is very strongly marked. On the hill north-east from Colburn's, in the edge of Lebanon, is another enormous accumulation of large gneissic blocks. On the College grounds, to the west of Culver hall, the surface was formerly covered by numerous large blocks of hornblende schist, sometimes ten feet across, derived from the adjacent ledges, and transported southerly by the Connecticut glacier. Excavations showed that some of them occupied an unstable position; if the earth were removed from their sides, they would topple over. It is a characteristic of till, that many of the boulders are so situated, and it bears witness to their method of removal. Had they fallen from an iceberg, they would rest with the centre of gravity *in equilibrio.* Now they are kept in a forced position, such as would result from the shoving along of a pile of débris, or such action as arises from the movement of a glacier. Underneath this clayey coarse drift the material is gravelly and less compact, derived from the gneissic rather than the slaty rocks of the neighborhood.

Quechee Railroad Cut. Between Hartford and Quechee villages the Woodstock Railroad has cut deeply into the lower till, affording the handsomest exhibition of the two varieties of till yet displayed in this region. The cut is 40 feet deep, three fourths of it being the lower member, very compact, full of small-sized glaciated stones cemented together by thick boulder clay. Every stone is striated. There are great numbers of the Burlington red sandstone, and many beautiful green serpentines. The most common are of gray quartzite. One was composed of a fossil coral. The red stones have travelled the greatest distance, from over the Green Mountains, about sixty miles. Concerning these and the similar ones at Hanover, it is to be remarked that they were raised over an acclivity of 3,000 feet altitude as well as transported a great distance. The upper ten feet of this cut is a typical locality for the upper till. There is the distinctively reddish-brown color, loose consistency, rough blocks common with an occasional striated one, and very many of the siliceous limestones of the neighborhood. None of the latter were observed in the lower till.

Boulders from Mt. Ascutney.

If different ice-currents have struck the ledges, and transported fragments in several directions, we shall expect to find the boulders quite far apart at a considerable distance from the source. As an illustration of this wide spread of materials starting from a small area, I will mention what is known about boulders starting from Mt. Ascutney, as their mineral character is peculiar, and not likely to be mistaken. In Claremont they are very abundant, about eight miles and a half distant, and the direction south-east. In Surry, on the west side of Thompson brook, in the north-west part of the town, Butler's rock, a boulder 20 feet long, 20 feet wide, and 12 feet high, came from Ascutney. The distance of transportation is 27 miles in the course S. 10° E. In Keene—west part—is a striated Ascutney boulder five feet in diameter, S. 8° E., and 35 miles distant from its source. G. A. Wheelock informs me of the existence of similar blocks at the west base of Monadnock, S. 20° E., and 42 miles; also one in Mr. Newton's garden in West Swanzey; 20 in Keene, the largest on Samuel Towns's farm; three in Surry; several in Alstead; very many at Paper Mill; and Dr. Prouty found one in Langdon, two in Gilsum, and one in Sullivan. Others are on Mr. Gilbert's farm in Walpole, two in Westmoreland, and one at Ashuelot. This last is nearly due south, and 45 miles distant. Another is at R. C. Fisher's in Hinsdale. The only other example in mind is in the north-east corner of Bernardston, a small stone 50 miles distant from Mt. Ascutney, and S. 4° W. in direction.

If lines were drawn from Ascutney to all these points they would correspond to radii. If the Claremont stones continue south-east, which seems likely, any occurring at the south state line in Pelham would be 85 miles distant, and 36 east of the Bernardston example. In this instance it is easy to account for the wide spread of the stones by the south-east current for some, and the Connecticut valley movement for the others. It is a question worthy of investigation, whether all boulders have a radial dispersion like these from Ascutney. The facts of this dispersion ought to be gathered in greater abundance, and compared with those obtained elsewhere.

BOULDERLESS AREAS.

In New Hampshire no considerable regions are devoid of boulders, except areas of sand where the stones are concealed by deposits of later age. The nearest approach to a boulderless area is in the limestone regions of Cornish and Colebrook. In eastern Vermont the absence of boulders over the same formation is very conspicuous, as may be seen in passing up Wait's river and the east branch of White river. The boulders of the underlying rock decompose readily, and it is believed that though once as common as the average of granite blocks in New Hampshire, they have been disintegrated by atmospheric agencies, leaving very few signs of glacial work. Occasionally lines of granite boulders occur in this calciferous area, enough to show that the glacier did not slight it. Such boulders would furnish excellent studies of the radial dispersion of fragments, as their distribution could be easily made out.

On the contrary, some kinds of rock seem almost incapable of decomposition, and leave the fields profusely strewn with them. The porphyritic gneiss and the Exeter sienite areas are remarkable for the great amount of rough blocks of their own kind scattered over them. They are mostly those that have just started on their travels. Between Dover and Exeter the loose fragments of sienite scattered over the area occupied by this rock are numberless, and commence abruptly on the northwest side. One knows that he has reached the sienite rock by the numerous blocks of it seen long before a ledge can be found, it may be. I suppose their abundance is to be explained by their difficult decomposition.

LARGE BOULDERS.

Although our state is noted for the great abundance of boulders strewn over its surface, it is only quite recently that I have seen boulders in our limits larger than any of which mention has been made in the writings of American geologists. They were brought to our notice by His Excellency Governor Prescott. Regret had been expressed to him that no boulder had been found in the state equal in size to those known to exist in the neighboring states. As if he felt the credit of the state impaired by the imputation, he immediately searched the neighbor-

CHASE ROCK.

hood of Pawtuckaway mountain, and found a very formidable array of giant fragments superior to anything else described elsewhere. The celebrated *Pierre-a-bot* of the Jura contains about 40,000 cubic feet, weighing 3,000 tons; the Green Mountain Giant of Whitingham, Vermont, has the same cubical contents; the one formerly existing at Fall River, Mass., now destroyed, is estimated to have weighed 5,400 tons. The Churchill rock of Nottingham, shown in a heliotype at the beginning of this chapter, measures 62 feet long by 40 wide, and is estimated at 40 feet high. Making liberal allowances for irregularities in its dimensions, it contains over 75,000 cubic feet, weighs 6,000 tons, and is therefore nearly double the size of the Jurassic and Vermont examples. Bingham's rock at Smuggler's notch in Vermont is larger, but is so connected with a ledge as not to be properly esteemed an erratic. The Swiss example has been transported much farther than either of the New England boulders.

Churchill rock is on the south side of north Pawtuckaway. It lies in a valley not shown on our map by contours, starting at the middle of the Deerfield and Nottingham line where it passes over this peak, and pointing east to Round pond, made a part of Pawtuckaway pond upon the county map. This valley is half a mile long, and displays a very remarkable lot of large boulders and moraines. The commencement of the valley is a narrow notch in the sienite of the mountain, full 200 feet deep and narrow. The boulders seem to have been detached from the cliffs on either side of the notch, and then transported by the ice, perhaps, or local glacier, eastwardly. Within a few rods of the starting-point are several large blocks, worthy of special measurement anywhere except in their company. About an eighth of a mile down, too far to allow of their accumulation by gravity, are six large boulders close together, each one averaging 30,000–35,000 cubic feet. A little beyond them is Chase rock, 40 feet long, 40 feet high, and 30 feet wide. About a quarter of a mile or a little less from the starting-point is Churchill rock, and close by it two others, one estimated as equal to 30 feet in each direction,—27,000 cubic feet,—and the other ten feet longer, with the same breadth and height, or 36,000 cubit feet. On climbing the mountain north of Churchill rock, some large blocks are seen, which have been severed from connection with the ledge; one of them 50 feet long, slab-like in form, rests slanting against the hill-side, so as to make a natural shed for the cattle.

Churchill rock received its name sixty years since, from the circumstance that a lunatic of that name escaped from his keepers, and was discovered on top of this boulder. It will be seen that the rock is divided by a crevice, originally a joint, providing a space usually a few inches in width. Mr. Churchill must have crawled up through this narrow opening, doing, like other persons in his condition, what seems almost impossible. It was found necessary to fell a tree upon the rock to insure for the man a safe descent. The base of the stone is below the feet of Gov. Prescott, as represented in the heliotype, who stands the lowest down of the four persons seen in front. The top is midway of a pine tree with a trunk nearly two feet in diameter, and was thought, by some on the ground, to be 80 feet high.

Chase rock is well shown in another heliotype, with a profile view upon its summit of Erastus H. Chase, the proprietor of all these large boulders. Fifty years had elapsed since he climbed the boulder before. He took great enjoyment when a lad in climbing this rock. It is much more narrow when viewed from either end.

On passing nearly to Round pond, almost three quarters of a mile from the Pawtuckaway notch, we reach Ballad rock, so named from a preacher who used one of the projections for a pulpit in the early history of the town. A heliotype sketch of this is presented, showing two or three of the constituent boulders of this moraine, for it is a terminal pile of rubbish. It may have collected behind a ledge, though it is not always easy to separate ledges from boulders in this vicinity. The largest stone is 60 feet long and 40 feet wide, and ovoid in shape. The moraine itself is 150 feet wide and over 100 feet high. Five or six of the large boulders in it are readily discernible to the visitor. The view is somewhat defective, because of the difficulty of obtaining a good light in the forest late in the afternoon. This moraine is really more remarkable than the single large boulders, because it is composed of several pieces, each as large as Chase, if not Churchill rock. The ridge extends to the pond, and its base is crossed by the road.

We find, therefore, in this short distance of three quarters of a mile, certainly a dozen boulders, each exceeding 25,000 cubic feet in dimen-

BALLAD ROCK.

sions. Their position requires the invocation of glacial action to account for their removal from the pinnacle or cliff from which they seem to have come. We could not have expected anything less than such a royal discovery, when the chief executive of the commonwealth set himself to search for something worthy of mention.

Vessel Rock. In Gilsum a large boulder (Fig. 55), called Vessel Rock, from its fancied resemblance to a ship, has long attracted attention. Dr. Jackson described it in his report, and thinks it came from a coarse granite ledge fifteen rods distant, according to G. A. Wheelock. The rock itself measures 46 feet in length, 24 wide, and 26 high, containing over 28,000 cubic feet. A piece was split from it by frost in 1817, measuring 33 feet long and 10 wide. The whole stone before splitting was said by Jackson to include 32,000 cubic feet, and to weigh 2,286 tons. Other large fragments of the same rock occur to the west and south. The building shown in the figure is a school-house. It is about a mile and a half south-west from the village.

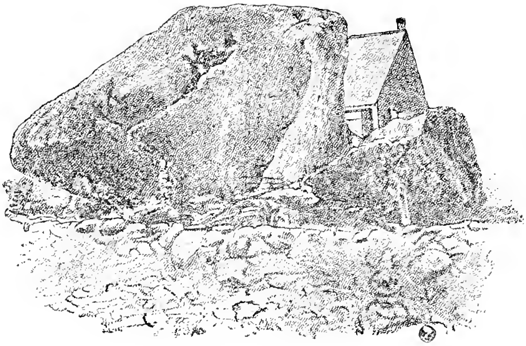


Fig. 55.—VESSEL ROCK, GILSUM.

Elephant Rock. This boulder is situated in Newport, within a few feet of the summit of Pike hill, fully 1,500 feet above the level of the sea. It is composed of graphic granite. Its length is about 29 feet, and its height not far from 23 feet. The rock is represented in Fig. 56.

Dr. Jackson says, in his report (p. 100),—"Some immense blocks of granite occur in Northumberland, on the estate of Mr. Mills Olcott, of

Hanover. One of them has the following dimensions: 30 feet long, 18 feet high, 27 feet wide, and contains 4,580 cubic feet. The other is 32 feet long, 6 feet high, 9 feet wide, and contains 1,152 cubic feet. It is a light-colored granite, of excellent quality for building. These blocks of granite are different from any rocks found in place in the immediate vicinity. The nearest granite ledge is one mile north of it, but is of a different kind. The original bed must be some distance to the northward."

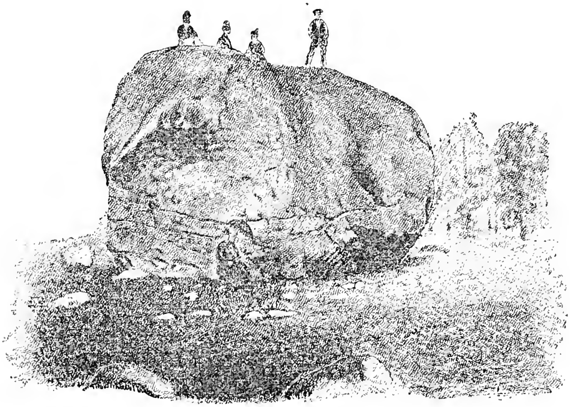


Fig. 56.—Elephant Rock, Newport.

Conway Boulders. Prof. E. J. Houston describes a large boulder, near the house of E. S. Stokes, North Conway, in much detail in the *Journal of the Franklin Institute*, Volume LXII, 1871. He calls it the Pequawket boulder. It is of coarse granite, with a preponderance of feldspar, considerable quartz, and very little mica. The general form is that of a parallelopiped, one of whose longer sides is partly buried. The length is 52 feet 6 inches; greatest breadth, 21 feet; greatest height, 33 feet 2 inches; and it is estimated to weigh 2,300 tons. Several large fragments surround the mass, seemingly once connected with it. One is 31 feet 3 inches long, 15 broad, and 21 high. On the south-east side is another piece 31 feet 7 inches long, 15 feet 3 inches broad, and 11 feet 7 inches high. Several spruces and beeches conceal the boulder from the road.

A moraine runs up the hill, N. 80° E. from the boulder, containing many large blocks. About 600 or 800 feet higher they average 12 by 13 by 15 feet. A few hundred feet below the Pequawket is another mass 31 by 18 by 21 feet.

There is another one called the *Washington Boulder*, represented in a heliotype. It is about a mile north-east from Conway centre, near Pine hill. Its dimensions may be expressed by about 30 feet high, 40 long, and 25 high. It is one of the notable objects of Conway, and is composed of the granite for which the town is famous. It cannot be shown to have travelled far.

Bartlett Boulder. This is not so noted for its size as position. It has the typical shape of glaciated stones,—15 feet long, 12 feet wide, 10 feet high,—and rests upon four smaller blocks. The entire assemblage rests on stratified sand: hence it was moved to its present position at the time of the melting of the ice. It is represented in a heliotype.

Ordination Rock. This is in Tamworth, west of the centre village, and has a flat top, reached by artificial steps, and is surmounted by a monument. It is 30 feet long, 30 feet wide, 12 high, and composed of Conway granite. It came from the north or north-east.

Flume Boulder. The photograph of the boulder suspended over the Lincoln flume, Volume 2, page 157, illustrates far better than words how this fragment happened to be caught, and now serves the useful purpose of keeping the walls of the chasm apart, and of affording amusement to thousands of summer visitors. No further description is needed above that already given.

Waterville. Several large boulders must be added to the list of attractions for this locality. Near Greeley's are some 8 feet high, of the celebrated ossipyte. Near Mad river are large granite blocks. The largest is just above the mouth of Greeley's Branch, or at the Swaseytown falls, 43 feet long, 25 wide, and 20 high. One lower down is 33 feet long, 27 wide, and 25 high. They are of Conway granite.

OTHER LARGE BOULDERS.

On crossing from Moultonville, in Ossipee, to the sources of Lovell's river, we observe a fragment of Conway granite near the height of land, 30 feet long, 27 feet wide, 18 feet high at the south end, and 10 feet high at the north end. There are no ledges near by, so that it has very likely been brought here from the valley north, and transported up hill, 200 feet of vertical height.

In Hanover, upon the west flank of Moose mountain, east of E. Wright's, is a boulder of hornblende schist 22 feet long, 12 wide, 16 high, from which a considerable piece has been separated by frost. It may have travelled less than a mile. A boulder of Vermont granite, perhaps half the size of the foregoing, is said to have been taken from the top of Moose mountain and made into monuments for the cemetery. On Gen. Jackman's farm in Bath, there was, a few years since, a line of large Huronian boulders averaging 12 feet through, arranged like a lateral moraine. The first cucumbers seen in Bath were raised upon the top of one of them. Near Jones pond in Raymond is a boulder of twisted gneiss 30 feet long, 25 feet wide, 22 feet high at one end, tapering to 8 at the other. In this neighborhood, Raymond, Epping, Nottingham, similar large boulders are frequent. Those derived from Pawtuckaway are quite noticeable for twenty miles to the south-east. Several large ones are located upon Governor Prescott's farm. South of the station at Raymond is a boulder of white quartz, transported several hundred feet, 48 feet long, 39 wide, 24 high (30 feet at one end), with two pine trees on top, one 16 inches in diameter near the base. This compares favorably in size with some of the Nottingham examples. Near Brackett's station in Stratham are two sienite boulders, each averaging twenty feet in three directions, that have come two or three miles. Near Bronson's house in Landaff are boulders of conglomerate 30 feet in each of the three dimensions. They probably came from some undiscovered layer not far distant.

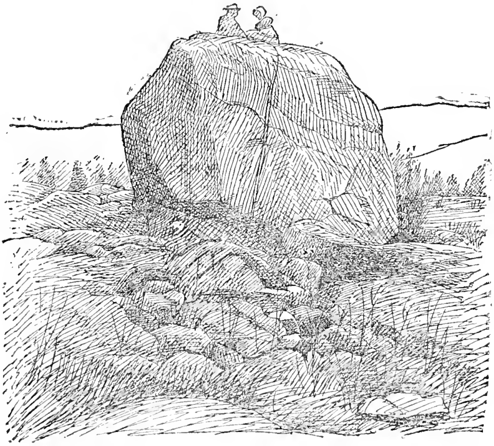


Fig. 57.—Great Rock in Wentworth.


BARTLETT
BOULDER

Fig. 57 represents Great Rock in Wentworth, with Mt. Carr in the distance. Two persons seated upon the summit illustrate the size of the boulder.

In the west part of Fremont are a great many boulders, each from 12 to 15 feet long. The same is true of many other portions of Rockingham county, as near Windham junction, on Clyde hill, where mention is made of one weighing 500 tons.

ROCKING-STONES.

When large boulders are left on ledges they may be so evenly balanced that a slight effort only is needed to make them oscillate. Such cases as have fallen under my notice are the following:

On Shirley hill, Goffstown, just east of Uncanoonuc, there are two. One of them is 8 feet high and 42 feet in circumference. The dimensions of the other are not stated. With them is a third large stone.

Governor Prescott speaks of a rocking-stone upon Mt. Pawtuckaway. Seneca A. Ladd, of Meredith village, informs me of the existence near his residence of a small rocking-stone.

Up Corey hill in Hanover, half a mile east of Dartmouth college, is a rocking-stone 12 feet long, 10 feet wide, 5½ thick, containing about 480 cubic feet. Its of Bethlehem gneiss, and has been transported only a short distance.

On a high hill, about a mile west of Newport village, is a rocking-stone weighing not far from 25 tons. It is about 9 feet high, egg-shaped, and stands upon its larger end.

Upon Russell Clifford brook in Warren there is said to be another, of these stones, with a tree growing on the top.

Boulders on top of high mountains. Those on Mt. Washington have been mentioned; see page 208. On top of Dixville mountain is a boulder of hornblende rock 5 feet long. Has travelled several miles. Cannon mountain shows a porphyritic gneiss block 4 feet in all directions, which may have come from Bald mountain, about two miles distant, and been elevated 1650 feet. Mt. Kearsarge exhibits a great many boulders of the same material, 5 feet long, that have been elevated more than those on Cannon. Granite boulders are common on the top of Moosilauke; also, Bethlehem gneiss, Lisbon Huronian, Montalban mica schist, Coös quartzites, besides the common rocks of the mountain. Of these, the Montalban may have come from the north, Essex county, Vt., forty miles away; the Huronian not necessarily more than twelve miles;

the quartzites a less distance. The origin of the Bethlehem gneiss is not clear;—if from west of north, it may have come from the north part of Haverhill, very near. If the current west of south brought any material to the summit, the boulders would naturally have come from Bethlehem, less than twenty miles away. Upon Mt. Lafayette are many boulders of the darker variety of Bethlehem gneiss, derivable either from the east or west of north. A fine-grained granite, Huronian hornblende, and gneiss occur about fifty rods below the top. Forty feet below the top, on the south side, is a boulder of porphyritic gneiss. None of them are necessarily great travellers, say twelve or fifteen miles from the north or north-west. The Sugar Hill staurolite is found at the Eagle lakes, indicating six miles travel to the south-east. This is different from the striæ on the mountain, which runs west of south. Both forces must have operated here. At the first tank on the Mt. Washington Railway, say 3,000 feet altitude, are stones of Essex county, Vt., pargasite and delicate staurolite; at least, no other localities of these minerals are known, a distance of twenty-eight miles north-west. At the third tank, 5,800 feet, are pebbles of Lancaster or Huronian rocks, that have come nearly twenty miles. Near the top of Mt. Madison are handsome granite boulders, of such material as occurs a few miles northerly. On Red hill, Moultonborough, are fine-grained granite, probably from Waterville, black mica schist like that of the Coös group, trap, hornblende, Montalban and Lake gneisses, all in place near by, except the second, which is unknown short of forty-five miles to the north-west. Mt. Mote shows slate from the upper Saco valley. From Mt. Chocorua I obtained a sparkling mica schist, which may have come either from the north-west or the north-east. Lovell's mountain in Washington shows mica schist and gneiss boulders, which cannot be definitely located. On top of Mt. Ascutney are argillaceous schist and Huronian diorite pebbles, the first from the north, the second probably, not necessarily, from the same quarter.

On the top of the north Twin mountain are boulders of Bethlehem gneiss from the north-west, ten to fifteen miles. The slide on the north side has many Huronian fragments, that have come about twenty miles. Cherry mountain summit shows Bethlehem gneisses from Jefferson, the next town. There are boulders of porphyritic gneiss on top of Mt. Gunstock.

Miscellaneous Items.

A few other facts concerning the dispersion of drift and other glacial phenomena are worthy of preservation, although it is not possible to state them systematically. I have placed several hundred specimens of boulders found in various parts of the state in the Hanover museum, properly catalogued, so that it may be consulted by those who wish to verify the statements of this report, or obtain hints of facts not alluded to in it. Many of the specimens represented strange information at the time of the collection, not now valuable except as illustrating the fact of dispersion. Others are from noted boulders, or collected upon the tops of mountains, or represent the supposed underlying rock in the absence of ledges.

On the west slope of Gardner's mountain, near Hunt's, are boulders of the Craftsbury concretionary granite (petrified butternuts), with ordinary granite and hornblende rock from Vermont.

In West Littleton are two houses (Wheeler), and others in Lancaster, built of the Vermont granite brought to New Hampshire by glaciers.

Mt. Carmel in Pittsburg, as seen from Dixville mountain and Mt. Washington, presents a good example of a large eminence rounded on the north-west by the ice striking it, and rough on the lee side where the force of the ice had abated.

Between North Lisbon and Streeter pond a mass of till more than 100 feet thick has been cut through by the south branch of the Ammonoosuc, and fine sections are exposed upon it. Ledges are scarce near the river.

Rocks full of segregated veins weather unequally, often affording curious shapes. It is quite common to see these stones placed in conspicuous positions upon walls or in dooryards by the farmers, who take pride in their exhibition. The siliceous limestone of the mica schist, the finer-grained sienites, and the segregated veined variety of (Lake) gneiss afford the best examples of this erosion. I recall examples in Bath and Center Harbor, resembling piano-stools and mushrooms.

The importance of soapstone has led to noting the position of boulders of it in certain parts of the state. Those in Pelham, Keene, and at Island pond in Hampstead, have not been referred to their source. The original bed is yet to be discovered. In New Boston, by the school-house west of S. Dodge's, are several large boulders, distant about four miles in the direction S. 20° E. from the bed on Mt. Misery, Weare, their probable source. The same occur in Weare, at the south foot of Mt. Misery.

Serpentine boulders are common but not abundant in Keene. One in Walpole weighs about 350 pounds.

The numerous gneissic boulders in West Epping led to the discovery of a small area of this formation in the Lamprey river.

There is an enormous quantity of porphyritic gneiss boulders about the village of Northfield, Mass. Until otherwise proved, they may be supposed to have been transported from the area of this ancient gneiss in Winchester by the Connecticut valley glacier. It is also interesting to note the derivation of the Triassic conglomerate. The largest constituent is an oval-shaped piece of granite. Several are two feet long; the rest are smaller. Twenty-nine specimens represent these pebbles in the museum. They all came originally from the formations to the north-east and north,—none from the west side of the Connecticut. The most abundant are the Montalban schists and granites. Others are the Vernon gneiss, hornblende schist, Coös schists and granites, and several varieties of quartz from veins.

Boulders of sienite occur at Freedom village, whose origin is unknown. On a high hill in Eaton are boulders of black quartz porphyry, probably from Albany, twelve miles north-west. At the east line of Madison are samples of Albany granite and fine-grained sienite from the same region. At the outlet of Newichwannock lake are black porphyries from the Ossipee mountains to the west, presumably.

In Center Harbor, between Squam and Winnipiseogee lakes, also further south, are many large pebbles of Huronian and Coös rocks. Assuming them to have come down Baker's river, they have travelled 40 miles. With them are pieces of the Calciferous mica schist limestone, seen also on Mark's island and in Grafton. These two travelled at least 50 miles.

At the sea-shore on Cape Elizabeth river are numerous glaciated pebbles of a porphyry like that of Mt. Pleasant in Bridgeton, or Burnt Meadow mountain in Brownfield, about 40 miles north-west.

At Littleton, west of the village and near Echo lake, Franconia, are pebbles of andalusite mica slate, with acicular crystals, like a rock in Granby and Victory, Vt. The course would have been only a few degrees east of south.

Handsome porphyritic gneiss occurs on the east line of Effingham. Its source is not clear, whether from the small Albany and Chocorua range, or from the north-east in Maine. The same rock in Haverhill probably travelled west of south from the Wing Road neighborhood.

A piece of clay slate in Lyndeborough, if from the north-west, travelled 42 miles. Mr. O. E. Randall has shown me pebbles of red sandstones, like that of the Potsdam west of the Green Mountains, picked up in Chesterfield. These are like those mentioned as occurring commonly about Hanover, page 260,—the distance probably greater—75 or 80 miles.

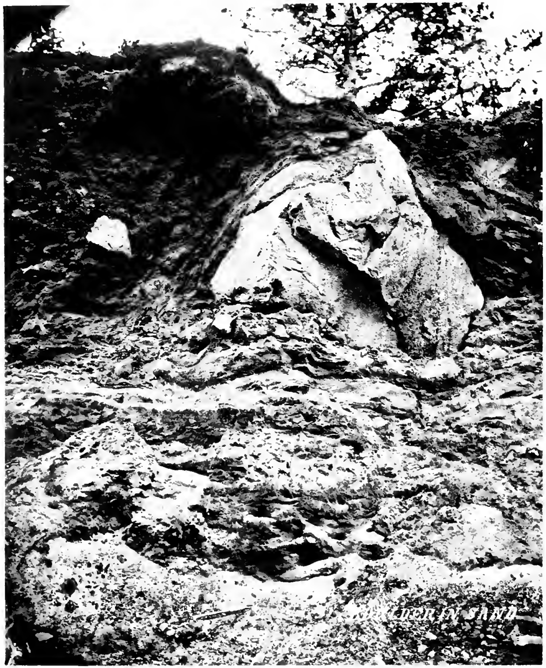
About two miles up Imp brook in Bean's Purchase, almost under the very countenance of the Imp, are loose blocks 50 to 60 feet long. Between Mts. Pleasant and Franklin are many granitic boulders, brought up from the Ammonoosuc valley beneath, 10 feet square. Jasper pebbles are common about Connecticut lake and Stewartstown. They probably came from Canada. The same occur upon Mormon hill in the north-east corner of Lyman. There is in the lower part of Hinsdale village a boulder about as large as an old-fashioned school-house, of which the traveller will see many in the hill towns. There is a multitude of large boulders in Franconia opposite the Valley house. They cover acres of land, some of them being 20 feet long. On top of Flume mountain is a boulder 25 feet long, 15 wide, and 12 high. Near Fifield's house in Thornton, on the east side of the Pemigewasset, is a boulder averaging 30 feet in each of the three dimensions. At the south part of Rattlesnake hill, Concord, is an uncommon amount of boulders of granite, whose dispersion must have been due to the ice. Near Gilmanton Iron Works, I found boulders of quartzite precisely like that of the Coös group from Moose mountain, Hanover, to Cuba, etc., 6 by 3 by 3 feet. The distance from here to the Cuba range, north-west, is nearly 50 miles. We have preserved samples of glaciated stones taken from the drift overlying the inter-glacial clay at the Weirs and in New Hampton. A block at Weirs is 6 feet square. On the Isles of Shoals are boulders that have come from the main land. On the south part of Chocorua are granite boulders 4 feet long, and bits of porphyritic gneiss 18 inches across. On the west side of Kimball hill, in the edge of Whitefield, are boulders like the Bethlehem gneiss, perhaps brought there by the glacier described by Agassiz. There is also a moraine of the Ammonoosuc glacier, not mentioned above, below Bethlehem Hollow. In North Lisbon are bits of Albany granite, 5 inches in diameter, brought down by the glacier.

In Brookfield are numerous boulders of a siliceous limestone, such as crop out in a single ledge in Wakefield, and abundantly in Newfield, Maine. These boulders are very numerous in Newfield, and they occur on Copp's Hill, Wakefield. Observations do not demonstrate the absence of ledges of this limestone in our state, but the question is raised whether these blocks have not been transported in a south-west direction. There is a probability that, when studied carefully, a south-west distribution of boulders will be indicated for Oxford and Carroll counties.

Boulders in Sand. The Portland & Ogdensburg Railway has made considerable excavation in the surface deposits between the Notch and Fabyan's, which illustrates the nature of the till and modified drift. At the Crawford house is the first excavation, 1,320 feet long and 20 feet deep at the middle, made through one of the river moraines described on a previous page. The material came down Cascade brook from the west. It is entirely stratified, though the materials are coarse, as is shown in our heliotype illustration of it. The swell of land crowned by the Crawford house is made by this gravel deposit meeting the till of the east side of the valley.

After proceeding 864 feet beyond the gravel cut, there are excavations, mostly on the upper side of the track in an ice drift, extending for 408 feet, where the nearest point to the Saw-mill pond is reached; then there is another small cut through the same material for 216 feet. After this is a fill of 120 feet. Then follows the cut figured in our heliotype, with the title *Ice-drift over sand* printed on a railroad tie. It is a compact, unstratified mass of rubbish, the stones consisting mainly of the Montalban granites and schists common in the neighborhood, overlying layers of sand, as shown in the illustration. The material appears to conform to the surface of the ground, being just as thick in the depression as over the elevations. This earth is evidently some form of ice accumulation; it is not water-worn gravel, nor does it correspond to either of the tills. It approaches nearer to the coarse gravel at the Crawford house than to any other class of deposits known in the state, but is unlike that, in the common absence of stratification and the angularity of the fragments. Its association with the sand about to be described may intimate the presence of a mass of ice in the neighborhood in the time of local glaciation.

The rest of the cut just entered into extends for 336 feet. It is composed of sand, with some large stones in it, underlying the angular drift, as seen in the illustration. The strata dip southerly underneath the ice drift, and at the north end of the cut they dip northerly to correspond with the depression of the surface, 120 feet wide, crossed by the railroad upon an embankment. Next is another cut in the sand 264 feet long, showing boulders in it, and depressions to correspond with the surface of the ground. After an embankment 528 feet long, succeeds another cut in the sand of 384 feet length. From a point in this excavation, about 4,300 feet north of the Crawford station, was taken the heliotype illustration entitled *Boulder in sand.* The fragment may be six feet through, composed of bright granite as fresh as if uncovered yesterday, and of the same character with the adjacent ledges. Horizontal strata of sand underlie it, while the layers are slightly irregular about it, as would naturally result from the varying velocity of the current striking against the stone. The layers above are regular, and conformable with those beneath. This is therefore a clear case of a mass of stone too large to have been pushed by the current of water, nevertheless brought to this spot by some agent and dropped as readily as if it were a grain of sand. There must have been water deep enough to float ice carrying this stone upon it; and owing to a change in the equilibrium of the berg at this point, the granite fell to the bottom, and lies in a condition of


BOULDER IN SAND

repose, not unstable like the rocks in the lower till. There may be twenty other examples of large stones of similar origin in the 1,200 feet of excavation passed through north of the ice drift mentioned. The conditions involved by the facts seem to be the presence of thick masses of ice upon the sides of Mt. Tom sliding down like glaciers, and carrying detritus, together with the existence of very much water,—possibly a glacial lake almost as high as the Crawford house,—into which the bergs loaded with stone floated, after being dissevered from their source, and dropped their burdens. The waters continuing to flow, layers of sand and other débris covered up the dropped fragments until the supply ceased. As these deposits are situated upon the surface of the ground, they belong to the close of the ice period, and must have been formed by local glaciation. If the railroad be followed to Fabyan's, three or four miles further, there will be seen a constant repetition of phenomena similar to those just described. The same is true of the excavations in the White Mountains Railroad below the White Mountain house, and between Fabyan's and Ammonoosuc. A cut through "Winding hill," near the "Base" on the latter route, shows coarse boulders, probably glaciated at the bottom, capped by stratified layers somewhat ferruginous, suggesting the lower and upper tills of other parts of the state.

The sand deposits east of Fabyan's have large stones resting upon them, obviously brought there at the same time and in a similar manner with those just described. The valley of the South Branch also exhibits fine examples of kames, which seem to have been contemporaneous with the sand, and produced by the same glacial currents.

Other examples of boulders lying in or upon sand have been mentioned, upon pages 89, 105, 107, 117, 162–163, etc. Notable instances are also just below the Glen house, the Bartlett boulder, at North Lisbon on the new Franconia road, and east of Rock Rimmon in Manchester.

SHAPES OF GLACIATED BOULDERS.

By far the most common shape of glaciated boulders is that of a rounded trapezoidal prism, whose longer sides do not vary much from parallelism to each other. One such is figured in the heliotype showing boulders from Hanover. In this the ends are rather sharper than is common. Perhaps half the thoroughly glaciated stones have such a shape. Of these the four longer sides are usually striated parallel to each other.

My attention was called to this as a typical shape by examination of certain large striated boulders. In 1856, a boulder of red sandstone was exhumed in Amherst, Mass., 6½ feet long, 5½ broad, 2¾ thick, having striæ upon the four longer sides parallel to each other.* This was described as something unusual. I found in Quebec, a few years later, similarly striated boulders somewhat larger; and in the glacier de Bossons in Chamouni, at the foot of Mt. Blanc, I noticed the same trapezoidal figures in a very large stone, 40 by 27 by 12 feet in its dimensions. It was striated on the same four sides as the others, and had the ends rough. It lay just below the ice, with its longer axis parallel to the course of the glacier. Since that time I have always observed the shape of glaciated stones, and think the majority have the same form with these that I have mentioned. Originally rough, and possibly somewhat rectangular, they have been both ground down and striated by the sliding over them of the glacial rasp, or have been themselves fastened into the foot of the ice, and ground over other stones and rocks. After miles of scouring, the largest boulders might be worn symmetrically to the size of pebbles. On scrutinizing the shapes of stones in the till, one can frequently find various stages of this process preserved. In Derry and Salem I noticed a large number of flat stones, of which only one side had been smoothed. Let the circumstances be changed so that these boulders be turned over, and the present upper rough side will be glaciated, and the whole become symmetrical. A few have several faces upon them, as if they had been fastened in the paste several times. Fig. 58 shows a glaciated stone in Moultonborough, striated in the usual way, and also by a second set *(b)* across the preceding. It is 30 inches long, 14 thick, composed of trap, and lies by the roadside upon a mass of till.

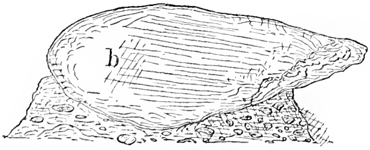


Fig. 58.—Glaciated Stone, Moultonborough.

A more interesting case has been partially preserved in the Hanover

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* *American Journal of Science*, ii, vol. xxii, p. 397.

museum. About two miles north of Norwich village, Vt., on the road to Copperas hill, is a hill thirty feet high, of lower till with innumerable glaciated stones cemented by boulder clay. One of a micaceous argillite may weigh 1500 pounds, perhaps five feet in length, of the typical trapezoidal shape, except it is narrower than usual. The longer axis points a little east of south, as the stone lies in the bank. The under surface and the sides are striated parallel to the longer axis, but the upper surface bears very plain marks at right angles to those beneath. I was able to preserve only a piece of this boulder, showing the upper surface and the beginning of the lower striæ at right angles to them. The boulder proved larger than was expected, so that I could not transport it entire to Culver Hall.

A common variation in shape is the elongated narrow one, a prolate spheroid. Geikie, in his work on the Great Ice Age, figures four striated stones from Scotland, three of which clearly possess the typical shape I have mentioned, while the fourth is blunt at one end and pointed at the other,—a form also seen with us. These stones show the same features the world over. Argillaceous boulders best preserve the glaciation.

Surface Deposits at Portland, Me.

The relations of the two varieties of till to the Champlain gravels are not exhibited in any outcrops yet discovered in New Hampshire. A familiarity of long standing with the fossiliferous clays and the drift of Portland, Me., led me to think the question of relative position well shown there; and upon examination I discovered that the fossiliferous beds occupied a place midway between the two kinds of till. Numerous excavations have made the sections in the till and sands perfectly satis-

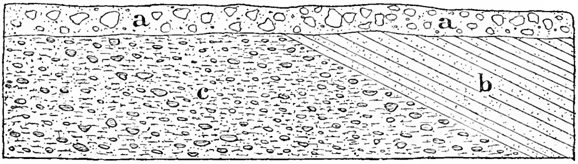

Fig. 59.—Section in Till, Portland.

a. Upper till; b. Fossiliferous Champlain beds; c. Lower till.

factory, so that the mutual relations of the three deposits, as displayed in Fig. 59, may be regarded as fixed beyond controversy. The massive beds overlie the lower till, and are covered by the upper till. These facts indicate the deposition, first, of the ferrous glaciated till; second, its submergence to at least 100 feet below the present level; third, the reädvance of the ice-sheet so as to cover the Champlain beds; fourth, the melting of the ice, and the falling down of the débris held in suspension in it. The formation of the upper till does not necessitate a submergence, as I have insisted in previous publications. That these positions may seem well sustained, I will state the most important facts observed about Portland.

The city is situated upon a promontory, or, practically, an island, with a north-east trend parallel to the coast. The island has two elevations, 150 and 160 feet above tide water, and at the remoter ends the extreme edges slope very sharply to the water's edge. The eastern elevation is Munjoy's, and the western Bramhall hill, and between the land sinks to 60 feet along the lowest ridge. These two hills consist of the two kinds of till; and each is environed by the Champlain deposits, which cover most of the lower area in the middle. These attain an elevation of about 100 feet; and the ocean must have stood a few feet higher, unless the character of the fossils in the lower clays—pelagic forms—necessitated a submergence of 300 feet. In that case, Munjoy's and Bramhall hills would have been deeply buried by the waters.

Munjoy's hill has been excavated in a multitude of places, showing an upper till, from 3 to 10 feet thick, as clearly defined and distinct from the lower deposit as at Boar's Head. Boulders from 3 to 4 feet in diameter occur upon the surface, and are of the gneissic, granitic, and schistose rocks common from four to ten miles to the north-west. Fig. 59 represents a cutting between North and Washington streets, and may be taken as a sample of excavations on that side of the ridge. Along North street for half a mile is a continuous exposure of the two kinds of till. Upon both sides is a cut 25 feet deep. The larger stones are all under or at the surface, but they are not striated. The lower deposit is compact, the stones of small size, and all glaciated and transported a greater distance than those above. I found pebbles of the White Mountain porphyries and sienites among them, indicating a carriage of 50 miles. The other hill in the west part of the city is broader, and no excavations of consequence are visible. The surface deposit is altogether that of the upper till, and identical with that on Munjoy's. The coarseness of this deposit has led to its reference to the usual glacier drift by many geologists; but I think its proper place is now found by a reference to the upper till. A few have regarded the fossiliferous deposits as of Tertiary age, because the upper till overlies them. It is very easy to see how such a mistake could be made, if the distinction between the upper and lower tills is overlooked.

An examination of the Champlain deposits shows they do not occur upon the tops of these hills, but encircle them, and in strata dipping quaquaversally outwards. Fig. 59 is chosen from a locality where Mr. C. B. Fuller found mussel shells lying in a position analogous to that assumed by the living animals. The siphon-holes above them still remained, where sand had silted into them from above. Such specimens could not have been transported by waves. A list of all the known fossiliferous localities is the following:

Along east side of Munjoy's hill for 400 yards between Eastern promenade and the Grand Trunk Railway.

Portland Company's works, St. Lawrence street.

Adams street.

Between Fore street and the custom-house.

Cove on Washington street opposite north end of race-course.

From this point to Fox street.

Between Washington and North streets.

In an old pit on Congress street above Mountfort street.

Almost anywhere north of Congress street between Alder and Anderson streets.

Congress street north of reservoir.

Old slide next canal, described by Prof. E. S. Morse.

For 200 yards at the foot of Emery street.

Knightsville,—nodules containing shells, fish, etc.; very abundantly in Deering, Woodstock, Cape Elizabeth, and islands in Casco bay.

A list of the fossils found about this city by Mr. Fuller embraces 5 vertebrates, 31 crustacea, 2 annulosa, 55 mollusca, 2 echinoderms, and 26 foraminifera,—121 species in all. Undoubtedly every one of these creatures lived at the same time in the New Hampshire waters, only a few miles distant, where the facilities for their preservation did not exist.

These animals were not exactly the same with those now living on our coast, corresponding better with those living farther north. The best writers name three different groups for the eastern American coast. The arctic fauna is at present confined to the limits of North Greenland, and about the pole at the isotherm of 0° C. This is succeeded by the Labrador or Syrtensian fauna, extending now as far south as to the mouth of the Bay of Fundy. Our present New England or Acadian fauna extends from the southern limit of the Syrtensian to Cape Cod, and also appears in several places above the lower limit of the latter. The lower British Provinces exhibit one or the other of these faunas according to the presence of the polar current or the influence of the Gulf stream.

The fauna of Portland in the Champlain period corresponded to the Syrtensian, or the colder one. It seems to have extended as far south as Gloucester or Cape Ann. The northern limit of the Acadian fauna during the same period was near Point Shirley, Winthrop, Mass. Thus the glacial cold was sufficient to bring the boreal life two and a half degrees farther south than it is found at the present day.

A list of all the Champlain fossils known to occur in New Hampshire has been given upon page 165. The whale's vertebra, cited from Somersworth, must be eliminated from the list. An inquiry into its authenticity has indicated that the specimen did not come from the locality specified upon the label.

The Ground Moraine.

The common masses of drift scattered over the state are known typically as ground moraine, such as is accumulated beneath glacial ice. The Scotch word for the material is *till*, which is adopted in this report to signify the ordinary unstratified glacial accumulations. For reasons derived from the Manchester exposures, this term is preferred to a common one of *boulder clay*. The sub-divisions of it have been defined upon page 9. We accept the theory there stated, that the lower till is the proper ground moraine, and the upper ferruginous division is derived from the melting of the ice-sheet.

Recent studies reveal the existence of curious lenticular-shaped mounds of till, some of quite large dimensions. These proved so interesting that Mr. Upham was asked to devote a season in studying them.

He will shortly present the results of this examination, and color upon the map of Surface Geology their geographical positions. No feature of our drift moraines is so striking as this, and it is singular that previous authors have almost universally overlooked or misunderstood it.

The question has been put to us, As New Hampshire has not been submerged since the Helderberg period, and there may have been other periods of cold besides the one called *par excellence* the glacial drift, why do we not find moraine accumulations of the earlier ones? I think we have abundant evidence of a Triassic glacier in Massachusetts, formed of materials partly derived from New Hampshire. The stones of the Mt. Mettawampe conglomerate are too coarse to have been moved by water alone, and the stones have a glaciated appearance. As there seem to be no rocks in our state analogous to the Triassic conglomerates, we may say, with assurance, that if any glaciation occurred previous to the post-tertiary, it could not have antedated the New Red Sandstone. It seems probable that Tertiary glaciated beds would be characterized by features quickly discernible, and not easily confounded with anything else earlier or later.

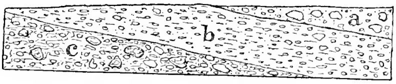

Fig. 60.—SECTION IN TILL, LYNDEBOROUGH.

a. Upper till; b. Lower till; c. Hardpan.

But certain beds are brought to our notice, which seem to antedate the lower till. The best known is represented in Fig. 60. A railroad cut in South Lyndeborough, two miles west of the station, exhibits three layers in the till. The top is the familiar loose ferruginous earth, such as universally covers the ground-moraine. Next, *b*, is a good example of the lower till, full of glaciated pebbles, porphyritic and granitic gneisses, mica schist, etc., 5 feet, and in one case 6 feet long. The laminated appearance arising from compression is clearly defined. Beneath this is a coarser mass, reaching to the bottom of the cut, so very compact that a pick had no effect when struck into it by the workmen; only gunpowder or a stronger explosive could excavate it, and it was necessary that the holes should be bored horizontally near the surface to become effectual in removing the earth. There is nothing visible in the earth itself different from the lower till above it, save that the components average coarser. This hardpan is certainly prior in age to the lower till; but that circumstance may not compel us to call it Tertiary. If length of time is requisite for the induration of till, this hardpan should be much older than the common moraine. There is nothing of significance in the shape of this earth heap. It is not as conspicuous as a small lenticular hill. After the access of air to the lower deposit, its great induration disappears. When it is well exposed to rain, water mixes with it, making a compound that will flow readily down a slope.

A case similar to this is in Pittsfield, midway between Webster's mill and the village. The railroad excavators had the same experiences that have been narrated for Lyndeborough. Gov. Prescott informs me that similar experiences befell persons endeavoring to excavate the earth for a well near his residence in Epping; and recently I found the same story told of drift in Amherst, Mass., and Hartford, Conn. The examples may multiply, and eventually furnish us the answer to our question as to the peculiarities of their origin.

DRIFT IN NORTH CONWAY.

As an example of the aspect of the difference between the ordinary till and the modified drift, I would refer to the accompanying heliotype, illustrative of these two deposits in North Conway where the road crosses Artists' Falls brook, near the Macmillan hotel. To render the sand more distinct, a faint brown color is employed to show its limits. It is about 10 feet thick, forming about one fifth part of the exposure. There are boulders in the till here about a yard in diameter. The sand of North Conway is usually widespread, but very thin. Quite a large mass of it, as long as a small lenticular moraine, occurs just to the south of the stream opposite the hotel. This is the position from which the fine view of Mt. Pequawket, employed for the frontispiece of Volume II, was taken.

PLANT RELICS OF THE GLACIAL PERIOD. Full descriptions of the Hudson's Bay and Greenland floras now existing in the White Mountains have been presented in Volume I, pp. 392 and 568. No better argument to show that an arctic climate once existed in New Hampshire than the presence of these plants, as well as the corresponding insects described in the same volume, Chapter XII, can be adduced. They also imply the correctness of the glacial instead of the iceberg theory of the drift, and also that the cold conditions spread themselves gradually over the continent, disappearing slowly also.


NORTH CONWAY

The Distribution of the Till.

By Warren Upham.

Before the glacial period, the rocks of New Hampshire had been through long ages subjected to the ordinary disintegrating agencies of rain and frost. The loose material derived from this source was doubtless spread with considerable evenness over the surface, collecting to the greatest depth in valleys, while on ridges or hill-tops it would be thin or entirely washed away. Except where it had been transported by streams and consequently formed stratified deposits, the only fragments of rock held in this mass would be from underlying or adjoining rocks.

Through this time temperate or tropical climates generally prevailed; but it also seems probable, if the causes of the glacial period have been rightly made to depend upon great eccentricity in the earth's orbit, that these genial conditions were at times interrupted by prolonged cold and the accumulation of slowly-moving ice-fields similar to the immense glaciers of Greenland and antarctic lands. Scarcely any hint, however, has been obtained in a full survey of our territory respecting these events, all records of which appear to have been erased by the last great ice-sheet, which pushed from the north and north-west straight forward over all the hills and mountains of New England, terminating beyond our coast-line. The beds which had been derived from long-continued decomposition of the ledges or gathered by previous glacial action, together with the thick fluviatile deposits that probably occupied the valleys, were ploughed up by this ice-sheet, and thoroughly kneaded with each other. Very large amounts of detritus were also added from erosion of the rock-surface. Fragments of all sizes and in great profusion were loosened and wrenched away, while the ledges were everywhere worn and striated by boulders and pebbles which were rolled and dragged along under the vast weight of ice, breaking up and grinding themselves and the underlying rock into gravel, sand, and even the finest clay.

At the end of the glacial period, the material which had been thus gathered, mingled and swept along by the moving ice, was left in three different classes of deposits, namely, modified drift, upper till, and lower till. The first and second of these appear to have been held in the body of the ice-sheet, principally in its lower portion. At its final melting, it has been shown that the modified drift was swept into the valleys, while the upper till, which escaped this erosion, fell loosely upon the surface, forming an unstratified, confused mass of boulders, gravel, and sand.

The characteristics of this upper division of the unmodified glacial drift are,—the large size of its boulders, which are usually abundant, being often from five to ten, and sometimes twenty or thirty feet in diameter; the angular form of these blocks, as also of smaller fragments, which have seldom been worn or rounded except by the weather; the occurrence of much of its iron in the form of sesquioxide, giving a yellowish or reddish color; and the comparative looseness of the whole deposit. Its thickness is quite variable, being commonly one to five feet, but sometimes reaching to twenty feet or more. This upper till generally forms the surface throughout the state, the only exceptions being tracts of valley or lowland, where it is covered by beds of modified drift, and frequent small areas, varying from a few square rods to several acres, or sometimes, especially upon mountains, perhaps hundreds of acres in extent, where scarcely any superficial material rests upon the ledges.

The lower till is distinguished by its smaller rock-fragments, which are commonly less than two feet in diameter, and often consist of pebbles not exceeding half this size, though occasionally it also contains large boulders; by the glaciated form of many of these stones, which are frequently marked with striæ; by the usually clayey detritus, in which they are held; by its darker and frequently bluish color, due to the imperfectly oxidized state of its iron; and by its very hard and compact structure without stratification, boulders, pebbles, sand, and clay being indiscriminately mixed, but at the same time showing traces of lamination, or perhaps cleavage, in planes parallel to the surface, usually noticeable wherever a section has been for a short time exposed to the weather. All these features indicate that this division of the drift was accumulated beneath the ice as its ground-moraine. Rough and angular boulders, pushed along under the glacial sheet, were worn to small size, having their sides planed off and striated; and in the same manner gravel and sand were pulverized to clay. Secluded from air and water, the iron remained in the protoxide combinations which it had in the solid rocks. Analyses of upper and lower till from Alton, by Mr. Hawes, show the following percentages:

	Upper till.	Lower till.
Iron protoxide, ...	1.42	1.75
Iron sesquioxide, ...	1.56	0.006

These samples were taken within a foot of each other, close to the line of contact of the two deposits. The hardness of the lower till, which requires it to be loosened by a pick before it can be shovelled, making its excavation cost two to four times as much as that of the upper till, appears to have resulted from the immense pressure of the ice. The imperfect lamination, which has been commonly observed in exposures of the lower till in New Hampshire, may be due to the same cause, but more probably to its accumulation by a gradual increase of depth. It seems to show that the ice in its passage added new material to the surface of its ground-moraine, which generally lay undisturbed below.

The distribution of the lower till is quite irregular, being much less uniform than that of the upper till. It occurs in all parts of the state, but is often wanting, and probably does not occupy more than half of its area. It is most commonly spread in flattened sheets, which may be nearly level, or inclined upon the flanks of hills or mountains. In the northern part of the state and among the White Mountains, the unmodified glacial drift often forms the slopes or rests upon the tops of the highest ridges. Its distribution seems to have no reference to the altitude or configuration of the land. The summits on the highland boundary between New Hampshire and the province of Quebec, as near Lake Magalloway and Mt. Prospect, near Third lake, are described by Mr. Huntington as principally covered with till. The same is true of the top of Moosilauke, 4811 feet above the sea. Striæ show that the ice-sheet moved over these elevations from lower areas at the north-west, where a large part of its drift was probably collected, to be carried forward and deposited at a higher level. The summit of Mt. Washington is covered by débris (described on p. 205), which seems to correspond to the upper and lower divisions of the till.

Lenticular Hills. In the south part of the state, the glacial drift is probably not more abundant than among the mountains, but becomes more interesting because of its accumulation in massive, rounded hills, principally composed of lower till, which form the most prominent elevations near our coast, in Essex county, Mass., and southward to Boston.*

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* These remarkable deposits of glacial drift have been described in the *Proceedings of the Boston Society of*

A special exploration has shown that these hills are also finely developed, being more numerous but somewhat less massive, in Merrimack, Hillsborough, and Cheshire counties, and in many parts of central Massachusetts. They vary in size from a few hundred feet to a third or a half mile in length, with usually about half or two thirds as great width. Their height, corresponding to their area, varies from forty or fifty feet to one hundred and fifty or two hundred feet. But whatever may be the size of these hills, they are singularly alike in outline and form, usually having steep sides, with gently-sloping, rounded tops, and presenting a very smooth and regular contour. From this resemblance in shape to an elliptical convex lens, Prof. Hitchcock has called them *lenticular hills*, to distinguish these deposits of glacial drift from its broadly flattened or undulating sheets, which are common throughout the state.

The lenticular hills have a well defined trend, which shows a very notable parallelism with the striation of the rocks. Next to the coast it is prevailingly north-west to south-east, while farther inland it has very few exceptions from a nearly north and south course. In addition to the occurrence of the glacial drift in lenticular hills, it is frequently amassed in slopes of similar lenticular form. These have their position almost invariably upon either the south or north side of the ledgy hills against which they rest, showing a considerable deflection towards the south-east and north-west in the east part of the state. It cannot be doubted that the trend of the lenticular hills, and the direction taken by these slopes, have been determined by the glacial current, which produced the striæ with which they are parallel.

Slopes of till accumulated on the lee side of projecting ledges have been described by European glacialists, the hill and the detritus sheltered behind it being commonly known as "crag and tail." The greater portion of these slopes which have been noted in New Hampshire are sheltered in this way; but about a third of them lie upon the northern side, which was exposed to the ice-current. In rare cases these slopes have gathered upon both north and south sides alike, blending together and assuming the form of a lenticular hill of glacial drift, but having exposures of ledge at the top. In many true lenticular hills outcrops of solid

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Natural History by Prof. N. S. Shaler (vol. xiii, pp. 196–203), and by Prof. C. H. Hitchcock (vol. xix, pp. 63–67). They seem to resemble the "drums" or "sowbacks" of the till in Scotland, mentioned in Geikie's *Great Ice Age*.

LENTICULAR HILLS, GOFFSTOWN.

rock occur near their base, and evidently form a pedestal capped by a rounded mass of till fifty to one hundred feet in depth.

These hills of glacial drift may be recognized by their smoothed surfaces, overspread, indeed, with the large boulders which are common in the upper till, but moulded in gracefully curved outlines unbroken by jutting ledges, which give to all our other hills a more or less angular and abruptly undulating surface. Our elevations of rock are commonly in irregular groups or ridges, with outlying spurs, and, except in the south-east part of the state, they are far more massive and prominent than the lenticular hills. These accumulations of till are further distinguished by their fertile soil, well adapted for pasturage or cultivation, which frequently makes them the most valuable land in the districts where they occur. On this account, they have almost invariably been cleared, while the more rugged, ledgy hills remain covered with woods.

During exploration for mapping the lenticular hills, notes were also taken of sections in the glacial drift, shown by excavations for building and repairing roads, or for wells. These observations are presented in the following table, which shows depths of upper till varying from one to seventeen feet, resting, in all but five instances, directly upon the lower till, their separation being a definite line. It will be seen that thin layers of sand are occasionally found in both these deposits, appearing to be most frequent in the lower till, where they are sometimes inclined or nearly vertical. In most cases where thick beds of gravel, sand, or clay occur in the glacial drift, their position is between the upper and lower till. A few examples appear in the annexed table, and others are described on pages 108, 131, 137, 159, and 163 of this volume. It will be seen, also, from this table, that thick stratified deposits are sometimes found in or beneath the lower till. Wells in this compact boulder-clay, which is usually impervious to water, often encounter springs issuing from these beds or from thin seams or layers of sand, which therefore must extend a considerable distance. In most of the sections noted, the base of the boulder-clay was not reached. Nearly half of these sections are upon lenticular hills or slopes, which are thus shown to consist of a thin stratum of upper till at the surface, while the larger central portion is a massive accumulation of ground-moraine or lower till.

SECTIONS OF THE GLACIAL DRIFT IN NEW HAMPSHIRE.

LOCALITIES.	Thickness in feet.			REMARKS.
	Upper Till.	Lower Till		
Ashland,—2 miles east of village	4	25		
Sandwich,—Notch road	2	3		
Lenticular slope at south town line	3	27		
Moultonborough,—several places	2	3–5		
Tuftonborough,—Fernald's hill, lenticular slope, resting against ledge at south-east	3	10–15	*a.*	*a.* Three wells, nearly alike in material, about 60 feet above the base of the slope. The lower till was here underlain by dark gray, loose gravel, "like that of a stream," extending 5 feet (not penetrated). The largest pebbles of this gravel were 3 or 4 inches in diameter.
Wolfeborough,—lenticular slope, 2 miles N. of village	2–4	20–30	*b.*	*b.* Two wells. Lower till underlain by a water-bearing stratum of sand or fine gravel.
Near Cotton Valley station	4	10		
Ossipee,—Fogg's ridge, lenticular hill	3	17		
Alton,—½ mile west of Alton Bay	2	3	*c.*	*c.* Specimens analyzed.
Gilmanton,—several places	1–2	10		
Sanbornton,—west of Hopkinson hill	2	3		
Tilton,—2 miles north of village	2	5		
Rochester,—top of Haven hill, lenticular	3	37		
At Walter S. Hussey's, on south slope of a lenticular hill	3	20		
At J. E. Chesley's, ½ mile south-east from last, on north slope of a lenticular hill	5	10		
Strafford,—2 miles south-east of Bow lake	1½	3		
Pittsfield,—Tilton hill, lenticular slope, resting againt ledge at south-east	1–2	20		
Loudon,—1 mile east of Hot Hole pond	3	5	*d.*	*d.* Very irregular in contour.
Lenticular slope 1 mile south-west of Clough pond	5	15		
Canterbury,—¼ mile east of centre	1½	4		
1 mile south-west of centre	2–5	10	*d.*	
Concord,—1 mile north of East Concord	2	8		
Road to St. Paul's School	2	3		
South-west side of Rattlesnake hill	1½	3		
Hopkinton,—lenticular slopes on south side of Beech hill, at A. P. Ober's	4	36	*e.*	*e.* Lower till contains occasional layers of sand a few inches thick.
" " C. H. & H. Merrill's	1½	18	*e.*	
" " S. Johnson's	2	32		
In south-west part of town	1–2	5		
Warner,—Pumpkin hill, lenticular in form, with small exposure of ledge at top	2	20		
Andover,—at west town line	2	3		
New London,—at Institution, upon a broad lenticular hill	2	43	*f.*	*f.* Lower till underlain by a water-bearing stratum of gravel.
¼ mile south-east from last	1½	26	*g.*	*g.* Lower till showed two or three seams of sand, 1–5 inches wide; it is underlain by a softer clayey stratum, 1 foot thick, resting on ledge.
Washington,—hillside south-east of Millen pond	2	18		
Sullivan, Harrisville, and Dublin,—several places	1½–3	5		
Swanzey,—1½ miles south of Wilson's pond	2½	3		
New Ipswich,—north-west part	1½	5		
1½ miles north-east of village, at north foot of a lenticular hill	1½	4	*h.*	*h.* Lower till underlain by 5 feet of stratified sand, which continues below the excavation.
Greenfield,—½ mile east of Cragin pond, on lenticular slope, resting against ledge at north	2½	20		
½ mile farther east, at north-west foot of Lyndeborough mountain	1½	26		
Bennington,—east part, on south end of a lenticular hill	1½	20	*i.*	*i.* Lower till contains occasional layers of sand, 1–2 inches thick.
Wilton,—north-west part, at county farm	1½	15		
⅛ mile north-east of East Wilton	12	10	*j.*	*j.* Upper till contains layers of sand, 3-6 inches thick.
⅛ mile west of East Wilton	15	....	*k.*	*k.* Upper till contains layers of sand, and is underlain by 10 feet of stratified clayey sand, which extends below the excavation.
New Boston, at S. Dodge's, on south slope of a lenticular hill	6	10	*l.*	*l.* Two wells. The upper and lower till were here separated by a stratum, 5 feet in thickness, of very compact ferruginous earth, free from pebbles. The lower till contains occasional thin layers of sand.
Beard's hill, lenticular, on its south slope	5	15		
½ mile east of last	2	4		
⅓ mile north of village, on east side of a lenticular hill	3	17	*m.*	*m.* A nearly vertical seam of ferruginous sand, 1–1½ feet wide and 10 feet long, was exposed in this lower till.
Cochran's hill, lenticular, on its north slope	2	35		
At the south-east foot of Wason hill	9	6		
Amherst,—lenticular mass upon Chestnut hill, ⅛ mile east of O. Carter's	6	15		
Goffstown,—on south slope of a lenticular hill, 2 miles north-west from Centre	4	18	*n.*	
1 mile north of last	2	3		
Stratham,—top of lenticular hill, 1 mile west of Rollins hill	3	40		

Kingston,—lenticular mass, on south-west side of Great hill	5	25		*n.* Two or three seams of sand, inclined 45°, 3–6 inches wide and several feet long, occur in the lower till, which is underlain by a stratum of black clayey sand 1 foot or more in thickness.
East Kingston,—lenticular mass, on south-east side of Great hill	3	60		
Kensington,—Moulton ridge, lenticular hill, at top	10	30		*o.* Upper and lower till separated by a layer of sand 4 inches thick.
1 mile south of last	17	5	*o.*	
Top of lenticular hill, south of Muddy pond	5	15		*p.* Upper and lower till separated by 6 inches of waterworn gravel.
North-west slope of same hill	13	15	*p.*	
South Hampton,—north-west village	6	10		

The average thickness of the upper till, obtained by taking the mean of these observations, is three feet and nine inches. If we subtract one tenth of this, due allowance will probably be made for areas that are destitute of this deposit, leaving three and one third feet, which would thus appear to be approximately the mean depth of the upper till, if it were spread in a sheet of uniform thickness over the entire state.

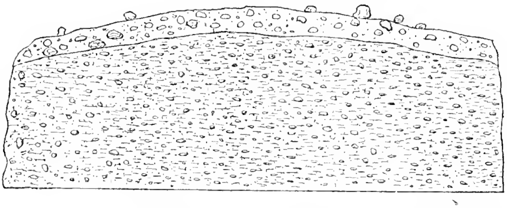

Fig. 61.—Section of Glacial Drift, two miles east of Ashland, illustrating the usual mode of occurrence of the upper and lower till throughout the state.

Thickness of the upper till, 4 feet; of the lower till, 25 feet. The most abundant boulders in the former were porphyritic gneiss; in the latter, Montalban.

The lower till, however, does not appear to have any development upon half of this territory, being accumulated in patches, sheets, and lenticular masses, while over adjoining areas of equal extent the ledges are exposed or covered only by the upper till. Very few of these sections show the whole thickness of the lower till; and its depth in the lenticular hills affords no basis from which to judge of its other deposits. It is impossible, therefore, to arrive at an estimate, as before, from this table. If we still wish to form some conclusion respecting the entire mass of the ground-moraine, it will be well first to consider the lenticular hills and slopes, of which about eight hundred and sixty have been noted in southern New Hampshire. The portions of these which consist of lower till may average equal to a depth for each of fifty feet upon an area of one tenth of a square mile. This indicates that the lower till, accumulated in such masses, would form a layer perhaps six inches thick, if evenly spread over the whole state. These hills and slopes are only found, however, upon small portions of this area, and for the districts of their greatest abundance in Cheshire and Hillsborough counties, as in portions of Walpole, Chesterfield, Dublin, Jaffrey, Rindge, New Ipswich, Temple, Wilton, New Boston, and Goffstown, would probably yield continuous sheets five to ten feet in thickness; while in Kensington and South Hampton, which represent their greater development near the coast, they may be equivalent to a uniform depth of thirty or forty feet. The average thickness of the lower till in flattened deposits, found throughout the state, can only be conjectured. It varies in depth from a few feet, as is most common, to twenty, thirty, or perhaps sometimes fifty feet. Our impression of its aggregate amount, including the lenticular hills and slopes, is nearly the same as the estimate derived from the foregoing table for the upper till. The modified drift, described in the first chapter of this volume, must also be nearly the same in its total mass.

The whole depth of the drift in New Hampshire, if uniformly distributed, would therefore be something like ten feet, of which nearly equal portions occur in each of its three divisions of modified drift, upper till, and lower till or ground-moraine. In this connection, we must bear in mind that a considerable part of the drift gathered by the ice-sheet from our territory was carried beyond our coast-line and deposited in submarine banks.

The distribution of the till has been carefully noted throughout that part of the state which lies south of Grafton county and the White Mountains. Its most interesting deposits are the lenticular hills and slopes. These have been represented in the atlas, on the map that shows the courses of striæ. It will be seen that their longer axes agree in direction with these tracings of the ice-current. The same map also shows lines of contour, with which the irregular distribution of the lenticular hills may be readily compared. It would be expected that their abundance or absence must be determined, or at least influenced, by the very irregular outlines of the surface; but we have been unable to discover this relation or dependence, if any exists. In the northern portion of the area explored, the till is common in patches and extended sheets, but forms only few and scattered lenticular hills or slopes. Farther south, these remarkable accumulations occur quite abundantly upon three belts of our territory, one of which extends through the west part of Cheshire county; another, from Goffstown and Weare south-west to New Ipswich and Rindge; and the third, through eastern Rockingham county. The general features of these lenticular deposits of till, which have been already given, apply to them in all parts of the state where they have been found, and also in north-eastern and central Massachusetts, leaving little that needs to be particularly mentioned, except the localities of their most conspicuous or noteworthy occurrence.

Sullivan County. The glacial drift does not form many prominently rounded masses in this part of the state. A lenticular slope of till, resting against higher ledges at the north, was observed two miles west of Meriden on the north side of Blow-me-down brook. Even such deposits are rare in most of the towns of this county. Southward, lenticular accumulations of till were noted on both sides of Sugar river one to two miles east of Claremont. The first of these on the north side of the river falls off abruptly at its south-east end, having evidently been undermined by this stream, which now flows thirty rods distant, separated by a low flood-plain. No lenticular masses were seen in Newport, but considerable till is spread out in flattened sheets. For fully a mile in the west part of this town, beginning a little below Kelleyville, such a deposit has been undermined by Sugar river, and forms a continuous bluff on its north side 75 to 100 feet high. The slope southward from Acworth centre to Cold river, amounting to about 500 feet in two miles, is principally covered with till, much of which is massed in rounded hummocks with several lenticular hills near the bottom. At the northward bend of the river, a half mile west of South Acworth, it forms a bluff 100 feet high The ascent on the south side of the valley towards Alstead is also marked by frequent patches of till.

Cheshire County. In the west and south-east parts of Cheshire county the lenticular hills are finely developed, but they are almost entirely wanting over an intervening area which averages ten miles in width. At East Alstead, and for a mile to the north and east, the surface is mostly till, which occurs in broad swells, resembling lenticular accumulations. Well marked examples of "crag and tail" occur one mile north-east and a mile and a half east-north-east from this village, the latter example being in the edge of Marlow. Many fine lenticular hills occur in the south part of Walpole, scattered among more prominent hills of ledge. At a mile and a half south-east from the village, the road which leads north from school-house No. 4 climbs a rounded slope of till nearly

200 feet in height. From its top two prominent hills of this class are seen within a third of a mile on the west. Another fine example was noted about a mile south from these; two more occur a mile west from the last; and several were seen in the south-east part of the town, one lying a short distance north-west from school-house No. 13, and others within a mile to the west and south.

The valley of Thompson brook, in the south-west corner of Alstead and north part of Surry, is bordered by large deposits of till, which at several places have a well defined lenticular form. These hills are also well shown along the Ashuelot valley in Gilsum. In Westmoreland they are numerous along the route of the Cheshire Railroad, occurring close north of East Westmoreland depot, at one mile west and south-west, and for one mile to the south. No typical lenticular hills were noticed near Westmoreland village, but similar masses of till rest against a ledgy hill one mile south-west; and at a mile and a half south a broad sheet of it forms the north slope of Pistareen mountain. These hills are very finely shown in Chesterfield, as many as fifty distinct lenticular accumulations being noted. They abound from Factory village west to Connecticut river, being especially numerous and massive within a circuit of one mile about Chesterfield centre. Only inconspicuous examples occur in Hinsdale; but Winchester has about a dozen well defined and prominent lenticular hills within four miles north from Ashuelot and Winchester villages. These constitute an isolated group, surrounded on all sides for three or four miles by irregular ledgy hills with no considerable accumulations of till. In each of these towns, other areas adjoining those which we have described are destitute of these deposits.

The central portion of this county, which has only very rare lenticular hills, comprises the towns of Marlow, Stoddard, Sullivan, Roxbury, Keene, Swanzey, Troy, Richmond, and Fitzwilliam. In Nelson, these hills are found near the village. Several good examples, 50 to 75 or 100 feet deep, occur within a half mile to the south-east and within a mile and a half to the west. In Harrisville and Marlborough a few lenticular hills are noted; but the greater part of these towns shows no trace of them.

Their best display in this county is at the south-east, in Dublin, Jaffrey, and Rindge. On the north side of Monadnock mountain they are finely developed, four very prominent examples occurring about two miles north-west from Monadnock lake, which is also bordered by small but typical lenticular hills on its north-west side. Their trend here is uniformly from north-west to south-east, or nearly so, while in other parts of this county it is almost always approximately from north to south. This divergence of 45° from the usual course was due to deflection of the ice-current, for the striæ of this vicinity show the same eastward deviation. Between Dublin village and Thorndike pond numerous lenticular accumulations occur; but many of them are not true hills, since they rest against ledges at the north. The east half of Jaffrey and nearly the entire township of Rindge are well filled with the lenticular hills, which vary from 50 to 150 feet in depth, but scarcely any of them have received special names. Their fertility has caused them to be cleared, and their smoothed fields of pasturage or mowing contrast notably with the ledgy hills of similar height but very irregular outlines, which abound in the next fifteen miles to the west.

Carroll County. The lenticular accumulations of till which have been observed east of Lake Winnipiseogee lie most frequently on the north-west side of hills, which was struck by the full force of the ice-current. The hill upon which Sandwich Lower Corner is built may serve as an example. The north side of this hill is a smooth lenticular slope of till, but ledge appears at its top and on its south side. Fernald's hill in Tuftonborough, a mile east of Melvin Village, also has a very regular north and north-west slope of till. A bed of stratified gravel and sand occurs in the lower till of this deposit, as shown by wells at Mr. Calvin Fernald's, described on page 290. The highest point of this hill is ledge, which forms all its south-east side, being in many places precipitous. A similar mass of lower till, with modified drift beneath or enclosed in it, lies on the north-west side of a hill two miles north-east of Wolfeborough village. Pray hill, north of Pine River pond in Wakefield, has a fine north-west slope of till, while its south-east slope is ledge. Fogg's Ridge, one mile south of Pocket hill in Ossipee, is the only true lenticular hill seen in Carroll county. This is a typical example, showing no ledges for 100 feet below its highest point. Its whole north-west and north slopes appear to be composed of till; on the south and south-east, ledges form the base of the hill, extending half way to its top. Its trend, like that of the slopes of till, is approximately north-west to south-east.

Belknap County. The till south and west of Lake Winnipiseogee is sometimes accumulated deeply on the north-west slopes of hills, as in Carroll county, but more commonly it is massed on the south-east or sheltered side. Prospect hill in Alton, and Ayers hill in the edge of Barnstead, four miles farther west, are fine examples of "crag and tail," the till lying only upon their south-east sides, having, in the first case, a very straight slope, and in the latter a rounded, lenticular form. Similar masses of till rest upon the south and south-east sides of Hall's hill, one mile north-east of Gilmanton Iron Works. Several small lenticular hills occur near Half Moon pond, which is crossed by the line between Alton and Barnstead; others were noted five miles farther south, near Clark's corner; and a fine example lies three fourths of a mile south-east of Lower Gilmanton. Far the greater part of these townships, however, are destitute of any such deposits; and in the remainder of the county, towards the north-west, lenticular hills and slopes are still more rare.

Merrimack County. The lenticular accumulations of till are well shown in several of the towns of this county. They are most numerous from Pittsfield westward to the Merrimack river. Farther west, typical hills of this class are very rare; but we occasionally find massive lenticular slopes, or broad, flattened swells, of till. The north, west, and south-east portions of this county have scarcely any examples of these deposits.

In Pittsfield, the north-west slope of Tilton hill, two miles east of the village, consists of three rounded masses of till, but ledges form its top and east side. Much glacial drift is accumulated west of the Suncook in this town and the north part of Chichester, forming lenticular hills, of which Perkins's, Prospect, Jenness, Leavitt, and Brown's hills are good examples. Two of these hills occur in Loudon north of Rollins pond; three more west of Crooked pond, near a saw-mill; and four were noted near together south-east of Clough pond. Others are scattered here and there through these towns and the south half of Canterbury. The most elevated of these bunches of till lie on the north-east slope of Garvin's hill in Chichester, near its top, and similarly on Oak hill in Loudon, both of which are principally ledge. For a third of a mile next above Webster's mills in Chichester, the Suncook river has cut its channel fully 75 feet deep through an accumulation of till, which appears to have rested against a ledgy hill on the south-east. This till forms bluffs that rise very steeply from the river on its north-west side. The finest development of lenticular hills seen in this county is in Concord, north-east of Snow pond, where a group of seven or eight is included within half a mile square. At a mile and a half to the north-west, another example with a double summit is crossed by the north line of this township.

West of the Merrimack river, Horse hill in the north-west corner of Concord, and several smaller rounded masses at its south-east foot; Beech hill, at the east line of Hopkinton, at least on its slopes both to the north and south; the massive north slope of Putney hill, well seen from Contoocookville; Gage's hill, one mile west of Hopkinton village; several small accumulations in Dunbarton; and Gove's hill, north of Gove's pond in Henniker, belong to this class. In Webster, till forms deep accumulations sloping to the north, at Corser Hill village; west of Long pond; and on the north side of Little's hill. Glitten's hill in this town, and Pumpkin and Burnt hills in Warner, are very massive hills of typical lenticular form. They have outcropping ledges at their tops, while their slopes on all sides are composed of till. In Salisbury till forms the south-east slope of Lovering's hill, and the gentle swells upon which the south and central villages are built. In Andover it is prominently massed in southward slopes west of Highland lake. Its most notable accumulation in the west part of this county is at New London village, where it forms a broad rounded swell nearly a mile long. The trend of these deposits in Merrimack county is generally north-west to south-east, varying in Canterbury, the west part of Loudon, the north-east part of Concord, and in Dunbarton to a course more nearly north and south.

Hillsborough County. The north-west and south-east portions of this county are nearly or quite destitute of any lenticular masses of glacial drift. They are, however, sprinkled very abundantly over a central area ten to fifteen miles wide, which extends across the county from north-east to south-west, being connected beyond its limits with the conspicuous development of these hills already described in Dublin, Jaffrey, and Rindge.

Beginning at the north-east, we find a very remarkable group of lenticular hills, about twenty in number, north of the principal village in Goffstown. Two prominent examples occur a mile east from these, but no others were observed in this whole township. Five miles to the west these hills are again well displayed in the south part of Weare. The massive south-east slope of Dearborn's hill, and the top of Chevy's hill, which lies north-west of Clinton Grove, are also till. In the latter case it forms a rounded mass crowning a high ledgy hill, while scarcely any other lenticular accumulations are to be seen for miles around. Several of these hills and slopes occur in Deering, the most massive being on the east side of Wolf hill, and a southward slope from the hill-top west of Chase pond.

Three or four prominent lenticular hills were found in the edge of Bennington and north-west corner of Francestown, at the north side of Crotched mountain. Others lie in the east part of Francestown, north of Haunted pond. New Boston, except at its east side, is well dotted with lenticular hills, of which Beard's, Clark's, and Cochran hills, one close north of Mr. Solomon Dodge's house, two or three others within a mile to the north-west, one north of the first saw-mill below the village, others north and south-west of Cochran pond, a mile south of the village, and one less than a mile north-east of Joe English hill, are typical examples. Bedford has a few of these hills, the finest of which, a mile north-east of the village, is well seen from Manchester. In Amherst the south slope of Walnut hill is till, which also forms three lenticular hills one to two miles north-west, and several rounded masses on the south side and near the top of Chestnut hill. Prospect hill in Mont Vernon, and several southward slopes south and south-west of the village, belong in the same class.

These hills are absent from the west part of Mont Vernon, most of Lyndeborough, and the middle of Francestown; but in the east part of Greenfield they are finely developed. Two miles north-east of Russell's crossing, till lies in rounded masses on the north-west slope of Lyndeborough mountain. It also forms a smooth area of several acres near its south-west summit, and is spread in extensive sheets on its south-east side.

In Wilton, Temple, Greenville, and New Ipswich, the lenticular hills are abundant. Fine examples occur in the edge of Milford, two thirds of a mile east of Wilton depot; upon Perham hill, in the north-east corner of Wilton; a mile to the north-west in the edge of Lyndeborough; several in the north-west and others in the south-west part of Wilton; four within one mile north-east of Temple village, known as Follett, Walton, Howard, and Wilson hills; Nobby hill in Mason, one mile south of the village; Bellows and Campbell hills in Greenville, and another north-east of the depot; Jefts hill in New Ipswich, one mile west of Greenville, with others close south-west and one half to one and a half miles north-west; several one mile south and south-west of New Ipswich village; and three on the west side of Barrett mountain.

A few hills of this class are found in Peterborough, being most numerous about Cunningham pond; also in Sharon, which has near its south-west corner one of the finest examples seen in New Hampshire. The trend of these hills and slopes throughout this county is almost invariably towards the south, or ten to twenty degrees east of south.

Strafford County. No lenticular hills or slopes were found in the north part of this county. Rounded masses of till occur at several places on the south-east side of the Blue hills, south-east of Merrill's corner, and in prominent ridges near Strafford corner and centre. In Rochester five lenticular hills were noted, the finest of them being Hayes hill, now owned by Walter S. Hussey. This rises with a very regularly rounded outline 150 feet above the lowland or valleys which surround it on every side. Another of similar height, but less typical in form, lies one mile south-east, near Gonic village. Two of these in Rochester occur east of the Cochecho, being Haven hill crossed by the road to Great Falls, and Gonic hill a half mile south. The former is less steep and prominent than usual, but was shown by a well at its top to be composed of glacial drift at least forty feet deep.

Green hill in Barrington is principally till in three lenticular masses, but ledge occurs at its north-west summit. Dover has two prominent lenticular hills, neither of them typical in form. Long hill represents one extreme, being more elongated than usual, with the nearly north-west to south-east trend which prevails in this county; and Garrison hill, which rises steeply about 150 feet, is at the opposite extreme, being nearly round. Farther south, the only lenticular accumulation of till seen in this county is Wednesday hill in Lee. This is a good example of these hills, rising 75 feet above the land on all sides. Its nearest neighbors of the same class are Bald and Grapevine hills in Newmarket, five miles distant.

The towns of Maine which border this county on the south-east similarly contain scattered lenticular hills, of which Butler's hill, close east of South Berwick, and Third and Frost hills in Eliot, are very fine and prominent examples.

Rockingham County. Deerfield is the only town in the western half of this county which shows frequent lenticular deposits of till. They were noted at about one mile from Deerfield centre towards the north-east, north-west, west, and south-west. At a mile and a half towards the south-east are two fine hills of this kind, with the north summit of Mt. Pawtuckaway one mile farther east. Southward through this part of the county lenticular hills are very rare, the only examples discovered being Waterman's hill in the north part of Derry, a small one a fourth of a mile north-east of West Hampstead, one close north-east of Salem depot, and Spicket hill, east of Salem village. The last is very massive, and is associated on the east with the extraordinary development of these hills through the north part of Essex county, Mass. The only other lenticular hills observed west of the Boston & Maine Railroad in Rockingham county are Red Oak hill in Epping, the top of which is till, with its whole south-east slope; Dimond hill, and several others in the east part of this town; Grapevine and Bald hills in the south-west corner of Newmarket, the latter a very fine example, 150 feet in height; Deer hill in Brentwood, one mile north-west of Marshall's corner, also typical, about 100 feet in height; Beech hill in Exeter; and the several rounded masses of Great hill at the north-east corner of Kingston.

In Newington, Portsmouth, Rye, and a width of four or five miles next to the ocean southward, these hills are entirely absent, if we except the single instance of Great Boar's Head, described on page 254. Stratham has a few fine examples, as Stratham, Barker's, Bunker, and Rollins hills. Three occur within one mile east of Exeter village, and others one to two miles farther south-east. In the five miles next to Massachusetts line, these deposits of glacial drift are very numerous and massive, being more conspicuous than anywhere else in New Hampshire. They are 100 to 200 feet high, and are the only prominent hills in this region. Nearly all of them have received names, including Sweet and Brandy Brow hills, one and two miles east of Plaistow; Morse or Falls hill in East Kingston, and Buzzell, Martin, and Hog hills, crossed by the east line of this township; Moulton Ridge, Hoosac, Round, Gove, Conner, Ward's, Horse, and New Found hills in Kensington; Cock and Great hills in Hampton Falls; and Indian Ground, Chair, Sawyer's, Aspen, and Bugsmouth hills in South Hampton.

The longer axis of most of these hills noted in the west part of Rockingham county trends to the south-south-east; in Epping, Newmarket, and Brentwood, to the south-east; while those last described have almost invariably an east-south-east course. In Kensington and South Hampton, besides this trend of separate hills, we may detect their succession in two series which extend from north-west to south-east. One of these embraces, in order, Buzzell's hill, Moulton Ridge, Hoosac, Gove, Conner, Ward's, and Horse hills; the other consists of Martin, Hog, Indian Ground, and Chair hills. The two last named are double lenticular masses, the higher portion of each being at the north-west.

Lenticular Hills in Massachusetts. These remarkable accumulations of till are very abundant and conspicuous over the greater part of Essex county, Mass. The principal exceptions to this are the east part of Salisbury; Newburyport; an area several miles wide extending thence to the south-west; Cape Ann, eastward from Essex river; and the vicinity of Salem. Prominent lenticular hills in this county are Grape, Beech, Butts, Monday, and Powow hills in Salisbury, the last of which is perhaps their finest type found in all our exploration; Whittier's and Pond hills in Amesbury; Bear and Red Oak hills in Merrimac; Great, Golden, Silver's, West Meadow, and Scotland hills in Haverhill; Bear hill in Methuen; Reservoir hill in Lawrence; Prospect hill in Andover; Gage's hill and others about Great pond in North Andover; Hazeltine and Dead hills in Bradford; Bald Pate hill in Georgetown; Long, Pipe Stave, Archelaus, Ilsley's, and Crane Neck hills in West Newbury; the Old Town hills in Newbury; Ox Pasture, Hundslow, and Prospect hills in Rowley; and Turkey, Bartholomew, Turner's, Scott's, Town, Heartbreak, Plover, Sagamore, and Castle hills in Ipswich. Nearly all of these come within the limits of the map of these deposits, presented in the atlas of this report. Others occur farther south in this county.

Lenticular deposits of till are also very conspicuous in the vicinity of Boston. They form many of the islands in the harbor, and the numerous prominent hills that occur in the city and for five miles to the north and west, in the towns of Winthrop, Revere, Chelsea, Everett, Malden, Medford, Somerville, Cambridge, Watertown, Brighton, Newton, and Brookline.

The trend of these hills in Essex county is prevailingly towards the south-east; but some of them vary from this to nearly north and south, while others have their longer axis from west to east. Perhaps one fourth of them, however, are nearly round, having no well marked trend. This form is rarely seen in New Hampshire. About Boston their course is quite uniformly from north-west to south-east.

In the north part of Middlesex county lenticular hills of glacial drift are rare, but are represented by a few fine examples, as Fort hill in Lowell, on the east side of Concord river; Forest hill at the south-east edge of Dunstable, with another close north-east; and Blanchard's hill, with two others at the north-east, situated near the north line of Dunstable, west of Salmon brook. They are wanting in Pepperell and Townsend; but a prominent one is crossed by the east line of Ashby north of Lock's brook, and they are quite numerous in the next ten miles to the west.

In Groton and Ayer, lenticular hills are well shown along the east side of the Worcester & Nashua Railroad. Thence to the south-west they are rarely seen till we reach Worcester, where they are again abundant, especially for three or four miles north and west of the city, varying from 50 to nearly 200 feet in height. Reservoir or Chandler's hill, Newton, Prospect, and McFarland's hills are good examples.

Westward from Ayer along the Fitchburg Railroad, they occur at Shirley station, in the south part of Lunenburg, and prominently north and north-west of Leominster. At Fitchburg, and for several miles to the west and north-west, all the hills are ledgy with no important accumulations of till. Their notable abundance in New Ipswich and Rindge continues into Ashby and the north part of Ashburnham; but the next five miles to the south and south-west showed very few lenticular hills.

In Gardner, they again become numerous and prominent, Cowee's and Parker's hills being very conspicuous examples. From their tops as many as twenty of these hills are visible, mostly within two or three miles. Parker's hill is separated by a hollow of about 40 feet from a contiguous lenticular hill that rises at about twenty-five rods north-east to a nearly equal height. At the bottom of this depression, which is 100 feet above the foot of the hill in each direction, a former water-course, fifteen to thirty feet wide and four or five feet deep, filled with boulders from among which all the earth has been swept away, extends from north-west to south-east twenty rods or more. Its explanation seems to be, that while the ice-sheet was melting over this area, portions remaining at the north-west side of the hill turned a stream through this gap.

On Plate xviii of the second volume of this report, Prof. Hitchcock has shown the position of prominent lenticular hills in Bernardston and the north part of Gill. He also reports their occurrence in the north part of Montague; in Amherst, where Mt. Pleasant, other hills at the north and north-east, and the College hill are examples, also the hills in the south part of the town, called Castor and Pollux; in South Hadley, Prospect hill near the Seminary being of this class; and in the west edge of Granby.

The trend of these hills in the north part of Middlesex county is between south and south-east; about Worcester, Gardner, and Amherst, it is nearly north and south; while in Bernardston and Gill it is commonly a little to the west of south. Probably lenticular hills occur at many other localities in this state, which has been specially explored for this report only in its north-east portion shown upon our map.

Cape Cod and Long Island. A hasty journey has been taken upon Cape Cod and Long Island, with a hope that some examination of the drift deposits near their southern limit might lead to a better understanding of the various questions suggested by exploration in New Hampshire. The description of Plymouth and Barnstable counties in the geological report of Massachusetts, and of Long Island in that of New York, seemed to indicate that these areas would show lenticular hills; but no accumulations like those which we have been describing under this name were seen.

The greater part of southern Plymouth county was found to be covered with modified drift. Much of this is spread in level plains, which in Middleborough have many shallow depressions that are occupied by swamps. In the west part of Plymouth the only hollows which break the plains are of small area with steep sides, containing ponds. These are so numerous that this township is said to have a pond for each day in the year. About Plymouth village the modified drift forms kame-like hillocks and small plains, which are separated by very irregular hollows and valleys. The tops of these deposits have a nearly uniform height which varies from 100 to 125 feet above the sea.

In the east part of Plymouth a massive ridge, known as Manomet or Rocky hill, extends three or four miles from north to south, having a continuous height 300 to 400 feet above the sea. Abundant angular boulders of all sizes up to twenty feet in diameter strew its surface, which seems to have no ledges, but to consist entirely of the very coarse glacial drift that we have called upper till. At the north end of this range the sea has undermined its base, forming a steep slope sixty feet in height. A section here showed twenty feet of upper till, yellowish, with abundant large and small boulders, nearly all of them angular, underlain by lower till, dark bluish gray, with small glaciated stones, exposed for twenty feet vertically but concealed below. The bed of boulders which forms the shore at this point came mostly from the upper stratum; their sharp corners and edges have since been worn away by the waves. This ridge is bordered on both sides by kame-like or nearly level areas of modified drift.

Southward, a broken range of lower hills, composed of the same coarse till, continues through Plymouth, Sandwich, and Falmouth. Thence it bends to the south-west, forming the chain of the Elizabeth islands. The highest elevations of this series of hills in Sandwich are about 300 feet, and in Falmouth and upon Naushon and the islands farther west, nearly 200 feet above the sea. Its length, from Manomet hill to the end of the Elizabeth islands, is forty-five miles.

Railroad cuttings thirty feet deep in these deposits, one mile north of Falmouth village and Wood's Hole, show only the upper till. All of Naushon island consists of the same material upon the surface, namely, mingled boulders, gravel, and sand, wholly unstratified. The boulders are often so abundant as to cover all the ground, and are of all sizes up to ten, or even twenty or thirty, feet in diameter. They are almost invariably angular, except as they have been rounded by exposure to the weather, none of them, so far as observed, being glaciated or water-worn. Cliffs forty or fifty feet high, which are being undermined by the sea south-west from Tarpaulin cove, appear to be composed entirely of this coarse upper till; but on the north-east end of the island a well sixty-seven feet deep passed through this deposit, and its last twenty-two feet were in very hard lower till, dark gray in color, with glaciated pebbles.

The contour of this island, as also of many localities throughout the whole series of these hills, is very irregular, consisting of hills, ridges, and rounds, with bowl-shaped hollows which frequently contain ponds. This feature has led some to regard these deposits as similar to kames.[*] Their material, however, is very different from that of the kames, which consist principally of stratified water-worn gravel, rarely containing any large or angular boulders, but frequently intermixed with layers of sand.

The conclusion of Mr. Clarence King, that this island, which he examined, forms part of a terminal moraine of the continental ice-sheet, seems to explain the accumulation of the till in this remarkable series of hills. The border of the ice-sheet probably remained almost stationary through a long period, in which the materials that it contained were being continually brought forward and deposited at this line of its melting. In many places these would be pushed into very irregular heaps and ridges by retreats and advances of the ice-margin. At the same time we should also expect that thick beds of ground-moraine would be gathered beneath the ice near its termination. The withdrawal of the glacial sheet would then leave these deposits as upper and lower till, one overlying the other, in a long but broken and undulating series of hills.

This terminal moraine does not, however, mark the farthest limit reached by the glacial sheet, which at one time extended six or seven miles beyond the Elizabeth islands, as shown by the prominent range of drift hills, which forms the north-west part of Martha's Vineyard. The origin of Cape Cod also seems to have depended upon this greater extension of the ice-sheet. Its terminal front appears to have continued from Martha's Vineyard north-easterly across Barnstable, thence to the east and north along the inner shore of the cape to Truro, which it probably crossed, extending onward to the north-east. This seems to be the outmost line at which we can assert the former presence of the continental ice-sheet.

Cape Cod, east from Sandwich, consists almost entirely of modified drift. Through Barnstable this is disposed in kame-like ridges, knolls, and small plains, separated by crooked and bowl-shaped depressions. The material here is gravel and sand, often obliquely bedded, with frequent boulders which appear to have been dropped upon these stratified deposits from floating ice. From Barnstable to South Wellfleet the surface is mainly level, consisting of plains of fine gravel or sand, and boulders are rarely seen. These plains vary in height from 25 to 75 feet above the sea. From South Wellfleet to High Head in the north part of Truro, the contour on the west side of the cape is again in very irregular kames, which are composed of gravel and sand with only rare boulders. These deposits, like those in Barnstable, rise to a height 100 to 150 feet above the sea. The east side of the cape is here a nearly continuous bluff of this height, horizontally stratified, being evidently a remnant of a nearly level plain, the east part of which has been washed away by the sea. Thick beds of clay have been exposed at a few points. At the Clay Pounds, near Highland light, the section is sand at the top, about 40 feet; finely laminated blue clay, also about 40 feet; then

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[*] *Proceedings of the Boston Society of Natural History*, vol. xix, pp. 59-63; and *American Naturalist*, vol. xi, pp. 674-680.

sand, with occasional layers of gravel containing pebbles up to six inches in diameter, exposed for 20 feet, and probably extending as much farther to the sea-level.

The accumulation of these thick deposits of modified drift, occupying an area more than forty miles long, with an average breadth of five miles, remote from any large river, and bordered on each side by the sea, seems capable of explanation only by supposing the material to have been held in an ice-sheet, which extended to the line that we have indicated, covering the Vineyard sound, Cape Cod and Massachusetts bays, and thence reaching to the north-east over a large part of the Gulf of Maine. When the return of a warmer climate drove back the front of these ice-fields to the long terminal moraine of the Elizabeth islands, Falmouth, Sandwich, and Plymouth, the rivers which flowed from their melting surface were principally discharged at two points, those at the south-west converging towards Barnstable, while those which descended from the glacial sheet over Massachusetts bay had their mouth in Wellfleet and Truro. The bordering walls and irregular masses and ridges of ice, which beset these rivers at their points of escape from the ice-sheet, caused their deposits over these areas to be massed in kames. The ocean at this period stood 150 feet or more above its present height; and the part of the burden of these glacial rivers, which was carried beyond their mouths, was spread by marine currents in nearly level plains, bordering the front of the ice-sheet. The true terminal moraine of till, formed by the ice at this bound of its greatest extent, is covered by the sea or by these beds of modified drift.

The north end of these Champlain deposits is at High Head. The whole of Provincetown consists of sea-sand, with no pebbles. This sand has come from the erosion by the sea of the east shore of the cape; has been swept north and west to its present place in the lee of this breakwater; lifted by the waves into beach-ridges; and further raised by the wind into hills a hundred feet in height.

On Long Island the farthest limit attained by the ice-sheet is probably indicated by a series of drift hills, which is commonly known as the "backbone of the island." These hills are well exposed along the south shore for about ten miles west from Montauk point, forming cliffs from 20 to 140 feet high. Westward, they extend through the north part of East Hampton, and from Sag Harbor south-west to the Shinnecock hills and Canoe place. Thence they continue in a nearly west course, including Osborn's hill, a few miles south-west of Riverhead; Terry's hill, south of Manor; Holman's hill, north of Yaphank; the Coram, Seldon, and Bald hills; Mount Pleasant, west of Ronkonkoma lake; Pine hill; the Commac, Dix, and West hills; Spring, Wheatly, and Harbor hills, the last of which, near Roslyn, is the highest point on this island. Farther west, this series of hills trends a little more to the south, passing near Lakeville, and close north of Creedmoor, Jamaica, and East New York. Thence it nearly coincides with the south-east boundary of Brooklyn, and reaches to the Narrows, forming the sites of Cypress Hill cemetery, Ridgewood reservoir, and the cemetery of the Evergreens, of the highest portions of Prospect park and Greenwood cemetery, and of Fort Hamilton.

The length of this range from Montauk point to the Narrows is about 115 miles. It is interrupted at Neapeague beach and marsh, 12 miles west of Montauk point; between Manor and Yaphank; and at Syosset. West from Roslyn it is very plainly recognized as a continuous, irregularly undulating ridge. The heights of prominent hills in this series are as follows:* Montauk point, 85 feet above the sea; Fort Pond hill, five miles to the west, 194; Neapeague hill, 135; Amagansett hill, 161; Shinnecock hill, 140; Osborn's hill, 293; Ruland's hill, south of Coram, 340; Jane's hill, the highest of the West hills, 354; Layton's or Wheatly hill, 380; Westbury hill, 260; Harbor hill, 384; John M. Clark's hill, near Manhasset, 326; Smith's hill, 332; Prospect hill in Brooklyn, 194.

In the east and middle portions of the island the majority of these hills are composed of modified drift, being gravel and sand, distinctly stratified, and containing few or rare boulders. Osborn's, Ruland's, Jane's, and Harbor hills are of this kind. They appear to be immense kame-like deposits, formed at the terminal front of the glacial sheet. As at Cape Cod, when this was obliged to retreat, its melting took place over a very wide extent of its surface; and the rivers thus formed were heavily freighted with gravel, sand, and clay, which had been contained in the ice. A large portion of this gravel and sand would be heaped at the mouths of these streams,—that is, at the points where they left these ice-fields and entered the lower open area beyond.

The part of Long Island south of these hills consists of nearly level plains of fine gravel and sand five to ten miles in width, and extending a hundred miles in length. The height of their north portion at the foot of the hills varies from 50 to 150 feet above the sea. These deposits, like the levelly stratified drift of Cape Cod, appear to have been brought by the glacial rivers which formed the kame-like hills. The ocean rolled its waves above the surface of these plains, spreading the material which it thus received over a wide area to the south.

Near the west end of Long Island this range of hills is composed entirely of unstratified glacial drift, full of boulders, having all the characteristics of the upper till. It is well exhibited in the south-east part of Brooklyn by many excavations, as for cellars and streets. This is the true terminal moraine of the ice-sheet. Its continuation eastward is for the most part covered by the later kame-like gravel and sand. Westward, this terminal moraine, principally composed of coarse, unstratified drift like the upper till, heaped in irregular hills and ridges, begins on the opposite side of the Narrows at Forts Tompkins and Wadsworth, crosses Staten island, and enters New Jersey† at Perth Amboy; it bends thence to the north-west and north, passing near Plainfield, Morristown, and Dover; next it runs west and south of west by Hackettstown to the Delaware river a little above Easton.

The boundary of the ice-sheet at its period of greatest extent appears to be thus

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* From articles on the geology of Long Island, by Mr. Elias Lewis, Jr., of Brooklyn, in *American Journal of Science and Arts*, third series, vol. xiii, pp. 235 and 236; and in *Popular Science Monthly*, vol. x, pp. 434–446. The greater part of these heights were determined by the United States Coast Survey.

† The course of these hills at the most southern limit reached by glacial action in New Jersey is from the annual report for 1877, of Prof. George H. Cook, the state geologist. He says,—"The whole line of this moraine is remarkably plain and well defined."

plainly marked for a distance of three hundred miles, reaching from Truro, near the end of Cape Cod, through Barnstable, the north-west part of Martha's Vineyard, Block Island, Montauk Point, the centre of Long Island, the south-east part of Staten Island, and northern New Jersey. Careful exploration will probably discover a similar series of hills, composed of unstratified upper till or of modified drift, at the border of the glaciated area through Pennsylvania, Ohio, and states farther west.

A later terminal moraine seems to be indicated by the line of drift hills which forms the north shore of Long Island through the greater part of Brookhaven, Riverhead and Southold. Its extension to the east appears to be through Plumb and Fisher's islands, and the southern edge of Rhode Island; thence to the Elizabeth islands, and from them northward to Manomet hill. At this line the ice-sheet made a long halt in its retreat. No similar series of drift deposits has been noticed farther north in New England, over which the melting of the ice-fields seems in general to have been without sufficient pauses for the formation of definite terminal moraines.

It remains for us to inquire what was the origin, or mode of accumulation, of the lenticular hills and slopes of till which have been found to be abundant and prominent in many parts of southern New Hampshire. We have seen that in Cheshire, Hillsborough, and Rockingham counties these lenticular masses are scattered here and there, and in some places quite thickly, upon three areas which vary from five to twenty miles in width, and extend twenty-five or thirty miles from north to south, or from north-east to south-west. The greater part of the most eastern of these areas lies beyond the state line in Essex county, Mass. These tracts are separated by others of equal or greater width, upon which scarcely any lenticular hills are found. This territorial division in three groups does not appear to have been caused by differences in the adjacent stratified rocks; it more probably resulted in some unexplained way from movements of the ice-sheet. It is the only indication of system which we have discovered in the distribution of these hills. Whether they occur rarely or very abundantly, they are alike irregularly scattered without any apparent order or connection, nowhere forming well defined series, like those of the terminal moraines of Plymouth and Barnstable counties in Massachusetts, and of Long Island and New Jersey.

In Sullivan, Carroll, Belknap, Merrimack, and Strafford counties, lenticular accumulations of till are sprinkled more sparingly, with no traces of system, being numerous in some localities, but generally rare or absent. With this diminution in numbers northward, the relative proportion of lenticular slopes of glacial drift resting against ledgy hills is increased. Carroll county is especially remarkable for the frequent occurrence of these slopes on the north-west side of hills, directly facing the powerful current of the ice.

Nearly the whole of New Hampshire presents a very uneven surface, consisting of broken and irregularly grouped hills and mountains. The distribution of the lenticular hills does not seem, however, to depend upon these features. They are very finely developed on the lowland near the coast, but not less so in Dublin, Jaffrey, and Rindge, upon the height of land between Merrimack and Connecticut rivers. Beside the coast they are spread over an area which would otherwise be nearly level; at many places inland they are equally abundant among high, irregular hills. They seem as likely to be found upon one side as another of any mountain or prominent hill-range. The altitude at which they occur varies from the level of the sea to 1,500 feet above it. By reference to a map in the atlas, the relation of the lenticular hills to contour lines and striæ will be readily seen.

The most noticeable feature of these remarkable deposits is their smoothed oval form with a definite trend or longer axis, which lies almost invariably in the same direction with the striæ. Thus their position is the one which opposed the least resistance to the glacial current, and is that which would be assumed by accumulations formed beneath the moving ice-sheet. Deflection in the trend of these hills at any locality from their prevailing course over adjacent areas is usually accompanied by deflected striæ. An instance of this occurs in Dublin on the north side of Monadnock mountain, where both lenticular hills and striæ point thirty or forty degrees more than usual to the east of south. A similar deviation of the striæ has been noted at Andover and Potter Place, on the north side of Mt. Kearsarge, but no lenticular hills occur there. It would appear that any isolated mountain like these, while enveloped in the ice-sheet, might cause only slight variation in its current, which must overcome as great resistance in turning aside as in passing upward without changing its course; but near the end of the glacial period, when such barriers were reached by the retreating terminal front of the ice, its current from the north would no longer be pushed upward by the continuous glacial sheet, so as to pass over the mountain, but would be deflected toward the vacant area at the south-east. It seems probable, therefore, that the hills mentioned were moulded with their unusual trend during the decline and departure of the ice-sheet. Such deflection of the lenticular hills is uncommon, their trend being nearly uniform over large areas, gradually changing from a south-east course in Carroll, Strafford, and Rockingham counties, to a nearly south course in the west part of the state.

The till of Scotland is described by Mr. James Geikie,* as massed in ridges which seem to be somewhat like our lenticular hills, but more prolonged and less prominent. His opinion that these accumulations of the Scottish till were formed beneath the ice-sheet, seems to be true also of the lenticular hills and slopes of New England. The reasons which lead us to this conclusion are the distance of these deposits from the end or outside limit of the ice-sheet, as it probably existed through the greater part of the glacial period; their difference from the hills and ridges of the terminal moraines there formed; the trend of the lenticular accumulations; their composition principally of lower till; the occurrence in this till of level sandy layers; the similarity of the lenticular hills to slopes which rest against ledgy hills, either upon the side which was sheltered from the ice-current or upon that which was fully exposed to it; and the obscure lamination, which may be commonly observed in sections of the lower till, whether in lenticular masses or in flattened sheets.

Below a thin covering of upper till, the material of which the inner portion of these hills and slopes is formed is the dark and compact lower till, which has been described on pages 9 and 286. It has been shown that the character of this deposit can be explained only by supposing it to be the ground-moraine accumulated beneath the moving ice-sheet. The small proportion of its iron that has become fully oxidized, and the

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* "In the Lowlands the effect produced by the varying direction and unequal pressure of the ice-sheet is visible in the peculiar outline assumed by the till. Sometimes it forms a confused aggregate of softly swelling mounds and hummocks; in other places it gives rise to a series of long smoothly-rounded banks or 'drums' and 'sowbacks,' which run parallel to the direction taken by the ice. This peculiar configuration of the till, although doubtless modified to some extent by rain and streams, yet was no doubt assumed under the ice-sheet." —*The Great Ice Age*, American edition, p. 88; second edition, revised, p. 76.

This explanation is quite different from that advanced by Prof. N. S. Shaler, respecting the lenticular hills of eastern Massachusetts, in the *Proceedings of the Boston Society of Natural History*, vol. xiii, pp. 196–203. He supposed these hills in the vicinity of Boston to be remnants spared by the fluviatile and tidal erosion of a once continuous sheet of drift, which had been contained in a glacier that descended the Charles River valley and was deposited at its melting.

very fine clayey detritus in which its glaciated pebbles and boulders are embedded, indicate that this portion of the drift has been mostly derived by erosion from the rocks, and pulverized under the grinding action of the ice-current.

The level layers of gravel, sand, or clay that are occasionally found in this lower till appear to have been formed by streams, which in summer found their way through crevasses to the bottom of the ice. These seams and beds of modified drift in the till frequently occur upon lenticular hills and slopes, where they could not have been deposited by ordinary streams, if the ice-sheet was withdrawn. The usually horizontal position and considerable extent of these beds show that after their formation they lay undisturbed, while the ground-moraine continued to be deposited above them. Where similar seams or beds are nearly vertical, inclined, or contorted, as they are more rarely observed, it shows that a large mass of the lower till was lifted up before the ice-current, and pushed forward with its included layers of modified drift.

The accumulation of these hills and slopes seems to have been by slow and long continued addition of material to their surface, the mass remaining nearly stationary from the beginning of its deposition. Obviously this was the case with the lenticular slopes gathered behind the shelter of higher ledgy hills, or upon their opposite sides. Except in their location, these slopes are like the lenticular hills, which seem to contain no ledge, being simply heaps of the ground-moraine 50 to 200 feet in height. This resemblance suggests that both hills and slopes alike increased slowly in extent and depth without much change in place, new material being lodged upon their surface from the ice-sheet which swept over them.

The obscure lamination or cleavage, which is one of the characteristic features of the lower till, was probably produced by this mode of its accumulation. In this deposit from the ice-sheet, it corresponds to the stratification of sediments from water, but it is less distinct; and the fine detritus in which it appears contains glaciated pebbles and boulders indiscriminately mixed through its whole mass. This structure was at first thought to be a true cleavage, caused by the pressure of the glacial sheet. If we take this explanation, it still proves, like the hardness and compactness which also mark the lower till, that this deposit was not ploughed up by the enormous pressure of the ice passing over it. How could this force permit the ground-moraine to be heaped in the steeply-projecting lenticular hills? Instead of this we should expect it to be left only in flattened sheets or behind sheltering ledges. The probable answer seems to be, that the finely pulverized detritus and glaciated stones in the bottom of the ice-sheet had a tendency to lodge upon the surface of any deposit of the same material. When such banks of the lower till became prominent obstacles to the ice-current, its levelling force was less powerful than this tendency of adhesion, which continually gathered new material, building up these massive rounded hills. At the melting of the overlying ice-sheet, the surface of hills and valleys, ground-moraine and ledges, were alike covered by the nearly continuous mantle of the upper till. W. U.

NOTE UPON LENTICULAR HILLS, BY C. H. HITCHCOCK.

Thorough search for these moraines has been made in all parts of the state south of the White Mountains, not including Grafton county. Not many more will be added by future observations. I do not think any occur in Grafton county. In Canaan, long drift covered hills south of the centre bear some resemblance to them. A trip through eastern Vermont revealed facts of interest. In Orange two hills in the south-west corner resemble lenticulars, and, as seen from a distance, there appear to be genuine examples on the north-west side of the church. In Peacham and Danville, numerous rounded hills resembling these moraines may be seen from elevated positions. Some that I examined proved to be composed of limestone, weathered roundish; so it seems probable that all the others are similarly constituted. One not familiar with the behavior of this rock, when acted upon by atmospheric agencies, might call all these mounds lenticular hills. Large drift hills are known to occur in Bethlehem and Whitefield. Another trip to the localities would be requisite to enable me to pronounce upon their existence in these towns or elsewhere in Coös county. It seems probable that the great drift hill just west of Chocorua pond in Tamworth should be of this character. The heliotype illustration of some of these hills in Goffstown admirably represents their general character. All the hills in the view are true lenticular ground-moraines, with no ledges in them. They are simply piles of earth and stones accumulated beneath the ice-sheet, and afterwards covered by the upper till. The information contained in Mr. Upham's description of these hills is one of the most valuable contributions to science obtained during our whole survey of the state.

LAKE RAMPARTS.

Under this name I have described in earlier state reports ridges of boulders and coarse gravel bordering certain portions of shallow ponds. They occur where the water is not deep, and there is a considerable exposure of shoal bottom strown with boulders. As the water freezes in the winter the ice encloses these stones, and by virtue of expansion moves them nearer the shore. The amount of pushing in a single season would be small; but the work would be resumed every winter, and in the course of ages the fragments would reach the shore, and perhaps be crowded inland. Farmers who build fences on the edges of a wide ditch often find them bent or prostrated in the spring for a similar reason; the expansion of the water in freezing has pushed them over.

Several instances of these ridges have been observed in New Hampshire. The best known is on the Vaughan shore in Moultonborough, in the north-east part of Lake Winnipiseogee. We find there a ridge one eighth of a mile long, opposite a broad expanse of shallow water about four feet in height. Passing easterly 125 feet, the ground is low and swampy, and another similar ridge about fifteen feet high is encountered, fronting a low terrace. It is very likely this ridge represents an older rampart, made when the lake stood at a higher level. The shore and the ridges are covered by shrubs and trees. A pine had been cut recently from the smaller rampart, whose trunk has a diameter of twenty-eight inches. From this I obtained a section for the museum, and counted 122 rings of growth upon it. As this had been cut twenty-five years previous to my visit (1871), it is obvious that certainly a century has elapsed since the formation of the rampart. I saw a tree still standing upon this ridge twenty-seven inches in diameter. A few years since, in the case of the town of Gilford *v.* The Winnipiseogee Lake Company, it was found expedient to use the facts shown by this rampart with the trees upon it, to prove that there had been no unusual flowage of the lake for the past hundred years. The whole court adjourned to visit the locality. Fig. 62 shows the two ramparts with a tree

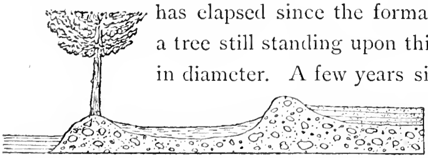

Fig. 62.—LAKE RAMPART, MOULTONBOROUGH.

standing upon the first. Another example may be seen at the south end of Long island. It is possible that Steamboat island and its culmination south in a ridge in shallow water is to be regarded as one of these ramparts.

SEA WALLS.

A variety of the sea-beach action is indicated by the term *sea walls*, which I suggested for them in 1861.* It is a long embankment of smooth boulders, without sand or gravel, lying just behind the beaches. When the more powerful storms prevail off the coast, stones up to two feet in diameter are carried a distance of hundreds of feet, and deposited just back of the beaches. Sometimes they are fifteen feet in height. I have noticed them in Rye.

DISTURBANCES IN MODIFIED DRIFT.

A few examples of curvature in layers of gravel and sand have been noticed. One of them is represented in Fig. 63. It is seen on the east side of John's river, in Whitefield, just east of the depot. Coarse gravel occupies the centre and lowest part of the arch, and there is another mass of it upon the steep slope to the left. The bank was exposed for about fifteen feet.

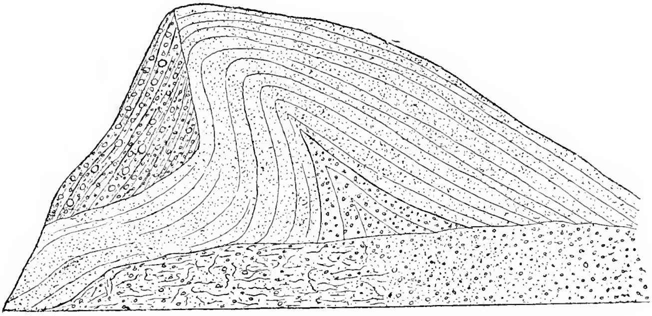

Fig. 63.—SECTION IN GRAVEL, WHITEFIELD.

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* *Preliminary Report Geology of Maine*, p. 270.

Another style of disturbance is indicated in faults, some of which have been referred to upon page 39. Many of them can be regarded as the result of local sliding. One more difficult to explain may be seen between Mink brook and the village of Hanover upon the West Lebanon road. The first bank next the brook, below Mr. Benton's house, dips 10° northerly. Near the base of the principal hill, north of Benton's, the dip is southerly at the same angle. Near the top the stratification is horizontal. The section along the road shows the loamy sand to have a synclinal structure, or, rather, there are two faulted segments dipping towards each other. Other highly inclined masses of alluvium occur close by the railroad depot in Norwich, at the north edge of the great plain two miles from Dartmouth college on the Lyme road, and near the mouth of Grant brook in Lyme, where the angle of inclination amounts to thirty degrees. It seems likely that the forces disturbing these terraces were analogous to the elevating agencies that displayed their power in the earlier periods of geological time. Earthquakes of greater severity than are now common in the state might have been adequate to produce the results. The facts are given to draw the attention of other and future observers to the subject, as they may find more important illustrations of a continental force, or else discover satisfactory evidence that the disturbances have been entirely due to gravity.

ICE ACCUMULATIONS.

Occasionally the conditions are favorable for the continuation of ice unmelted through the entire summer. The best known example is in Tuckerman's ravine, described in Volume I, page 623. Here it is exposed to the sun and air, continuing very long because of an immense accumulation. In other cases the ice is preserved in caverns, or in the midst of large fragments of rock, as in Lyman, Effingham, and Plymouth.

In Lyman, about half a mile west of Parker hill, ice accummulates beneath large stone fragments at the base of a cliff. I found no ice there September 4, 1870, though the air issuing from the side was very cold, indicating its existence. The people in the neighborhood often obtain ice from this locality in the summer. In a journal published in Concord in 1823, it is related by Caleb Emery, of Lyman, that in 1816, a memorable cold summer, he saw a well frozen over solid, eight feet from the surface, in June. The ice had to be cut to enable the draught of water. In July, he found a mass of ice floating in this well as large as a wash-tub.

In Plymouth, there is said to be an ice-cave in the west part of the town, where ice can be obtained every summer as late as the month of August.

Upon the north slope of Green mountain in Effingham I found large masses of ice in the latter part of August, 1875. Near the edge of a precipice enormous blocks have been separated from the ledges, making large passages like caves, where different fragments rest upon each other like arches. On descending twenty feet I found ice, and then followed along forty feet to a much larger opening. This ice-cellar is well known to the people living in the neighborhood.

A study of similar ice-masses elsewhere shows the existence of currents of air, downward in the summer and upward in the winter, which evaporate the water, and, by the accompanying removal of heat, induce cold sufficient to freeze water and to preserve the ice thus formed. The principle has been made use of in warm countries to produce ice artificially in merchantable quantities.

Beaver Dams.

Several bogs in the state owe their existence to the former presence of the dams made by beaver. This animal is now entirely extinct, owing to the advance of clearings and the removal of the forests. It is not uncommon to find sticks that have been gnawed by these creatures. One such example is in Plainfield, where they occur underneath pine trees more than a foot in diameter. It is plain that here a bog was filled up by the natural accumulation of sediment in the beaver pond, and the land became dry enough for pines to grow. The name of "beaver meadow" is frequently heard throughout the state, and indicates the prevalence of bogs reclaimed by animal agency. One of the largest of these lies between Mts. Misery and Odiorne, in Weare, on the land of Hon. Moses Hodgdon, nearly a mile in length. It is used for grass, and in wet seasons is often flooded with water. Logs occur quite deep down, in a soft mud in which poles can be thrust for several feet.

North America in the Ice Period.

Candid geologists admit that no part of their knowledge is so obscure as that of the cause of glacial cold. Various theories have been suggested to account for it, but none of them command universal acceptance. Before it can be properly answered, we shall find it necessary to consider somewhat the conditions of glacial envelopment, the dimensions of the areas occupied by the ice, and the directions in which movement has been effected. In such a study we shall find it necessary to look far beyond the confines of New England, for the movements in this comparatively limited area are unlike those occupying the greater part of the continental ice-sheet. Some of the difficulties we have experienced in generalizing our observations result from the smallness of our field of study. I will therefore present upon a small map of the north-east portion of our continent a delineation of the areas occupied by the ice in its period of maximum development, with arrows to indicate the principal directions of movements. An examination of this map, with a brief description of the principal features of glaciation may furnish the means for satisfactory generalizations respecting the origin, extent, movements, and duration of the ice-sheet.

The Alps of southern Europe furnish the most accessible example of glaciers in action, with indications of greater extent in the ice-period. The higher portions of the range are occupied by immense fields of snow, which are the source of the numerous glaciers pushing out from it on every side, both towards Switzerland and France on the north, and towards Italy upon the south. These glaciers may be said to radiate from a central line of dispersion. In the Alpine district the accessible glaciers behave like streams of water, occupying only the bottoms of the valleys, and descending to the lower levels apparently in obedience to the laws of gravity. A study of the former extent of these glaciers indicates their former extension across the valley of Switzerland to the Jura mountains. The Rhone glacier moved over the great valley to the Jura mountains, occupying an area 50 miles wide, 150 long, and 2,000 feet deep. Lateral, medial, terminal, and ground moraines occur in connection with all these glaciers. Large boulders have been transported from Mt. Blanc to the Jura.

An example more nearly analogous to our own is afforded by the former extension of the Scandinavian glaciers. Erdmann's map represents striæ pushing northerly into the Arctic ocean; south-easterly, in the promontory between the gulfs of Finland and Bothnia; south-east and south, varying west of south, also, in the lower part of Sweden; west, north-west, and south-west, in Norway towards the Atlantic ocean. Croll supplements this map, by showing the continuation of the southerly course into Prussia; a bending of the direction to conform with the Baltic sea, passing over Denmark to both the south and north of England. Scotland and England are made to send off additional ice-currents; and the western edge of the ice-sheet reaches to west longitude 14°, or as far as the seaward limit of comparatively shallow water. This area is certainly 1,700 miles wide, and 1,500 from north to south. This will compare favorably in size with our American glaciated area. The latest authorities show that the phenomena are all explicable by the existence of a principal central ridge of dispersion in Scandinavia and subordinate ones in Great Britain; also, that there is no evidence of the flow of ice from the polar regions into northern Europe. There exists, therefore, a close analogy between the glacial conditions of Scandinavia and North America;—and if the former can be explained upon the theory of a centre of dispersion, so can the latter.

Before considering the location of the American centre of dispersion, it will be well to recall the glacial conditions existing at the present time in Greenland, since they will illustrate the state of things in New England during the period of the greatest cold. We discover there how the ice can move up hill, and how the ground moraine can be formed.

GLACIERS IN GREENLAND.

Greenland was discovered by Gunnibiorn in 872. In 983, Eric the Red, banished from Iceland, established a colony near the south end of Greenland, imposing upon it the name it now bears. The settlement prospered; and indications of civilization left behind by these Norsemen exist as far north as Upernavik (latitude 72° 50′), or as far north as the stoutest ships of modern times can sail without encountering serious risk. The population increased sufficiently to require the services of a bishop; and a list of seventeen of them, from 1126 to 1406, has been preserved. A change of political relations led to the destruction of the commerce between Greenland and Scandinavia, and, followed by attacks of pirates, and the Skraellings or Esquimaux, led to the complete extermination of the Norse colony. The history of the last man has been preserved in Icelandic annals, whose death occurred early in the fifteenth century. Europe has been in doubt respecting the fate of this colony ever since, it having been claimed very recently that it was established on the eastern coast, and that the descendants of the original settlers might still be found there, shut off from the rest of the world by ice that had increased in amount since the last ship had communicated with them. The name *East* Greenland has led to confusion, since it might be interpreted to signify the coast looking towards Iceland instead of Baffin's bay. The most southern of the settlements upon the south-west coast was *east* of the others, and hence the use of the term East Greenland. The ruins of ancient churches and monuments found on the south-west coast clearly confirm the truth of the Icelandic *sagas.*

The island is almost continental in dimensions (perhaps consisting of an archipelago), being over 1,200 miles long and 400 broad, as far as from Boston to the mouth of the Rio Grande, or to Utah. The interior is covered by a field of ice, never entirely traversed by any human being. From three points attempts have been made to learn something of its nature. In 1830, Keilsen went 80 miles inland from Holsteinberg (latitude 67°), reaching the edge of the ice-sheet, which could not be climbed.

Nordenskiold, in 1870, went in 30 miles, reaching the altitude of 2,200 feet. He observed that the ice rose gradually towards the interior. The outer edge is a high wall. Once entered upon the broad surface of the ice, it is like travelling upon the sea, away from all sight of land. From North Greenland Dr. Hayes penetrated to a distance of 70 miles. It was a day's journey to the wall from the sea. The second day was spent in climbing to the table-land; the third day allowed a progress of thirty miles, the angle of ascent falling from 6° to 2°. On the fourth day an ascent of 5,000 feet was reached, not the highest point,—but the weather became too inclement to permit a longer stay. The view was that of a frozen Sahara, immeasurable to the human eye.

It is probable that Greenland slopes westerly in general, thus placing the highest ice-ridge near the eastern border; for there are very few icebergs off the eastern coast, such as would be seen if the glaciers discharged themselves as they do upon the western side. At the rate of increase indicated by the observations of Hayes, the height of land may be averaged at 5,000 feet, and the thickness of ice above it as 10,000 feet. This flows mainly into Baffin's bay, Smith's sound, and the other waters to the west. A northward transportation is indicated at Polaris bay, where Dr. Bessel found numerous granitic rocks containing peculiar garnets, such as abound in South Greenland, resting upon Silurian limestones. On the western side are no less than thirteen well marked glaciers discharging their bergs into the sea, as far north as Upernavik, about 73° north latitude. The largest ones occur further north, some of them being 3,000 feet thick. The bergs derived from them are of this thickness, as measured by Hayes. The Humboldt glacier enters Smith's sound with a width of 60 miles, the ice-cliffs, from 50 to 300 feet high, extending 2,000 feet deep in some places. The adjacent rock-cliffs are 500 to 1,000 feet high.

The derivation of icebergs from glaciers is well proved. The glacier pushes down the fiörds into the sea, till the buoyancy of the ice, lifted up by the waters, causes it to separate in large blocks which float out to sea, urged onwards by the land motion, and afterwards by the oceanic currents. Baffin's bay and Davis straits are filled with these bergs, which float southerly till the warmer air and water of the lower latitudes dissolve them. It is uncommon to see them as far south as 40° north latitude. The romantic history of Tyson's party illustrates the long continuance of floating ice. This party consisted of nineteen persons, and they floated southwards 1,800 miles in six months' time, before they were rescued,—October 16 to May 1.

These bergs often carry earth and rocks in immense amount. Scoresby saw some carrying from 50 to 100,000 tons of material. Every Arctic traveller describes them. This rubbish falls to the bottom as fast as the bergs melt or topple over. It has been suggested that much of the Great Banks of Newfoundland has been accumulated from the leavings of icebergs.

Greenland may be compared to a broad platter slightly inclined westerly, with occasional chinks in the sides through which the ice discharges itself, as if it were a viscous body. We might say the ice accumulates in immense amount till it makes a conical pile like a heap of grain upon a floor. When additions are made to the grain upon one side, a motion is induced, and more of the kernels will flow down on that side than were added, because of cohesion. If the floor be slightly inclined, the flow of grain would be greatly facilitated. In a similar manner we may believe the flow of ice down certain valleys will carry with it other parts of the ice sheet, even where much of it is dragged over hills. This rise would always be less than the amount of descent from the top of the ice accumulation. With the ice would be carried the blocks of stone imbedded in it through the pressure of the weight of the overlying mass. Except near the coast, none of the Greenland ice would show boulders upon the surface, because, unlike the Alpine *mer de glace*, the mountains are entirely covered, and no moraines could be accumulated by the falling down of fragments from the hillsides. The moraines of Greenland are therefore different from the ordinary heaps displayed on the sides, tops, and ends of Swiss glaciers; they must accumulate mainly beneath the ice-sheet, and not be visible so long as the ice remains unmelted. The finer parts and the favorably situated blocks would, however, be carried along with the glacier to some extent, to be distributed eventually as submarine deposits, or to become a species of residual moraine after the melting.

Further peculiarities of distribution appear in connection with the subglacial streams. From the ends of the glaciers issue muddy torrents derived from the melting of the ice. Immense supplies of heat penetrate the ice from the sun's rays, which must give rise to very much water, seen also in the numerous surface lakes and streams. As all water seeks the lowest levels attainable, these currents will find a place at the bottom of the ice-sheet, and wear away the rocks and ground-moraines already accumulated into the sea. Hence will arise banks of earth or clay more or less continuous from the ice cliff to the point where the current ceases to transport material. In these banks would be found remains of such marine animals as lived in the vicinity. These deposits remind us of the fossiliferous clays along the coast of New England, sometimes attaining an altitude of 150 feet. Boulders would occur in this clay, brought by bergs, so that it might be styled boulder clay. This deposit is analogous to that called the Champlain clays.

Evidence has been often stated showing that the south end of Greenland, for a space of 600 miles, is sinking, and the north end rising. Tyson and Bessel speak of marine shells found 1700–2000 feet above the sea level near Polaris bay. If there were shoal water between Greenland and Labrador, the glaciers would push across to the main land of the American continent.

The American Centre of Dispersion.

It seems probable from the latest grouping of facts that some part of the Labrador peninsula may be considered as the centre from which the ice west and south-west from Greenland has radiated. Greenland may be regarded as an area by itself, never confluent necessarily with the Labrador or principal American ice-sheet. The various facts in support of this view will now be stated.

The greatest amount of glaciated territory indicates a south-westward course. This is seen over the highlands between Hudson's bay and the St. Lawrence valley, the valley itself, western New York, Ohio, and so on to the extreme west edge of the drift. It is very prominent from the Lake of the Woods and Lake Superior, near the national boundary to the Rocky Mountains. In New England the dominant course is south-easterly, with both south and west of south directions. The same is true of New Brunswick and Nova Scotia. Accounts differ for Newfoundland. J. F. Campbell's observations indicate greater variation, possibly a radiation in every direction. Murray's observations are said to show a south-westerly course, but a recorded observation from him is about S. 30° E. On the east coast of Labrador the map shows several fiords, as if there had been an ice-sheet upon the upper part of the peninsula moving north-east and east. Hind finds glacial markings on the Moisie river, and notes a remarkable absence of boulders up to 1,000 feet in height. He does not state in what direction the ice moved. Prof. O. M. Lieber's sketches in the coast survey report do not suggest universal, but local glaciation, as if the ice came from the peninsula itself, not from Greenland. Packard describes glacial markings in the Hamilton inlet fiörd running to the north-east. On the southern shore, Packard thinks the movement was to the south-east, towards Newfoundland.

Farther north, the Meta incognita just north of Hudson's straits shows an extensive *mer de glace* with glaciers moving southerly, and, most likely, northerly also. McClintock describes boulders at Leopold harbor (North Somerset), and at Graham Moore bay (Bathurst island), which have been transported 100 and 190 miles north-east and north-west. West of Hudson's bay, all explorers describe glaciated conditions, but give scarcely any data to enable us to learn the direction of the movement. In Franklin's first voyage (1819–22), loose stones are described, whose "angular forms" militate against their having travelled great distances. In his second voyage are quite a number of notices, implying transportation in a westerly direction.

There is a marked difference in the distances to which boulders have been transported by the south-west and south-east currents. The latter, as indicated heretofore, are not known to have travelled as much as 100 miles. The average distance may not exceed 12 to 15 miles, and there are no boulders in New Hampshire that have come from the north side of the St. Lawrence, nor from great distances in Maine on the north-east. In Ohio many have come from more than 100 miles. Boulders of native copper in Iowa and Wisconsin have travelled from 300 to 465 miles. The greatest transportation in the north-west region has been that of boulders from the Lake of the Woods, 700 miles towards the Rocky Mountains, upon British territory. Transportation upon ice-floes or bergs has been greater, as from Canada West to Baton Rouge, La.; but the others were mostly ice-carried. The greater south-west transportation seems to be connected with topographical features, viz., the continuation of this St. Lawrence valley to the south-west and south.

The distance of observed continuous south-westerly striation from the Laurentian highlands to the base of the Rocky Mountains is about 1500 miles. From central Greenland to the same place it exceeds 2500 miles. We have the means for determining approximately the thickness of the ice-sheet requisite to cause a flowage. It would require an average slope of about one half of a degree to make the ice move reasonably fast. This is forty-six feet to the mile, or one foot rise in every 115 feet of distance, or one mile for every 115. These data would necessitate an ice-cap 13 miles high if the centre of dispersion were in Labrador, or 22 miles for the whole distance to central Greenland. Making use simply of what would be required to move the ice over New England, we find that 800 miles represents the distance to central Labrador, requiring a cap 7 miles higher than Mt. Washington, or over 8 miles thick in all. If the movement came from Greenland, the distance is estimated at 2,000 miles, and the elevation of the ice-cap at 17 miles above Mt. Washington Prof. Dana, from somewhat different data, obtains smaller results. Assuming the starting-point to have been on the height of land between the St. Lawrence and Hudson's bay, and the descent at 15 feet per mile, the sheet must have been at least 13,000 feet thick above the land to carry it over Mt. Washington. These figures sound less formidable, but the slope does not seem adequate to have produced the results.

Prof. Torell, of Sweden, read a paper before the American Association for the Advancement of Science, in 1876, advocating the source of the American drift to have been in Greenland. He writes thus: *

> It has been the opinion of many distinguished American geologists that the source of the eastern ice fields is to be sought in the Canadian highlands. Against this opinion several important reasons may be urged. First: in the portions of Canada in which the glaciers in question are supposed to have originated we have reason to believe that the rocks are rounded and scratched, phenomena everywhere recognized as glacial,—but I think in no case characterizing rocks known to have been covered with perpetual snow. Again: the elevation and extent of the highest portions of Canada are hardly sufficient to account for the requisite accumulation of snow and ice. And finally, so far as I have learned, there is not found upon the rocks of the northern slope of Canada, nor yet in boulders moved by glacial force, any satisfactory evidence that there had been a northward as well as southward movement of glaciers from the highlands of Canada. If, therefore, the phenomena of the northern and eastern United States, usually supposed to be glacial, are indeed such, and if there is not sufficient reason for assuming the Canadian highlands to have been the source of the glaciers which produced these phenomena, then the source of them must be sought for elsewhere.
>
> I think it will be conceded by all geologists who have studied the glacial phenomena of these regions, that both the character of the erratics and the direction of the scratches upon the rocks show that this source must lie to the north-east. Following the line of the glacial movement across Baffin's bay and Davis straits to Greenland, we find the largest body of land in the northern hemisphere covered by ice and snow to a depth of not less than 2000 feet, and at this moment sending down its icebergs as far as the middle Atlantic. From the sixtieth degree of latitude to above the eightieth, this vast area of land is known to be ice-covered, and from the scarcity of the icebergs upon the eastern compared with the western coast of that land, it may be concluded

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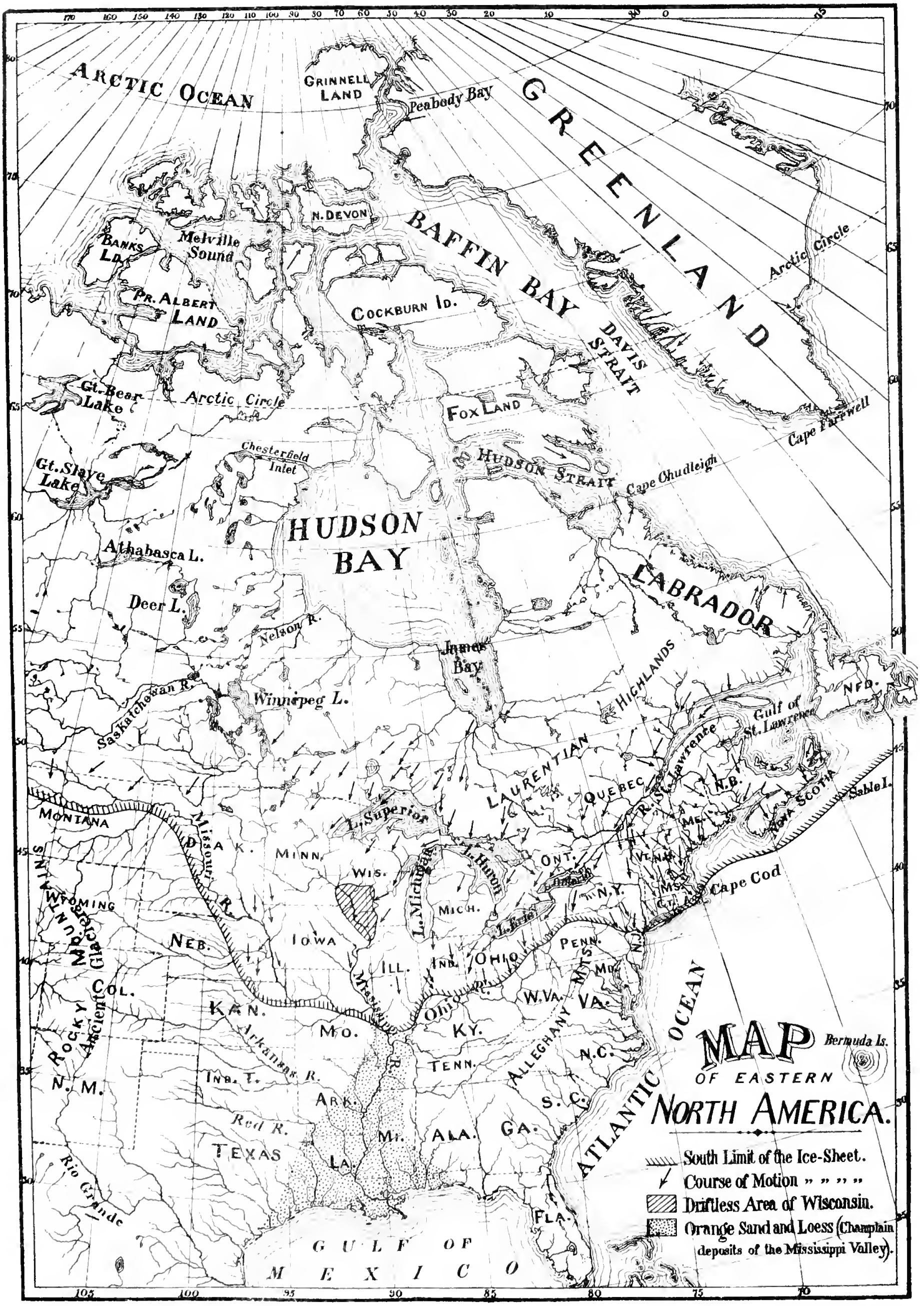
* *American Journal of Science*, iii, vol. xiii, p. 78.

that the general slope of the land is to the south-west, and in exact direction of the glacial markings of what is known to have been the course of the transported boulders in north-western America. Moreover, if we bear in mind the certainty that during the glacial period the glaciers moving from the height of Greenland towards the sea could not have formed detached icebergs as now, but must have for the time blocked up all avenues except the one of easiest escape for the immense accumulations of ice, we may easily assume this avenue was south-westward across British America and the north-eastern part of the United States.

Prof. Dana accepts this theory, saying that "we [self and Torell] agree in all essential points." A few suggestions have occurred to me, to the effect that the Greenland theory is untenable. (1) Accepting the notion that the ice moves as Croll proposes, on the molecular theory, there must be a piling up of ice to an enormous thickness, as much as twenty-two miles, to account for a motion from Greenland to the extreme south-west known limit of the ice-sheet. (2) The bridging of Davis straits seems very difficult to explain. The water is deep, and the straits or bay (Baffin's) wide, sufficiently so, it would seem, to discharge all the glacial products poured into it from either side. (3) Good instances of a northward transportation have been mentioned, the best known being northward from Hudson's bay. The great lack of observations of such a nature everywhere to the north of the Laurentian water-shed renders affirmation of their presence or absence valueless. Some have said that, on account of the cold, there would be little motion northerly. (4) The Labrador peninsula seems to me to offer a good situation for the accumulation of an ice-cap large enough to account for all the phenomena. The fiörds on the east indicate north-east movements of the ice; and three other courses have been mentioned, so that we find good evidence of motion in four directions from the central table land. Supposing this a centre, Greenland would have been a second, of equal or greater height, and the two would discharge their surplusage into the Atlantic. A cap of thirteen miles would be required for the thickness of this ice, if there were a flow from it to the western edges of the plains. (5) The growth of Greenland and the neighboring parts of the continent suggests the origin of the great basins, as of Baffin's bay, in Eozoic times, and a probable submergence ever since. The Hudson's Bay depression is similar (see Fig. 1, Vol. II). The Miocene deposits of Baffin's bay were made



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in the earlier formed basin, but did not fill it up. There was rather more subsidence, showing that the tendency in modern times has been to enlarge rather than restrict the size of the bay.

(6) The coldest part of the continent lies to the west and north of Hudson's bay. A comparison of meteorological tables given in various arctic expeditions indicates a greater average degree of cold in the west—say at Fort Reliance in Rupert's Land—than very far north. No greater degree of cold has been observed, but a lower average is reported for Greenland. For example: the lowest temperature indicated during the whole of one winter on the *Hansa*, which drifted along the entire east coast, was only —11° F. On the contrary, the average temperature for the four winter months,—December, January, February, and March,—for 1833–34, at Fort Reliance, as reported by Capt. Back, was —13°.9. For the winter ensuing, the average temperature for the same months was —21°.8. The Mackenzie valley, and the regions to the north-east, are noticed in meteorological treatises as remarkable for their cold. Being so very cold, the continental parts west and south-west from Greenland would be favorable for the preservation of ice in the summer, and thus for its accumulation in enormous sheets as time progressed.

Map of North America.

I have prepared a small map of the northern part of the continent to illustrate the dispersal of the drift. Observations will be found recorded there, indicating the directions of the movements in all the states and provinces so far as known. Reference to it will save much time in description. There is also represented the southern limit of the ice-sheet, the driftless area of the north-west, and the boundaries of the territory occupied by the Champlain deposits, termed the "Orange sand," by Prof. Hilgard. All the geological reports of the several states, provinces, and territories, besides other volumes too numerous to be cited here, have been consulted for the preparation of this map, and it is believed to represent accurately the existing information respecting the dispersal of the drift. Where several courses have been described in a limited territory, only the predominant one can be given because of the smallness of the scale. Nor is the Rocky Mountain area delineated, since that belongs to a different centre of dispersion.

The facts seem to bear out the theory presented above of radial dispersion from the Labrador peninsula in all directions except west and north-west. Observations are wanting for that part of British America. There seem to have been three centres of dispersion for our continent when the ice possessed its maximum development: Greenland, Labrador, and the Rocky Mountains. There seems, also, to have been a movement of icebergs up the St. Lawrence valley, possibly coeval with the Orange sand deposit.

CAUSE OF THE GLACIAL COLD.

Various theories have been proposed to account for the reason of the very severe climate of the glacial period. First, was the view that earthquake-paroxysmal waves passed southerly over both continents. Second, came the iceberg theory, involving a submergence of over 6000 feet to explain all the phenomena. Third, the extreme glacial theory received much favor, where an elevation of the land was relied upon to produce the cold. If the land were extensively elevated, extreme cold would result, both because of increased cold in mountainous regions, and the deflection southerly of the warm oceanic currents. Both the iceberg and extreme glacial theories involve more extensive earth-movements than have appeared before in geological history, and hence do not fully commend themselves to general acceptance. There is no objection to the adoption of a modified glacial theory, such as has been advocated by A. S. Packard, Jr., where only 600 feet of elevation is called for to explain the phenomena.* Prof. Dana, in the last edition of his Manual, seems to accept a modification of the enormous elevation—5000 feet—advocated in the first edition, though he does not say how great an uprising of the land is called for.

The less extreme our theories, and the less the variation from existing conditions required by our suppositions, the nearer will be their approximation to truth. The following conditions probably existed, and by their combination brought about the extreme cold. 1. Elevation of land in the northern part of the continent for a few hundred feet, accompanied by the necessary partial withdrawal of the warm oceanic currents in both the Atlantic and Pacific oceans. 2. Coincidence of longer

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* *Memoirs Boston Society of Natural History*, vol. i, p. 260.

winters than summers, induced by precession of the equinoxes, with a period of great eccentricity of the earth's orbit. This might have been cited as a fourth theory of glacial cold, and has been abundantly presented earlier in the volume, page 5, *et seq.* The coincidence of these astronomical and physical conditions would be fully adequate to produce the intense cold. 3. Some authors add the existence of conditions favorable to the abundant precipitation of moisture in northern regions. Certain collateral conditions seem to have been connected with these, as, 4. The greatest accumulation of frozen moisture seems to have been about Labrador and Hudson's bay, whence it pushed outwardly in all directions, but mainly southerly, because that was the direction of least resistance. 5. The accumulation of several miles thickness of ice seem necessary in order to understand how motion could be induced. The land about Labrador is not so high as the mountains of New Hampshire, and we cannot reasonably assume such an enormous elevation of it as would be required to cause the flow over New England, or to the plains of Dakota. 6. The adoption of Croll's Molecular theory of ice-motion, or something similar to it, seems necessary. 7. The New England south-east movement probably resulted from the overflow of the St. Lawrence basin. The ice must have accumulated sufficiently to overflow the St. Lawrence-Connecticut water-shed before it could have moved over the White Mountains. 8. How extensive the earlier south-west movement over much of New England may have been is not yet determined. Only scanty traces of it remain.

INTER-GLACIAL DEPOSITS.

Messrs. Geikie and Croll insist upon the existence of warm periods in the midst of the long glacial winter sufficient entirely to melt the ice, and give rise to a succession of cold eons, alternating with the warm ones. Mr. Upham has already referred to the untenability of this position, page 7, and has described phenomena similar to those called inter-glacial by the Scotch authors (pp. 108, 131–137, 163, 164, 176, 290). It seems very clear that there are no phenomena in New Hampshire requiring us to accept the view of a succession of ice-periods. When the ice had once formed, it must have continued to rest upon the land until the removal of the eccentricity of the orbit restored the warmer conditions.

Two suggestions respecting the probable origin of all the inter-glacial deposits found in New Hampshire will not be out of place. 1. An explanation of Prof. Torell, of Sweden, is adequate to account for the example underneath the lenticular hill in New Ipswich,[*] and any other stratified beds in similar position. He represents that as the glacier commenced to exist and to move extensively, there must accumulate in favorable localities many stratified glacial deposits, so that a geological section of the edge of the ice would present (*a*) pre-glacial beds; (*b*) stratified glacial deposits; (*c*) a ground moraine; (*d*) the ice with its terminal moraine. Hence the advancing glacier may often cover stratified sandy deposits not of inter-glacial origin. 2. Our sections indicate that the stratified beds commonly occur between the lower and upper tills, as in Figs. 29, 32, 34, and 36. The Champlain fossils occupy the same position in the Portland section (Fig. 59). Assuming the correctness of our views regarding the origin of the two tills, all the inter-glacial phenomena are beautifully explained. It is not to be presumed that no variations in the position of the edge of the ice-sheet existed. The outer limit must have varied very much from time to time, just as it does at the present day in existing glaciers. When the ice retreated a few thousand feet, its melting would give rise to currents transporting sand. A change in temperature, or other conditions causing a re-advance of the ice-sheet, would cause the stratified beds to be covered again, and the mass might even push a short distance over marine deposits at the ocean border. But no ground moraine made its appearance with this reädvance. No deposits were left behind except the débris contained in the ice itself, or upon its surface; and this fell to the ground during the melting process, and now remains as the upper till. This distinction between the tills has been lately recognized by English and Scotch authors. It also appears that the British inter-glacial beds occupy the same position with ours between the two kinds of till,[†] so that probably our explanation of the New Hampshire beds would

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[*] This is situated just south-west of Jeft's hill. By the side of the road an excavation shows about five feet of sand beneath the glacial drift, probably the lower till. The total thickness of the sand is not seen. In the overlying drift I observed a boulder of porphyritic gneiss four feet in length. Between this point and New Ipswich village the road cuts through a sand containing boulders, which is also probably underneath the glaciated till.

[†] "The till or boulder-clay that rests above these intercalated beds usually differs from the stony clay which

fit the corresponding cases in Europe. In such case the name "interglacial" would still be applicable to them, although not in precisely the same sense in which the term is now understood. The preposition *inter* would signify a place between the two tills. These do not properly represent two glacial periods: they are different accumulations produced by a single ice-sheet, with a varying outer edge.

LENGTH OF THE GLACIAL PERIOD.

I desire to call attention to another feature of glacial history that has been overlooked. Granting that the cold period commenced 240,000 years ago, as determined by the orbital changes, it does not follow that it terminated 80,000 years since, when the extreme eccentricity disappeared. The conditions would have been analogous to the state of things observed every year in our climate. The extremest cold of winter does not occur at the shortest day, but fully six weeks later, while the snow may continue till the first of May, though usually disappearing by the middle of April, so the great glacial winter would not have terminated with the end of the cycle. The prodigious quantities of ice and snow covering the northern latitudes would not have allowed the return of spring for many thousand years. If we were authorized to compare directly the annual duration of winter after the shortest day with this glacial period, it would be possible to fix the date of the disappearance of the ice. About one fourth part of our year elapses between the winter solstice and the vernal equinox. A fourth part of the long glacial winter would be 40,000 years. This would bring the close of the glacial, or, better, the Champlain period, to an epoch 40,000 years ago. If there is any variation from this estimate, it appears as if the subsequent period would have been shorter rather than longer, because of the enormous quantity of ice to be melted.

The description of the events occurring in the Champlain period, such as the deposition of the kames and terraces, shows that the time of melting need not have been greatly prolonged. The kames, being laid down

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immediately underlies them in being less hard and tough. It is often sandier and more frequently contains very large blocks and boulders, while at the same time its included stones and boulders are not so universally well smoothed and striated—or, to express it otherwise, angular unpolished stones and boulders are more common in the upper than in the lower mass of till. Again, I may note that the intercalated beds often thin out so as to allow the upper and lower deposits of boulder-clay to come together."—Geikie's *Great Ice Age*, second edition, revised, p. 19.

in ice-walled ravines, could not have taken many years for their accumulation; and if the higher terraces are remnants of the immediately succeeding freshets, there is no reason to believe them long continued. Following out the analogy of seasons as already commenced, this should be compared with the spring freshets. These require very little time for their rise, culmination, and termination, while they may occur at successively later and later points of time, as you pass from the mouth to the source of the streams flowing southerly.

The time when man was introduced is connected with the figures assigned for the termination of the glacial period. There seems no likelihood that our ancestors would have found the conditions of life favorable to their existence among the glaciers, so that they would not have emigrated here from warmer latitudes before the Champlain period. No certain evidence of man earlier than the Champlain period has yet been discovered in any part of the world. Hence there is little reason to believe he was introduced more than 40,000 years ago.*

Recent Scotch authors insist upon a greater antiquity for man than this, because his implements have been found in the inter-glacial beds, thus carrying him back at least 100,000 years. The observations stated above intimate the unreliability of the theory respecting the great antiquity of these inter-glacial beds. Those in New Hampshire can all be accounted for without assuming the intercalation of warm periods into the glacial age. It would be ungracious to assume that our phenomena should be taken as the standard of measure for those elsewhere; but as very few other writers have perceived the distinction between the lower and upper till, we desire to be informed whether their inter-glacial beds cannot be referred to a place between the two kinds of drift, before accepting the Scotch conclusions. The use of astronomical calculations in the determination of the duration and definite place of the glacial period is of great importance, and if thoroughly proven will form a basis for the establishment of a geological chronology, not merely for the latter part of the Cenozoic, but of all time, even to the era of the Eozoön or the simpler denizens of the Eophytic period.

Mr. Upham has prepared some brief statements respecting the relative

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* This is given as the remotest possible date for the introduction of man. Other evidence might be presented illustrating the fact that very exaggerated notions of the great age of man prevail at the present day; but the subject has no connection with phenomena discovered in New Hampshire, and is therefore omitted.

heights of land and sea during the glacial and Champlain periods. They are the result of much reflection upon his part, and are worthy of careful consideration.

Changes in the Relative Heights of Land and Sea during the Glacial and Champlain Periods.

By Warren Upham.

Evidence has been found of the accumulation of immense ice-sheets, probably in the same epoch, over the north part of America, Europe, and Asia, also in New Zealand and the south part of South America. This points to some cosmical cause for the glacial period, like that assigned by Croll, rather than to the causes appealed to by Lyell and Dana, namely, elevations of the earth's crust. It would be a very improbable coincidence that such extensive regions surrounding both poles should be thus elevated in the same period; but these would obviously be the parts of the globe to be covered by ice if its origin was due to eccentricity of the earth's orbit. There seem to be reasons (pp. 7–9), however, to discredit the conclusion of Croll, that the ice-sheets were alternately wholly melted away in each hemisphere once in every 21,000 years; instead of which it seems probable that the ice-mantle existed upon both hemispheres at the same time.

The effect of this extraordinary accumulation of ice about the poles would be to take away a large amount of water from the ocean, and, furthermore, to draw the sea, by gravitation, away from the equator, leaving the sea-level lower than now within the tropics, but at the same time causing it to rise even higher than now near the lower limit of the ice-sheets, and much higher than now near the poles. Marine shells in the modified drift show that the sea thus rose 150 to 200 feet above its present height in the latitude of New York city; 500 feet in the valley of the St. Lawrence; and 1,000 to 2,000 feet in arctic regions. Everywhere in high latitudes, both in the northern and southern hemispheres, we have proof of such a submergence of the land when the drift was accumulated, increasing in amount the nearer we go to the poles. On the other hand, the coral islands of the tropics are witnesses of a depression of the sea, amounting to 3,000 feet or perhaps much more at the equator, while different proof shows that at the mouths of the Mississippi, Ganges, and

Po rivers it was at least 400 feet. If we reflect upon the widespread changes of sea-level that marked the glacial period, occurring only where they would be produced by taking water from the sea to form the ice-sheets, and by gravitation through their influence, and if we compare these recent simultaneous changes with the general stability of the continents, it seems reasonable to attribute them to movements of the sea rather than of the land.

In North America the southern edge of the ice-sheet varied from 38° to perhaps 50° north latitude. Nearly all of the continent north of this line, with portions of the sea next to the coast, the archipelago farther north, and much of the Arctic ocean, Hudson's and Baffin's bays, and Greenland, were probably covered by ice in the glacial period. This would be about one twenty-fourth part of the whole area of the globe. In the eastern hemisphere, Europe and Asia were apparently overspread by ice as far south, on the average, as to 50° north latitude. The North and Baltic seas, and a considerable part of the Arctic ocean, are to be added, making an area, as before, equal to about one twenty-fourth part of the earth. The glacial sheets of the antarctic continent and adjacent ocean, with Patagonia and its sea-border, were probably equal to each of the foregoing, so that in all about one eighth of the earth's surface was covered by ice. If a slope of one half of a degree is needed to cause the motion of these sheets of ice, an estimate of four miles for their average depth does not seem to be too great. The removal of the water thus taken from the sea and stored up in accumulations of ice would lower the surface of the ocean more than a half mile.

The effect of the ice-caps to draw the sea towards the poles remains to be considered. Because the ice was limited to high latitudes, its influence to raise the ocean over these areas would be much greater than if the same amount of ice had been spread in a thin covering, reaching, with gradually decreasing depth, to the equator. It may therefore be near the truth, to consider the effect in gravitation over glaciated regions to be the same as would result from an increase of the polar diameter by twelve miles of ice. This would be massed, as we have seen, in the proportion of two to one about the north and south poles, the greater part being accumulated in the northern hemisphere; still, the effect upon the sea-level would be nearly alike about both poles, in the same way that the moon produces two tides, one on the side next to it, and the other exactly opposite on the earth's surface. Now the specific gravity of ice, compared with that of the earth as a whole, is about as one to six. Therefore the ocean would be raised one mile at each pole, or nearly a half mile above its present height. At the same time, because all the ice was massed in high latitudes, it seems probable that everywhere within the tropics the sea would fall, through the influence of gravitation, below the depression of a half mile, which resulted from the removal of water to form ice.

These glacial sheets, when at their greatest extent and depth, caused the sea to rise 200 feet higher than now at Long Island, as shown by marine shells. At a somewhat later date, when the ice-front was retreating, the sea stood on the coast of New Hampshire and Maine 150 to 225 feet above its present level. Probably at this time so much of the ice northward had disappeared that this height does not correspond to that of 200 feet at Long Island; for we have evidence (in the sub-marine channel of Hudson river) that after the ice began to retreat, the sea-level at New York was depressed till it was at one time 600 feet or more below its present height. When the sea was elevated 200 feet upon the coast of Maine, or perhaps later, it stood 500 feet higher than now in the vicinity of Montreal and along the St. Lawrence valley. This somewhat greater height than we might expect seems to have resulted from proximity to vast depths of ice resting upon the highlands of Canada and Labrador. Near the middle of the Champlain period, when the ice-sheet over the northern United States and the south part of British America had principally melted away, but while immense ice-fields still lay farther to the north, the amount of water restored to the ocean would not probably raise it more than half of the whole amount that it had been depressed. At this time the tendency from gravitation to raise the sea-level at the latitude of New York would be small, and no longer sufficient, as when the ice-sheet had its greatest extent, to counterbalance the depression, so that the sea might stand 600 feet or more lower than now at New York, while the Hudson must form a channel now covered by the sea.

The testimony on this subject, which we have from Long Island and the submarine channel of Hudson river, may be summed up as follows:

When the ice-sheet over New York and southern New England melted, the sea stood, at least for part of this time, about 200 feet higher than now.* At this time the extensive plains of modified drift, forming the south side of Long Island and the submarine plateau that extends fully fifty miles south and south-west to the New Jersey shore, were deposited, being spread nearly level by the waves and currents of the sinking ocean. The valley of the Hudson river was also filled with modified drift to a height at Albany of 330 feet above the sea. The submarine channel proves that after this the sea-level was depressed at least 600 feet lower than now, while immense floods pouring down the Hudson valley excavated these deposits below our present sea-level from Albany southward. This channel at Haverstraw bay and the Tappan Zee is two to five miles wide. Its south-east portion with the areas on each side is now covered by the sea, but it is plainly traceable by soundings for more than a hundred miles south-east from New York bay.† This channel must have been excavated, as we have shown, after the melting of the ice-sheet over southern New England and New York, for otherwise it would have been filled with the modified drift which forms submarine plains on each side.

Although the deposition of modified drift seems to have ended in this region before the sea was thus depressed and this channel of the Hudson was formed, it still appears that very immense floods were discharged here. The ice had probably retreated from the most of New York state, and mainly from the basin of the great lakes, but still obstructed the St. Lawrence valley, turning a large part of the floods of this basin into the Mohawk and Hudson. This submarine channel thus appears to belong to the same epoch in which the beach-ridges about the great lakes were being formed.

At the east edge of the sketch map † representing this former extension of Hudson river, may be seen (south-south-east from Montauk point) the similar channel of Connecticut river in the same period, less notable than that of the Hudson, because the latter discharged vastly greater floods. A difficult point in our surface geology, which was before unexplained, is made clear by this depression of the ocean below its

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* A bed of marine shells at this height in the modified drift of Long Island is described by Mr. Elias Lewis, Jr., in *Popular Science Monthly*, vol. x, p. 440.

† Dana's *Manual of Geology*, p. 441; new edition, p. 422; and *Popular Science Monthly*, vol. x, p. 444.

present level, following the departure of our part of the ice-sheet. In the first chapter of this volume it was shown that very large amounts of modified drift were excavated by the rivers in deepening their channels. Taking Connecticut and Merrimack rivers as examples, it seemed inexplicable, if the ocean from being 150 feet higher than now simply fell to its present level, to account for the disappearance of all the modified drift eroded between the upper terraces of these valleys. This explanation of the Hudson submarine channel is made more worthy of our belief because it also solves this difficulty. If the ocean was thus depressed, the modified drift excavated would be carried by the descending streams beyond our coast-line. W. U.

Origin of the Blue and Gray Clays.

In the first chapter (pp. 94, 153–155, and 158–161), Mr. Upham has brought together various facts respecting the distribution of the blue and gray clays overlying the till. He finds that the former invariably underlies the latter. This is true throughout New England, but not in the Western States, where alternations of the two kinds have been observed. The reason of this invariable order in the east has never been given satisfactorily. In order to contribute to the solution of this problem, I requested Mr. Upham to select for analysis typical specimens of the two tills and clays. Mr. G. W. Hawes presents the following as the result of their chemical examination. Only the iron percentages were determined:

	Upper till.	Lower till.	Gray clay.	Blue clay.
Iron protoxide, ...	1.42	1.75	2.75	3.17
Iron sesquioxide, ...	1.56	0.006	4.15	2.53

The tills came from Alton, the clays from Dover. The facts indicated are,—the proportionate increase of the sesquioxide of iron in the upper over the lower till, and in the gray over the blue clay; also, the clays contain more iron than the till. These facts are sufficient to explain the difference in color. They agree with the theory already propounded for the origin of the two tills,—that the first resulted as a ground-moraine from the pulverization of the rocks, and the second from the dropping down of all the materials in the ice-sheet at the time of melting. The upper deposit would be loosely aggregated and more highly oxidized than the lower beds, because the opportunities for the addition of oxygen were more favorable.

The very first question suggested by the position of the analyses is, whether the gray clay has not been derived from the upper and the blue from the lower till. The two classes of deposits agree in their chemical character, color, and superposition. I will advocate the affirmative answer to this question, and state how the conditions would favor such a derivation.

The blue clay is not continuous throughout the Connecticut and Merrimack valleys, but occurs in definite and limited areas, as has been set forth in Chapter I. Its origin may be conceived to be like that of similar clays near the mouths of glaciers. The water gathering from the various sub-glacial rills gathers the fine clayey material pulverized by the motion of the ice, and transports it to some lake or place of comparative quiet, and the sediment is deposited as a blue clay. In Hooksett and Pembroke is a mass of clay four miles or more long. Suppose that the glacier were still unmelted above Franklin, the pulverization of the rocks on the upper Pemigewasset would furnish an abundant supply of clay, which might have been transported to Hooksett before the current slacked sufficiently to allow the turbid water to settle. In this way the blue clay might have been formed, and it would have been derived altogether from the lower till. Subsequently, we may suppose, the ice began to melt more rapidly, and the detrital residue, or upper till, would be subjected to carriage. The first result would be the soiling of the streams with the more oxidized clay, and there would be formed the gray deposit over the blue. In the continuation of the process, the streams would become still larger, and the material brought down would be sand covering the gray clay; or the gray clay may be conceived to be the result of the washing of the upper terrace deposits. The finest particles in the case of a washing would be the first to show themselves low down the valley; and the material exposed is essentially the upper till.

This view explains how the formation of clay may be connected directly with the ice. The ice nearest the edge of the sheet, or on the ocean border, first melted, producing the upper till and a massive clay.

The next stage of the process would naturally be the deposition of blue clay, derived from the ice twenty or fifty miles away, and resting upon either of the tills where the glacier had once been present. When all the clays and sands had been supplied to the second area, the scene of action was transferred to a locality still nearer the ice, and so on till the whole had disappeared. Throughout the valley the clays overlie the till, although the stratified beds low down may have existed while the lower ground-moraine was forming among the mountains. The order of the conditions and of the deposits was strictly uniform, although at the present time it is difficult to realize that a clay at Newburyport should have been formed earlier than the same material at Hooksett. Some have imagined that no clay was formed till after the entire disappearance of the ice. In that case, we could not have had two kinds of clay. The waters washing away cliffs would mix together the protoxide and sesquioxide débris, and the resultant deposit would be unlike either of the beds now situated beneath the many brick-yards.

This view is in agreement with previously expressed suggestions about the rapidity of the accumulations of modified drift. The principal work of depositing the modified drift belongs to the epoch of the melting of the ice; and, following the analogy of spring freshets, the time must have been comparatively short, whether as compared with the antecedent glacial or the subsequent alluvial period.

Mr. Hawes expressed different views about the origin of these clays when the analyses were returned. I subjoin extracts from his letters:

> My interpretation of those analyses was something as follows: Finding *only iron protoxide* in the lower till, I thought the analyses indicated that, at the time of its deposition, the whole till contained iron only in the lower state of oxidation; that, being formed beneath the glacier by the grinding and pulverization of the rocks, it had no opportunities to oxidize. The upper till is lighter in color on account of the oxidation of its iron by the subsequent action of the atmosphere and percolating waters, which action has proceeded only to a certain depth. In being washed down into the valleys, a portion of the iron was oxidized,—and hence the *lower* clays contain iron oxide; and after the clays were deposited, the external agencies of air and water, acting on them as on the till, oxidized more iron in the superficial portion, making them again lighter in color than the lower clays. Thus the two colors of the till and of the clay are both referable to one cause,—the action of external agencies that have been in operation since the time of the deposition of these deposits, and are still in progress, driving the

dividing line deeper down. The fact of the presence of more iron in the clay than in the till is readily supposable, since iron is quite likely to be concentrated with the finest materials in the lowlands, leaving coarse pebbles behind. This, I think, answers all your questions, as I had understood the matter; but you will be the best judge as to the correctness of the suppositions.

The second letter is as follows:

In reference to the questions you propose in your last letter, you understand that I am unfamiliar with the field facts and the geological relationships involved, and so am not very able in my opinion. As I understand you, your opinion is, that the lower till was made from the clay derived from the grinding of the rocks by the lower surface of the glacier, and the upper till from the rubbish in and on the glacier, which was deposited on the melting of the glacier; and that subsequently the lower blue clay was derived from the lower till, and the upper gray clay from the upper till, by transportation by water; and you put the questions, "Could the lower blue clay have been derived from the lower till by deposition in water?" and "Could such material be transported without oxidizing the iron?" It does not seem to me that the lower clays could be derived from lower till, for if the washing took place after the deposition of the till, the strata of the till would be inverted in the clay beds, and the upper till would make the lower clay, since it would be the first to be transported by erosion. I do not think that material could be transported without any oxidation of ferrous compounds; but as the lower blue clay contains ferric oxide, this is not necessarily supposed. I incline to my former opinion of the production of an upper gray layer, in both cases, by those processes of oxidation,—by the external agencies that are everywhere going on in the rocks as well as soils. If, now, as is believed, the end of the glacial period was accompanied by great floods, and the latter end of the melting was rapid, the material in and through the glacier would not be deposited on the ground on top of the lower till, but would be washed away, and concentrated in the gravel beds. Clays in some cases may have resulted from the deposition of the finer portions, assorted by the rapidity of currents; but the material is usually coarse that rests on and in glaciers, and composed of broken fragments. The fine clay is that which is ground and pulverized by the lower surface grinding the underlying rocks. If, then, the till on the disappearance of the glacier was a substance uniform in composition from top to bottom, and of the same nature as the present *lower* till, then, by the action of running water, material from this bed might be transported to form clay beds without further oxidation of the iron than is shown by the difference between the lower till and lower blue clay. If the beds of both till and clay, as first deposited, were of the same nature as the lower beds at present, atmospheric and aqueous agencies would in time produce the differences in both now seen.

In speculating upon this subject, I was at first troubled by the somewhat similar origin of the upper till and blue clay, both in connection with water. Why should the former be so much and the latter so little oxidized? Relief came by examining the analyses. The blue clay contains more sesquioxide than the lower till, just as would be expected from the nature of the deposit. Furthermore, all blue protoxide clays have come from deposition in water;—hence there is nothing abnormal in believing in the origin of the lower clay from the older till.

Order of Events.

The following list of occurrences expresses our most recent opinions respecting the order of events occurring in New Hampshire in the Glacial, Champlain, and subsequent periods:

1. The country was covered presumably with forests of late Tertiary type, partly exhibited to us by the nearest fossils, yet of Eocene age, in Brandon, Vt. The beech, bass-wood, buckeye, Aristolochia, peperage, and cinnamon have been found there, with some others allied to the *coniferæ*. The change of climate induced by the change of land, combined with astronomical causes, would destroy most of these plants, and render the region sterile. Then the ice commenced to spread over New England, with alternate meltings of limited extent, so as to give rise to beds of sand and gravel.

2. The ice accumulated in the St. Lawrence valley so as to flow over New England, possibly preceded by a south-west current. The whole country would have been covered by a sheet of ice, thousands of feet in thickness,—probably 7,000 or 8,000 feet in the lower part of the state,—flowing south-east towards the ocean. This was the period of the formation of the lower till, and of the great terminal moraines of lower New England. The broad sandy plains of Cape Cod and Long Island mark the beginning of the Champlain period.

3. The melting of the ice has progressed steadily until no more ice is supplied from the St. Lawrence valley. New Hampshire is now covered by local glaciers, pushing down the Connecticut, the Merrimack, and other streams. The lower fossiliferous deposits of the coast are coeval with these glaciers. Variable seasons cause temporary advances and retreats of the ice, and thus allow of conditions favorable to the production of the inter-glacial beds.

4. The thermal influences prevailing, the ice is driven back to the

mountains; the débris which it contained forms the upper till; the kames show themselves, deposited between walls of ice; and the valleys are filled with plains of modified drift, including the blue and gray clays.

5. The terraces are produced by excavations of the last formed deposits; vegetation and animal life return; the horse and wild boar, whose remains have been found with us, flourished.

6. A warmer period followed, as illustrated by the presence of the rhododendron, cedar, and other plants upon the land; the quahog and oyster in the ocean, and the introduction of the American aborigines.

7. A somewhat colder climate, only a few hundred years back from the present date, ensued; New Hampshire was colonized by Europeans; and the present type of civilization has abolished the forest and exterminated the larger forms of animal life.

Notes on the Surface Geology of Coös County.

By J. H. Huntington.

Fluvial Deposits. These frequently have the appearances, as far as outline is concerned, of ordinary river terraces; but an examination of the material of which they are composed shows that they have an entirely different origin. In these the material is very coarse; and we often find boulders 8 or 10 inches in diameter. Usually they are not very extensive, and they are found only at the mouths of very rapid streams. The most extensive deposit of this is in Pittsburg, near the mouth of the stream which is the outlet of Back lake. Was all this coarse material, which occupies an area of many acres, brought down by the present stream? Mr. David Blanchard, who is well acquainted with the outline of the country, thinks that Perry stream once had its outlet here. The theory is very plausible, and there is little doubt but that such was the case. The barrier of rocks where the road crosses this stream, when it was a few feet higher than it is now, would have turned Perry stream into Back lake; thence it would have followed the course of the present outlet of that lake. Most of the drift that has been brought down by Indian and Hall's streams is of the same coarse material. Another deposit of this character is in the town of Stark along Nash stream. Almost every stream that comes down from high lands or mountains has brought down immense quantities of this kind of material, but nowhere to the extent that has been done in the localities just mentioned. How was this deposit formed? The present amount of water could not, even at times of the highest floods, have brought down this material and deposited it as we now find it. The resource to which we are led to explain this phenomena is this: At the time of the final retreat of the glaciers, just before they disappeared entirely, they were confined to the deep ravines of the high lands and the mountains. The melting of the glacier and the snow, with copious rains, for the moisture-laden currents coming in contact with these fields of ice would have been suddenly condensed,—all these would have had a tendency to produce floods that are now unknown.

Kames. The best examples of kames seen in Coös county are those which were formed as the glacier retreated from the valley of the Connecticut, in Columbia and Colebrook, and nowhere are they more striking than at Colebrook village. These are interesting, from the fact they show that for years the great glacier that filled the valley of the Connecticut here had its terminus. The fact that these gravel ridges do not appear above Colebrook shows that the change of climate was such as to cause the glacier to disappear rapidly when it receded above that point. The expansion of the valley at the village and just above, and its contracted limits below, were also causes that may have produced this phenomenon.

Erratics. There are very few but that have noticed, scattered through the fields, boulders unlike those of the rocks in the immediate vicinity. These boulders we call erratics or wanderers, because they have come from some distant place. Throughout northern New Hampshire, on account of the extensive tracts of forests, the study of all phenomena of drift is pursued under the most unfavorable circumstances, since in the forests there are no excavations, except that done by water along the streams. The boulders as well as the ledges are much more commonly covered with earth, or, at least, they are overgrown with moss, which has to be removed before we can tell anything about the rocks. To study thoroughly the geography of a country covered with forests, would, under most circumstances, be an endless task, although the area might be quite limited. On account of the fragile nature of many of the rocks in the extreme northern part of the state, boulders are not so numerous as in some other sections; and the absence of granite boulders is especially noticeable. North of Connecticut lake I do not remember to have seen but one granite boulder in all that area, and that was three or four miles east of Third lake. On Indian stream, eight or ten miles from its mouth, there were several boulders of conglomerate, and just north, three of brecciated iron ore. In Colebrook, near Mr. L. Dinsmore's, there is a conglomerate which is quite attractive even in hand specimens. None of these just mentioned were found in place, and where they came from is a matter of conjecture; but it is altogether probable that they came from Quebec province. Most of the boulders found in New Hampshire as far south as Columbia are derived from the hard bands in the argillaceous schist, or they come from the band of hornblende rock extending from Colebrook to the boundary. Everywhere south-east of this band, as far as Maine and even beyond the Magalloway, boulders of this rock are seen. As the rock is unlike any other, they are noticeable wherever they may be found; and they show that the general direction of the drift was considerably east of south.

In Stratford, just north of Little Bog brook, there is quite a remarkable collection of granitic boulders, both on account of the number and the limited area where they are found; besides, they must have come from Vermont, as granitic rocks of this kind are not found in New Hampshire.

In Errol, along the road to Upton, Me., we find an abundance of boulders of granitoid gneiss, which probably came from the vicinity of Wentworth pond. In Milan, particularly in the vicinity of Mr. Moses Hodgdon's, we find boulders of sienite that must have come from Mill mountain in Stark, or from the hill immediately north; consequently the drift here could not have been more than fifteen or twenty degrees south of east. There are two remarkable collections of boulders in the south part of Bean's Purchase, though they are derived, evidently, from ledges near where they are found. One of these is found a mile south from the summit of the Carter notch. The boulders are piled up so that they form a barrier across the valley, which is perhaps fifty feet higher than the depression towards the notch, in which there are two small ponds that have no visible outlet; but the water finds its way by an underground passage through the barrier, and where it issues from the rocks it forms quite a large stream. Above the barrier there are also many large boulders that have fallen down from the sides of the notch. Everywhere the boulders are angular, and their detachment from the ledges must have been quite recent.

Another remarkable collection of boulders is on the east branch of the Saco, a few miles east of the last mentioned. Here the rock is a gneissoid granite. The boulders are of immense size, and are scattered over an area of half a mile in width. They are everywhere covered with moss; and this supports a growth of firs, which are from eight to ten feet in height. Travelling is extremely difficult, both on account of the trees and the size of boulders. After a heavy rain, far down among the rocks streams of water flow, the existence of which would not be suspected if they could not be heard.

Lake Margins. The effect of the expansion of ice on our lakes, although noticeable in many places, is nowhere so marked as on the margin of Connecticut lake. At low water the rocks can be seen piled up in a wall-like structure, which on the south shore has a height of three or four feet, in places almost vertical. These rocks have been pushed a little year by year until they reached their present position, and were beyond the reach of ice-pressure. As the lake is now several feet above its natural level, a dam having been built at the outlet, if kept thus this wall will in time be removed to a higher level.

APPENDIX TO PARTS I AND II.

APPENDIX A.

DISTANT POINTS VISIBLE FROM MT. WASHINGTON.[*]

By W. H. Pickering.

IF an observer were to go up four particular peaks in the White Mountains he could see all the distant points visible from any of the other summits, together with a good many more not visible from them. These four peaks are Washington, Moosilauke, Passaconnaway, and Lafayette. I name them in the order of the extent of the distant views obtained from them alone. Now, looking at the subject the other way, no matter from what distant point the White Mountains are seen, one of these four points must always be the most conspicuous object in view, provided no near hills intervene. By means of the following formulæ the distance visible from any mountain may be readily calculated, and also the elevation a mountain must have in order to see a certain distance: $d=\frac{4}{3}\sqrt{h}$, $h=\frac{4}{7}d^2$, where $d=$ distance in miles, and $h=$ elevation in feet. They may also be used to calculate mountain profiles as seen from distant points. In this connection I may add that there is a slight inaccuracy in the Guide Book relating to Chocorua. It says,—"It is the noblest peak in all the view from Washington, and lifts its white pyramidal ledges far into the sky, flanked by bare supporting ridges." This must be a rhetorical hyperbole, for it is not at all true. And far from lifting its pyramidal ledges into the sky, it does not even come up to the level of the horizon by 420 feet.

For some time there has been a question whether Katahdin was visible from Washington or not. It is 163 miles distant, and would be the most distant point from which the White Mountains could be seen. According to calculation, 3500 feet of it should be visible if the land between were on the level of the sea. Now the horizon line as seen from Mt. Washington passes five or ten miles south-west of Moosehead lake. Moosehead lake has an elevation of 1023 feet above the sea. Now, allowing the land

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[*] Read before the Appalachian Mountain Club, October 11, 1876.

five or ten miles below it, measured on the river, to have an elevation of 1500 feet, Katahdin would still rise 1170 feet, and it would require an elevation of 2300 feet to hide it. Moreover, on remarkably clear wintry days, a very distant mountain has been seen in about the right direction, with a very peaked summit, which coincides with the descriptions of Katahdin. I should add, however, that as seen from Moosehead lake, which is in much the same direction, Katahdin does not present this appearance. It is claimed by some that Katahdin is visible from Kiarsarge; and there is a distant mountain visible from there on rare occasions, which I have seen once, but which is not in the right place. And, moreover, if there was an elevation between them of 390 feet above the sea, and near Mt. Blue, Katahdin would be hidden. Now, as all the country near Mt. Blue has an elevation of something over 1000 feet, it seems rather improbable that Katahdin should ever be seen. As to seeing it from Osceola, as some claim, one would have to look something like 100 feet below the sea horizon to see it.

The following is a list of some of the more interesting distant points to be seen from Mt. Washington, many of them being visible only on rare occasions:

Mt. Belœil: distance 135 miles, position north 45° west, and nearly over Prospect hill, Lancaster. It is quite a high mountain near Montreal, and is said to be visible.

Lake Memphremagog: distance 70 miles, position north 40° west, and over Jefferson hill. It requires a very clear day, as distant water is difficult to distinguish.

Mt. Carmel: distance 65 miles, position north 10° east, and just over Mt. Adams. It is very near the northern boundary of Maine, and is readily recognized by the steep slope on the eastern side. It is said that a very fine view may be obtained from it.

Mt. Bigelow: distance 70 miles, position north 35° east, and nearly over Mt. Hayes. It appears as three rounded hills. Just to the south of it, and far beyond, is a mountain with a very sharp apex, which is sometimes called Katahdin, but this is a mistake.

Mt. Abraham: distance 65 miles, position north 40° east, and somewhat to the right of Mt. Hayes. A long serrated ridge, also sometimes called Katahdin.

Mt. Katahdin: distance 103 miles, position north 45° east, and about half way between Mt. Hayes and Mt. Moriah. It is said to appear rising over a nearer saddle-shaped mountain, and to be recognized by its sharp peak, the sharpest in all the view from Washington. If visible at all in summer, it would be far the faintest object in sight in that direction.

Mt. Blue: distance 57 miles, position north 57° east, and half way between Surprise and Moriah. It is quite a conspicuous pyramidal peak, and is near Farmington, Maine. It is used as a Coast Survey station.

Portland: distance 65 miles, position south 51° east, and over the northern summit of Doublehead. It appears as a low white hill, with a long light-blue line beyond it. With a telescope the hill resolves itself into a mass of closely packed white houses, and the blue line is seen to be thickly studded with sails. The ocean, however, is not as often seen as some more distant objects in other directions, partly on account of the difficulty of distinguishing distant water, and partly because the atmosphere in this direction seems generally to be somewhat thicker than elsewhere.

Lake Sebago: distance 43 miles, position south 48° east, and over Mt. Gemini. It is 14 miles long, and about 11 wide.

Mt. Agamenticus: distance 80 miles, position south 24° east. A flat rounded hill of considerable height in the southern part of Maine, and forms a conspicuous landmark for sailors.

Isles of Shoals: distance 97 miles, position south 22° east. They are very difficult to see, and are situated on the horizon just to the right of Agamenticus.

Mt. Wachusett: distance 126.5 miles, position south 13° west, and just to the right of Whiteface, if it is visible.

Mt. Monadnock: distance 104.5 miles, position south 22° west, and a little to the right of Sandwich Dome. A very regular rounded summit.

Mt. Kearsarge: distance 70 miles, position south 24° west, and half way between Sandwich Dome and Carrigain.

Mt. Uncanoonuc: distance 92 miles, position south 9° west, and half way between Mts. Crawford and Passaconnaway. Twin summits near Manchester.

Mt. Ascutney: distance 85 miles, position south 45° west. Situated in Windsor, Vermont, close to the Connecticut river.

Killington Peaks: distance 91 miles, position south 59° west, and between Mts. Liberty and Blue. Twin peaked summits near Rutland, Vermont.

Camel's Hump: distance 80 miles, position north 87° west, and just over Bethlehem street. It is a striking looking mountain, shaped like a truncated cone, with very steep sides. Readily visible at sunset on a clear day.

Mt. Whiteface: distance 130 miles, position north 86° west. It is just barely visible, hardly rising above the right hand slope of Camel's Hump. This is one of the highest of the Adirondacks, rising to a height of 4900 feet. Two lower peaks are seen just to the right, and three more some distance to the left. These however have not yet been identified, but if Mt. Marcy and any of the other higher summits are visible, they should appear about 7° to the south of Whiteface, and nearly over the Fabyan house.

Mt. Mansfield: distance 78 miles, position north 78° west, and between the Twin Mountain house and Mt. Deception. It is the highest of the Green Mountains, being 4300 feet high, and appears as a long ridge bearing a fancied resemblance to a human face.

APPENDIX B.

Altitudes, Contour Lines, and Raised Maps.

During all our explorations of the state for the study of its geology and the collection of rock-specimens, frequent barometric measurements have been also obtained, and the prominent topographic features of the country have been carefully noted. Only a small portion of all the heights thus measured appear in Volume I (pp. 210, 211, and 242, chap. x, and pp. 304–314), the altitudes there given being those of mountains, villages, ponds, or other points of special interest. Since the publication of that volume, many additional barometric observations have been made.

The information thus gathered respecting the configuration of the state, although incomplete because it has been impossible to make a detailed examination of our entire territory, yet seemed worth preservation, and sufficient to justify an attempt to present contour lines on the new map accompanying this report. Numerous series of altitudes, accurately determined by surveys for railroads, or by levelling done specially for the geological survey, have formed a basis to which the barometric measurements have been referred. According to these observed heights, and others estimated for adjacent hills and valleys, lines of contour for each one hundred feet above the sea were first drawn on the county maps of large scale, which had been used in our explorations, and thence were transferred to the draft of the new map. These lines have been engraved separately from the rest of the map, so that they may be printed in a color different from that of the streams, roads, boundary-lines, names, etc. They are thus easily distinguished from all other lines, but are required to be printed separately, so that they are liable to slight misplacement, sometimes making streams and contour lines disagree in their positions. These contours not only show the place, shape, and height of separate mountains and hills, but permit a comparison of their heights above the sea and in relation to each other throughout the whole state. For convenience in such comparison, the lines of 500, 1,000, 1,500 feet, etc., above the sea are dotted, and their heights frequently marked, while the other lines are continuous and unmarked.

The eastern part of Rockingham county, and the portion of Essex county, Mass., which comes within the limit of our map, being occupied more or less fully by the remarkable lenticular hills of glacial drift, have received special attention. Contour lines are shown upon these areas for each 50 feet, those marking heights 100, 200, and 300 feet above the sea being continuous lines, while those intermediate are dotted. The Ammonoosuc mining district has been surveyed by Mr. John N. McClintock, whose map with contour lines for each 10 feet is presented in Part V of this report. Besides these, the White Mountain district has perhaps been as well represented as any other portion of the state; but many of the smaller peaks, ridges, spurs, and ravines remain to be explored and mapped in this region. It is hoped that our efforts to show the form of the surface of New Hampshire by these lines will serve to call the attention of our people to the value of such work, and ultimately lead to a detailed topographic survey and map.

The same information respecting the altitude and contour of the whole state, which is shown by these lines on the maps in the atlas of this report, has been otherwise and more noticeably displayed by a model or raised map of New Hampshire, the original of which has been placed in the vestibule of the state-house at Concord. The museum of Dartmouth college has a copy moulded from this, and others might be easily made. It will be seen, however, that the construction of the first model, to show all our principal mountains, hills, and valleys, involves a large amount of painstaking labor. This relief has a scale of one inch to a mile in distance horizontally, and of one inch to 1,000 feet in height, making it about fifteen feet long, with Mt. Washington a little more than six inches high. The elevation is five times too great, as compared with the extent,—this exaggeration being necessary to give any prominence to the numerous hills less than 1,000 feet in height.

A map on the horizontal scale of the proposed model was first drawn, by enlargement from the draft of the new state map, with contour lines for each 500 feet above the sea. Tracings of these lines were then made and transferred to boards of pine or basswood half an inch in thickness, corresponding on the scale of height to 500 feet. The boards were then sawed to the irregular form of the successive contours. Upon each set of boards, the line next above that followed in sawing was also drawn, and showed the exact position to be occupied in placing them one upon another to build up the highlands and mountains. The projecting upper edges of the layers of board were then bevelled to a continuous slope, or cut into the hills and valleys required by intermediate lines of contour. The surface is painted, showing township lines, streams and ponds, railroads, etc., with their names, and those of villages and mountains.

In the study of the modified drift, a large amount of levelling has been done, principally along Connecticut and Merrimack rivers. The heights of all the terraces in both these valleys north of the Massachusetts line have been accurately determined, and are shown on Plates I–VI of this volume. Heights of these rivers and of localities near them were also determined, and are given, with the elevation of the highest terraces, on pages 39, 59–61, and 102 and 103. The most important corrections from altitudes along these rivers, published in Volume I, are in regard to the height of a portion of Connecticut river, which at Brattleborough is 200, at the mouth of Ashuelot river, 185, and at Massachusetts line, 180 feet above the sea (corrected from Vol. I, pp. 304 and 319); and the height of Pemigewasset river at the mouth of the east branch, which is 710 feet above the sea (corrected in this volume, p. 70, from Vol. I, pp. 288, 308, and 322). The height of Winnipiseogee lake obtained by levelling (pp. 103 and 125) suggests the possible need of a still more important correction to be applied to nearly all the connected series of altitudes determined by railroad surveys in the western and northern parts of the state, published in Chapter X of Volume I. These altitudes may be said to be reckoned from Concord depot as a starting-point, which appears upon good evidence to be 16 feet higher than was formerly supposed (see Vol. I, pp. 250–252). Referred to this datum, however, the height of Winnipiseogee lake appears to be 11 feet above that obtained by the survey for the Portsmouth, Great Falls & Conway Railroad (Vol. I, p. 265). One of these determinations of the level of the lake must be incorrect. Heights along Contoocook river and on streams in Antrim, with corrections to be made in Volume I, page 268, are stated in this volume on pages 102 and 119; heights along Salmon Falls river, on page 150; and in Dover, on page 156. Mr. George L. Whitehouse, of Farmington, informs us that the height given in Volume I, page 264, for the summit between Alton and Farmington, refers to the highest point of the railroad, while the greatest depth that would have to be cut through to turn Winnipiseogee lake into Cochecho river is only 28 feet, which calls for a correction on page 129 of this volume.

To the tables of altitudes previously published, we append a few additional observations, principally in the mountain region:

Heights in the White Mountain District.

From barometric measurement in 1876 and 1877 by Prof. F. W. Clarke:

On the Mt. Washington Range.

Nelson crag, north of Huntington's ravine,	5615
South wall of this ravine,	5432
Lion's Head, north of Tuckerman's ravine,	5016
Boott's spur,	5524
Foot of Mt. Adams path,	1430
Camp of Appalachian Mountain Club, Mt. Adams,	3307
First bald ledges on this path,	4342
Cliff at head of King's ravine,	5125
Summit of Mt. Adams (Guyot),	5794
Samuel Adams peak, nearly ½ mile west,	5554
John Quincy Adams peak, ⅓ mile north,	5384
Nowell's peak, a little more than ½ mile north-west,	5313
Star lake, between Adams and Madison,	4890

Heights near Jefferson.

Starr King house,	1437
Mt. Starr King (Prof. C. R. Cross),	3925
Mt. Adams house,	1648
Boy mountain,	2278
Randolph hill,	1518
Jefferson Mills bridge,	1022
Bridge at Stag hollow,	1380
Israel's River bridge, Cherry Mountain road,	1085
Owl's Head, spur of Cherry mount.,	3302
Farmhouse at the foot of Owl's Head path,	1442
Bray hill,	1637
Mt. Prospect, Lancaster,	2062
Mt. Pleasant, "	1896
Road between these,	1447
Farmhouse at the foot of path up Mt. Prospect,	1310
Summit of road from Jefferson to the Twin Mountain house,	1676
Lunenburg heights, Vt. (Prof. C. R. Cross),	1618

Heights in Bethlehem and Whitefield.

Sinclair house,	1459

Maplewood house,	1489
Dodge's, Whitefield,	1279
Fiske's, "	1250

On road from Whitefield to Bethlehem:

Railroad crossing,	1109
Ammonoosuc bridge,	1119
Summit of road.	1305
Summit of stage-road by Mt. Agassiz,	1840
" upper stage-road from Bethlehem to Franconia,	1913
Wallace hill, Bethlehem,	2124

Heights near Franconia.

Summit of road between Littleton and Franconia,	1360
Bridge, Franconia Iron Works,	920
Lafayette house,	990
Franconia house,	1054
Profile farmhouse,	1302
Bald mountain,	2310
Notch on Lafayette path by Eagle cliff,	2990
Clearing between Profile and Flume houses,	1772
Moran or Lonesome lake,	2750
Summit of Sugar hill, Lisbon,	1895
Sugar Hill post-office,	1351

Ossipee Mountain, from a recent barometric measurement of Prof. C. R. Cross, is found to have a height of 2950 feet, instead of that given in Volume I, page 280. An eastern peak of this mountain is, by the same authority, 2774.

Heights in Cheshire County.

In Section II, Volume I, page 284, correct the height of bridges in Swanzey by subtracting 550 feet.

From levelling by George W. Sturtevant, of Keene:

Goose pond, Keene, source of city water-works,	638

From levelling by J. J. Holbrook, of Keene:

Beech Hill reservoir,	595
Summit of Beech hill,	1060

Also from Mr. Holbrook's levelling, Troy station being taken as 1002 (Vol. I, p. 259):

Troy school-house No. 3, lowest step,	1166
Jaffrey school-house No. 12, threshold,	1231
John Mann's house,	1488
Monadnock Mountain house,	2072
Summit of Monadnock mountain,	3169

(Compare with Vol. I, p. 279).

From levelling by A. P. Little, of Keene:

Swanzey, Sawyer's crossing, R. R. bridge,	485
West Swanzey, railroad, 495; Ashuelot river above dam, 461; below dam,	454

APPENDIX C.

APPENDIX TO THE CATALOGUE OF THE PLANTS OF NEW HAMPSHIRE.

The number of plants known to grow without cultivation within the limits of the state has been somewhat increased since the publication of Volume I. These additions to the catalogue of that volume (pp. 395–414), together with those found in its appendix, are here presented, marked with letters and signs which are there used and explained, indicating distribution, relative abundance, and introduced species.

A paper on the "Distribution of Plants in New Hampshire and Vermont," by William F. Flint, occurs in the *American Naturalist*, Volume XI, pages 89–95. The flora of the White Mountains has been described by Edward Tuckerman, in T. Starr King's *White Hills*, pages 230–241; and by J. H. Huntington in *Appalachia*, Volume I, pages 100–106.

POPPY FAMILY.

Papaver Rhœas. Corn Poppy.
Hanover.

MUSTARD FAMILY.

Dentaria maxima.
Near Bedell's bridge, Haverhill.

Arabis perfoliata.
Fields along Connecticut river.

A. Drummondii.
Island in Connecticut river near White River Junction.

PINK FAMILY.

Cerastium vulgatum.

Spergularia media. . . . . . *S*

VINE FAMILY.

Vitis cordifolia; var. riparia.

MILKWORT FAMILY.

Polygala cruciata. . . . . . *
Near the coast.

PULSE FAMILY.

Colutea arborescens.

Astragalus alpinus.
A. Robbinsii.
Growing together at Sumner's Falls, Plainfield.

Vicia tetrasperma.

ROSE FAMILY.

Prumus maritima. Beach Plum. . *
Near the coast; also on the upper terrace west of Amoskeag falls.

Poterium Canadense. Burnet. . . *
Near the coast.

Pyrus arbutifolia; var. erythrocarpa.
var. melanocarpa.

SAXIFRAGE FAMILY.

Mitella nuda.
Hanover.

WATER-MILFOIL FAMILY.

Proserpinaca palustris. Mermaid-weed.

LOOSESTRIFE FAMILY.

Lythrum Hyssopifolia. . . . *S*

PARSLEY FAMILY.

Ligusticum Levisticum. Lovage.
Around old dwellings.

Zizia integerrima.

HONEYSUCKLE FAMILY.

Lonicera parviflora.
Connecticut valley.

COMPOSITE FAMILY.

Eupatorium teucrifolium.

E. pubescens.

Sericocarpus solidagineus.

Aster tenuifolius.

A. carneus.

A. Novæ-Angliæ.

Solidago stricta.

S. patula.

Ambrosia trifida.

Bidens bipinnata.

Anthemis arvensis. Corn Chamomile.

Artemisia vulgaris. Mugwort.

Onopordon acanthium. Scotch Thistle.

Cynthia Virginica.

HEATH FAMILY.

Leucothoë racemosa. . . . . . *
Near the coast.

Chimaphila maculata.
Seabrook.

Pterospora Andromedea. Pine-drops.
Hanover.

BLADDERWORT FAMILY.

Utricularia purpurea.
Winchester.

U. resupinata.

Pinguicula vulgaris.
Mt. Willard.

BROOM-RAPE FAMILY.

Aphyllon uniflorum. Cancer-root.

FIGWORT FAMILY.

Veronica peregrina.
Fields in Connecticut valley south of Bellows Falls.

Gerardia purpurea. . . . . . *
Near the coast.

G. maritima. . . . . . . *S*

MINT FAMILY.

Monarda fistulosa. Wild Bergamot.
Rockingham county.

Galeopsis Ladanum.
Hanover to Hinsdale; rare.

GENTIAN FAMILY.

Gentiana quinqueflora.
Hanover.

Bartonia tenella.

DOGBANE FAMILY.

Apocynum cannabinum; var. hypericifolium.

AMARANTH FAMILY.

Amarantus hypochondriacus.

A. spinosus.

BUCKWHEAT FAMILY.

Rumex salicifolius. White Dock. . *S*

R. maritimus. Golden Dock. . . *S*

OAK FAMILY.

Quercus bicolor. Swamp White Oak.
Low'r Merrimack valley and Rockingham county.

Q. Primus; var. humilis. Dwarf Chinquapin Oak.
Same range as the last.

WILLOW FAMILY.

Salix tristis.
Lower Merrimack valley.

S. nigra; var. falcata.

PINE FAMILY.

Cupressus thyoides. White Cedar.
Manchester, and near the coast.

ARUM FAMILY.

Peltandra Virginica. Arrow Arum.
Walker's pond, Conway.

DUCKWEED FAMILY.

Lemna polyrrhiza.

CAT-TAIL FAMILY.

Sparganium simplex; var. androcladum.

ORCHIS FAMILY.

Spiranthes Romanzoviana.
Bogs; New Hampton.

Pogonia pendula.
Winchester.

IRIS FAMILY.

Iris Virginica. . . . . . . *
Near the coast.

RUSH FAMILY.

Juncus militaris.

SEDGE FAMILY.

Eleocharis pygmæa. . . . . *S*

Scirpus polyphyllus.

S. lineatus.

Rhynchospora capillacea.

Carex siccata.

C. Emmonsii.

C. Kneiskernii.

C. polymorpha.

C. Houghtonii.
Franconia.

GRASS FAMILY.

Calamagrostis Nuttalliana.
Hampton.

Spartina cynosuroides.

Poa cæsia.
Summit of Mt. Willard.

Bromus Kalmii.

Hierochloa borealis.
Hanover and Amherst.

Panicum virgatum. . . . . . *
Near the coast.

P. pauciflorum.

HORSETAIL FAMILY.

Equisetum scirpoides.
Along Connecticut river.

CLUB-MOSS FAMILY.

Isoetes echinospora; var. Braunii.

I. riparia.

CATALOGUE OF THE MOSSES AND LIVERWORTS OF NEW HAMPSHIRE.

The nomenclature is that of Sullivant's *Musci and Hepaticæ*, from which the species found upon the White Mountains (designated by M) are compiled. The others have been collected in the vicinity of Hanover by William F. Flint and Edward Hyde, or in the south-west part of the state by Charles C. Frost, the distinguished cryptogamic botanist, of Brattleborough, Vt. Commonness is indicated by a star (*).

MOSSES.

Sphagnum cymbifolium.	*
S. Lescurii.	
S. sedoides. Ethan's pond.	
S. squarrosum.	*
S. acutifolium.	*
S. cuspidatum.	*
Andræa rupestris.	M
A. crassinervia.	M
Phascum serratum.	
P. cuspidatum.	
P. Sullivantii.	
Gymnostomum curvirostrum.	*
G. rupestris.	*
Weisia viridula.	*
Rhabdoweisia fugax.	M
Arctoa fulvella.	M
Dicranodontium longirostre.	
Trematodon longicollis.	*
Dicranum gracilescens; var tenellum.	M
D. varium.	*
D. rufescens.	*
D. subulatum.	M
D. heteromallum.	*
D. Blyttii.	M
D. Starkii.	M
D. flagellare.	*
D. interruptum.	
D. longifolium.	
D. scoparium; var. pallidum.	*
D. undulatum.	
D. Drummondii.	M
Ceratodon purpureus.	*
Leucobryum glaucum.	*
L. minus.	
Fissidens minutulus.	
F. bryoides.	
F. osmundiodes.	*
F. subbasilaris.	
F. taxifolius.	
F. adiantoides.	*
Conomitrium Julianum.	
Trichostomun pallidum.	*
Barbula unguiculata.	*
B. cæspitosa.	*

B. convoluta. *
B. mucronifolia. *
Pottia truncata.
Tetraphis pellucida. *
Tetrodontium repandum.
Near the Glen house.
Encalypta ciliata.
Hanover.
Zygodon Lapponicus. M
Z. Mougeotii. M
Drummondia clavellata. *
Orthotrichum obtusifolium.
O. strangulatum. *
O. Canadense. *
O. Ludwigii. *
O. Hutchinsiæ. *
O. crispum. *
O. Bruchii. M
Ptychomitrium incurvum.
Schistidium apocarpum.
S. confertum, var. M
Grimmia Olneyi. *
G. Pennsylvanica. *
G. Donniana. M
Racomitrium aciculare. *
R. lanuginosum. M
R. fasciculare. *
R. ellipticum, Br. and Sch. *
R. canescens. M
Hedwigia ciliata. *
Diphyscium foliosum. *
Atrichum undulatum. *
A. angustatum. *
A. crispum. *
Pogonatum brevicaule.
P. urnigerum. M
P. capillare. M
P. alpinum. M
Polytrichum commune. *
P. formosum.
P. juniperinum. *
P. piliferum. *
Aulacomnion heterostichum. *
A. palustre. *
A. turgidum. M
Bryum pyriforme. *
B. crudum. M
B. nutans.
B. cucullatum. M
B. roseum. *
B. Wahlenbergii. *
B. argenteum. *
B. pseudo-triquetrum.
B. alpinum. M
B. bimum. *
B. capillare. *
B. cæspiticium. *
Mnium affine. *
M. hornum. M
M. stellare. *
M. cinclidioides, Hedw.
M. punctatum. *
M. Drummondii. M
M. rostratum. *
M. cuspidatum. *
M. spinulosum. M
Meesia uliginosa. M
Bartramia ithyphylla. M
B. Oederi.
B. pomiformis. *
B. fontana. *
Conostomum boreale. M
Funaria hygrometrica. *
Physcomitrium pyriforme. *
Tetraplodon angustatus. M
Fontinalis antipyretica. *
F. Eatonii, Sulliv. *
F. disticha.
Saco river in White Mountain Notch.
F. Lescurii.
F. Frostii, Sulliv. *
F. Dalecarlica. M
Dichelyma falcatum. *
D. capillaceum. *

Leucodon julaceus.	*
Leptodon trichomitrium.	*
Anomodon viticulosus.	*
A. tristis.	*
Leskea obscura.	*
L. rostrata.	*
L. nervosa.	M
Clasmatodon parvulus.	
Thelia hirtella.	*
T. asprella.	*
Anacamptodon splachnoides.	
Palaisæa intricata.	
Homalothecium subcapillatum.	*
Platygyrium repens.	*
Pterigynandrum filiforme, Hedw.	*
Cylindrothecium cladorrhizans.	*
C. seductrix.	*
Neckera pennata.	*
N. bifida, James. White Mountain Notch.	
Omalia Jamesiana.	M
Climacium Americanum.	
Hypnum tamariscinum.	*
H. delicatulum.	*
H. scitum.	*
H. abietinum.	*
H. paludosum.	*
H. triquetrum.	*
H. brevirostre.	*
H. splendens.	*
H. umbratum.	
H. Oakesii.	M
H. Allegheniense.	*
H. strigosum.	*
H. serratulum.	*
H. rusciforme.	*
H. recurvans.	*
H. demissum.	
H. cylindricarpum.	*
H. eugyrium.	M
H. palustre, L.	*
H. ochraceum.	M
H. montanum.	M
H. cuspidatum.	*
H. Schreberi.	*
H. cordifolium.	*
H. stramineum.	*
H. uncinatum.	M
H. fluitans.	*
H. aduncum. Ethan's pond.	
H. Crista-Castrensis.	*
H. cupressiforme.	*
H. imponens.	*
H. reptile.	*
H. curvifolium.	*
H. Haldanianum.	*
H. nemorosum.	
H. pratense.	*
H. salebrosum.	*
H. lætum.	*
H. rutabulum.	*
H. plumosum.	*
H. populeum.	*
H. reflexum.	M
H. Starkii.	M
H. Novæ-Angliæ.	
H. stellatum.	*
H. polymorphum.	*
H. hispidulum.	*
H. dimorphum. Ellis river.	
H. subtile.	
H. adnatum.	*
H. serpens.	*
H. radicale.	*
H. orthocladon.	*
H. riparium.	*
H. Lescurii.	
H. denticulatum.	*
H. Muhlenbeckii.	*
H. sylvaticum.	*

H. elegans.	M

LIVERWORTS.

Riccia natans.	*
R. fluitans.	*
Anthoceros punctatus.	*
A. lævis.	*
Marchantia polymorpha.	*
Fegatella conica.	*
Reboulia hemisphærica.	*
Fimbriaria tenella.	*
Mentzgeria furcata.	*
Aneura palmata.	*
A. multifida.	
Pellia epiphylla.	*
Blasia pusilla.	*
Chiloscyphus polyanthos.	*
Lophocolea bidentata.	
Sphagnœcetis communis.	*
Jungermannia trichophylla.	*
J. setacea.	*
J. connivens.	*
J. curvifolia.	*
J. bicuspidata.	*
J. divaricata.	*
J. setiformis.	M
J. barbata.	*
J. intermedia.	*
J. Schraderi.	*
J. Taylori.	
J. crenulata.	*
J. exsecta.	*
Scapania nemorosa.	*
Plagiochila spinulosa.	*
P. asplenioides.	*
P. porelloides.	*
Sarcoscyphus Ehrharti.	*
Gymnomitrium concinnatum.	M
Frullania Grayana.	*
F. Tamarisci.	*
F. Virginica.	*
F. Eboracensis.	*
Lejeunia cucullata.	*
Madotheca platyphylla.	*
Radula complanata.	*
Ptilidium ciliare.	
Trichocolea Tomentella.	*
Mastigobryum trilobatum.	*
Lepidozia reptans.	*
Calypogeia Trichomanis.	*

APPENDIX D.

THE RELATION OF GEOLOGY TO DISEASE.

By G. W. Hawes.

Mr. J. T. Gardner, in his address before the American Public Health Association at Boston,* has drawn attention to the intimate connection between geology and health. He indicates that controlling causes of some of our most fatal diseases are to be found in local structural and lithological conditions, which are of even greater weight than the condition of the air. In some regions above the palisades of the Hudson malarial diseases are very prevalent. This region is underlaid by dense basaltic rocks, through

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* Boston, October 6, 1876.

which water cannot percolate, but is accumulated in basins beneath the surface, there to become stagnant and breed disease in a high region which has pure clear air and apparently all the conditions for the best of health. Many cases are cited; among which is one of interest to us, as it shows that considerations of this kind are worthy of closest attention in New Hampshire. The case is derived from the study of the geological conditions in the town of Greenland, N. H., and is quoted from an article by Dr. Henry I. Bowditch on "Consumption in New England, and locality one of its chief causes."

Dr. Bowditch thinks that the most powerful agent in promoting the disease called consumption is the soil moisture which results from the structure of the country and the character of its soil and underlying rocks. In Greenland there are three distinct varieties of soil:—1. A high and dry sandy plain. 2. A middle fertile and rather moist portion. 3. Extensive low marshes. Between these three portions the inhabitants, 715 in number, were about evenly divided; and yet, in a given length of time, there were three deaths by consumption on the sandy plains, five in the middle moist region, and ten in the lowlands, or three times as many in the wet as in the dry region. But in a town in Maine the conditions were exactly reversed: the *lowlands* were of porous gravel, while the highlands were clayey and impervious to moisture. Here, in a given length of time, the number of deaths was two times larger on the *highlands* than on the lowlands.

These cases indicate that the character of the rocks, and their mode of arrangement, are important elements in the control of health or disease, and that the character of our rocks and the mode of arrangement, which have been described at such length in these volumes, have an important influence on the duration of human life. They indicate that the crystalline condition, the schistose or compact structure, the geological arrangement of rocks, and all those characters of rocks and soils which facilitate or impede drainage, are powerful influences in determining local conditions for health, and that, therefore, the lithology and geological structure of their special region should be a study of each member of the medical profession.

APPENDIX E.

NOTE ON SOME POINTS IN THE GEOLOGY OF STODDARD AND MARLOW, CHESHIRE COUNTY, N. H.

By Sanborn Tenney.

The prevailing rocks in this region are gneissoid and mica slate. Their strike is north-easterly, being north 30°–40° east by the needle, and they dip easterly at a high angle, in many places 60° or more. In some places, as near Stone pond, in Marlow, the bedding is exceedingly well defined, so that the effect is very beautiful, especially as dark and light colors alternate more or less with one another.

The whole region gives the most ample evidence that it was once subjected to long continued glacial action. The rocks are planed down and grooved, and boulders in many places almost cover the ground over areas miles in extent. Probably there are but few places, if indeed there are any in our country, where the boulders are more numerous than in this part of New Hampshire. Between Hancock and Marlow, inclusive, the boulders are, in a great majority of cases, porphyritic granite. In the vicinity of South Stoddard, some of the boulders are of enormous size. One boulder, not far from the road, and on the right hand in going from the "Box tavern" to Stoddard village, is about fifty paces in circumference, and probably contains 40,000 cubic feet of rock. Many others in the vicinity approximate this in size. Another of very great size is found about half a mile from the village of Marlow, in a southerly direction, and just east of the Ashuelot river.

Rocking-stones are not uncommon in this region. Two beautiful examples of this kind are found in Marlow, not far from a place in the Ashuelot river well known as the "Bend." Several of these stones are found on a hill westerly from the Abbot pond, which is on the right hand of the main road leading from Stoddard to Marlow. But I hasten to say that not one of these last will now "rock," for they have been tipped and wedged up by stones, put in by the farmers, as I learned, under the impression that the flocks and herds might be injured by them. I believe that an ox, or some other creature of the farm, did get caught by the tipping of one of these boulders, and this fact led to the wedging of them so that they could not rock. We examined them, and satisfied ourselves that they would rock again as soon as these props or wedges were removed.

The drift striæ in Marlow are nearly due north and south, varying only slightly from a due northerly and southerly course, as the needle points. The effect produced by the planing down of the highly inclined slate near Stone pond is very interesting and beautiful. Not a projecting point is left, and the bare, clean, and smoothly planed edges of the dark- and light-colored layers of the gneissoid rocks present a very striking and beautiful appearance to the eye of the geologist.

Very near the outlet of Stone pond are very beautiful examples of granite dykes in the gneissoid rocks, some crossing others, and thus showing that they were formed at different times. Northerly from Stone pond, at a distance of a mile or less, is Trout pond, interesting from the fact of its being nearly surrounded by high hills of drift. One large moraine is, as it were, cut off by the pond; the moraine continues for a considerable distance northerly and southerly, interrupted only by this pond. How this pond was formed in the line of this moraine, is an interesting question. Was the pond there before the moraine? If so, why was it not filled by the drift material? Is it not probable that the age of the pond dates from the glacial period, and that there was a vast accumulation of ice just where this pond is to-day?

APPENDIX F.

GEOLOGY OF THE REGION ABOUT THE HEAD WATERS OF THE ANDROSCOGGIN RIVER, ME.

BY J. H. HUNTINGTON.

If we examine a map, and look at the western part of New Hampshire, we see that Hall's stream, one of the principal branches of the Connecticut river, has a part of its branches in the province of Quebec; then eastward, all the streams as far as the St. John's in Maine have their waters wholly in the states. Of the streams included in this area, Indian, Perry's, the Connecticut, the Magalloway, the Cupsuptic, the Kennebago, Dead river, and Moose river, I have followed from their sources to their confluences with other waters; and, besides this, I have traversed much of the intervening country. As a continuous forest extends along the north-western border of Maine, geological work is slow and extremely laborious. The topography of the country is somewhat peculiar. The boundary itself is a mountainous ridge, rising from 2,500 to 3,000 feet above the sea, and it is extremely irregular in outline. The streams from Hall's to Dead river have a course almost due south; then to the north-east the streams at first all begin their courses by flowing northerly and north-easterly. The glaciation of the continent, and the trend of the strata of the rocks, have given in part, at least, this peculiar feature to the streams of this region, though there is no doubt but that the great depression of the St. Lawrence valley is the primal cause.

The area of country to which this paper relates more specifically borders on the Cupsuptic and Kennebago rivers. Both of these streams rise on the boundary. On the first, three fourths of a mile from the boundary, the beavers, by building a dam, have formed quite a little lake. This is 600 feet below the highest point of the ridge. For five miles in a direct line the stream is sluggish, and is frequently interrupted by beaver dams; then for half a mile it cuts a deep gorge through an argillaceous schist, and has a fall of some thirty feet; then for six or seven miles it has very much the same character that it has above the gorge; then for nearly a mile it rushes along in a series of wild cascades, while here and there it plunges down into great eddies, when it rests only to leap again over the rocky strata below. The falls passed, it assumes again its sluggish character, which it retains until it flows into Cupsuptic lake. The entire length of the stream in a direct line is about 13 miles. The Kennebago is quite a different river. On the boundary rise numerous streams, which widen into lakelets, and then flow southward until they unite in No. 4 R. 3. Then the descent is quite gradual until after it passes Kennebago lake,—then there are extensive falls; thence for the most part the descent is gradual for the rest of its course. There are some things about the topography that are quite noticeable. From a point a mile south of the outlet of Kennebago lake a range of mountains begins, which runs north-west, and extends to the

Cupsuptic. On the Kennebago, the rock is fissile slate; on the Cupsuptic, the rock is an argillaceous schist; but the summit, at least of the north-west peak, is granite. From the point where the streams unite in No. 4 R. 3, a range of mountains on the west side of the Kennebago runs north-west; and on the east side of the river a range runs north-east. Between these ranges are the streams mentioned above as widening into lakelets.

The area about the lakes was briefly mentioned by Prof. C. H. Hitchcock in the report of the scientific survey of Maine for 1862.

The conglomerate found at the outlet of Rangeley lake has been described by Prof. Geo. L. Vose. Some notes on the geology of the area north-east of Kennebago river were presented at the Portland meeting of the American Association for the Advancement of Science. The rocks found on the west of the Cupsuptic have been described by me at some length in the report of the geological survey of New Hampshire (Vol. II). As I understand the rocks, the following formations are represented:

I. STRATIFIED GROUPS.

LAURENTIAN.	Gneiss.
	Gneiss containing limestone.
HURONIAN.	White Mountain gneisses and schists.
	Mica schists with staurolite.
	Chloritic and whitish argillitic mica schists.
	Sandstone schists.
	Diabase.
	Diorite with serpentine.
	Argillitic mica schist with staurolite.
	Rangeley conglomerates.
PALÆOZOIC.	Wrinkled argillaceous schists with hard micaceous bands.
	Slaty conglomerates.
	Calcareous sandstones with fossils.
CENOZOIC.	Glacial drift.
	Modified drift, including kames, etc.

II. ERUPTIVE ROCKS.

Granite (Conway).
Diorite.
Felsite.

Gneiss. The area of gneiss is very small, and it was seen only on the boundary on the head waters of the north-west branches of the Kennebago river. It is a fine-grained rock, and the outcrops were so few that the dip could not be well determined. As an intrusive granite and a fine-grained diorite were the only rocks seen in the vicinity, its stratigraphical relations have not been satisfactorily determined; but its resemblance to the Laurentian gneiss in the vicinity of the chain of lakes to the north-east makes it altogether probable that it is a part of the Upper Laurentian.

Gneiss with Limestone. Approaching the lake region from the east at the village of Phillips, we find an intrusive granite that is somewhat coarser than the common Concord granite. It extends a mile east of the village. On Sandy river, where the road crosses the river for the first time above Phillips, we find the intrusive character of the rock clearly seen, as here great masses of schist have been caught in it; and elsewhere the granite appears only as veinstones in the schist. About two miles above the village, on the north side of the river, there is a fine-grained micaceous gneiss that has intercalated beds of a dark limestone: this at some time has been burned for lime. The whole breadth of country occupied by this gneiss does not here exceed a mile. The stratum is very irregular in strike, and has an inclination of 30° to 50°.

Huronian—White Mountain Gneisses and Schists. These rocks, which belong to the Montalban series of the New Hampshire geological survey, are found north-west of the outlet of Moosetocmaguntic lake. The strata here have nearly an east and west strike, and are vertical; but this is probably due to a great mass of intrusive granite between this and the river that joins the lakes on the south. The lithological character of the rock is similar in every respect to the rocks found in the vicinity of Mt. Washington, and it is probably a continuation northward of the rocks so extensively developed along the Androscoggin river in Gorham, N. H., and eastward. This is near the northern limit of these rocks in the area we have studied.

Mica Schists with Staurolite. South of Moosetocmaguntic lake, in townships D and E, and extensively developed in the town of Byron, is a series of rocks consisting of fine-grained, thick-bedded mica schists that carry staurolite. These schists, wherever observations were made, have a dip almost directly north; and the inclination does not usually exceed 45°, especially northward. From the south, they follow directly on the White Mountain gneisses.

Chloritic and Whitish Argillitic Mica Schists. North of the rocks last mentioned, and east of the White Mountain gneisses, near the northern part of Moosetocmaguntic lake, and extending east beyond the outlet of Rangeley, there is a series of rocks consisting chiefly of chlorite and whitish argillitic schists. They are noticeable on account of their unconformability with the rocks east and south, and the abundance of quartz which they contain, and which lies in the line of the stratification. This rock forms ledges at Frye's Camp, at Houghton's Camp, and on the ridge immediately south of the Mountain View house at the outlet of Rangeley lake.

Bald mountain, an isolated peak between Rangeley and Moosetocmaguntic lakes, although chiefly granite south of the ridge just mentioned, has upon its top a great mass of this schist, which was caught in the granite. Indian Rock, at the mouth of Kennebago river, and famed in the annals of fishermen, is a wonderfully contorted argillite, and may possibly belong to a different series of rocks. The hill immediately north of Cupsuptic lake is a light gray argillitic schist. The strata are nearly everywhere vertical, and the strike is N. 40° E. Northward along the river there is no outcrop of rocks for several miles; but at the falls of the Cupsuptic a rock similar to the last is found. It differs from it in being of a darker color, somewhat more siliceous, and weathering with a pitted surface near where it comes in contact with an intrusive granite. Having seen a similar change elsewhere in the same kind of rock, under the same circumstances, it is more than probable that the granite was in some measure the cause of the change.

Sandstone Schist. Three miles north of Kennebago lake, on the Kennebago river, we find a sandstone schist. Although it often resembles a mica schist, yet nearly everywhere there is no doubt as to the character of the rock; and in some localities the fragments of which it is composed are a quarter of an inch in diameter, and very distinct, especially on the weathered surface of the rock. Elsewhere it has been greatly changed; and in some localities we find crystals of feldspar that have been produced since the sedimentation of the rock. This sandstone extends northerly some eight miles along the Kennebago river. On the mountain ridge north of Kennebago lake, where the sandstone first appears, the strata are nearly vertical, and the strike is N. 70° E.; but along the river the strike is more northerly. South of this great area of rock we have red and light gray argillites, and on the north we have diorite with serpentine. This sandstone schist is the rock on the boundary at the head waters of the Cupsuptic river, and it extends at least three miles southward along that stream; and the same rock outcrops on the Magalloway at Little Boys' falls north of Parmachena lake,—so that the area of this rock is exceedingly irregular in outline.

North-west of Kennebago lake, and extending south below the falls on the Kennebago river, there is an area of light gray, dark purple, and red argillites. The strata are vertical where observations have been taken; and there are sudden changes from one variety to the other. These argillites are probably the finer sediments derived from the great mass of material from which the sandstone schists were formed.

Diabase and Diorite with Serpentine. Diabase occupies an area on the Kennebago river. The most northern outcrop is about a mile from its mouth, and it extends a mile and a half northward along the river, and eastward towards Quimby pond. It is not altogether certain that this is a metamorphic rock. If only the southern outcrop had been seen, and the rock had been studied only in the field, we could have reached no other conclusion than that it was intrusive, yet other outcrops strongly indicate that the rock is metamorphic. At the head of one of the north-west branches of the Kennebago, which rises near the point where the boundary extends farthest southward, there is a fine-grained greenish rock, which would probably be distinguished as melaphyre by the German geologists. The area is limited here; but there are extensive outcrops on the boundary of New Hampshire, the summit of Mt. Carmel being composed of similar rock. The metamorphic diorite is one of the most interesting rocks found in this section of Maine. It outcrops on the Kennebago about twelve miles north of

Kennebago lake. Very few ledges are seen. The boulders, however, are large and numerous. But what is most important, it is undoubtedly the rock the *metamorphism* of which has produced the serpentine, which is also abundant here. The boulders of serpentine are first found in great numbers about ten miles north of Kennebago lake. They are enormous in size, sometimes 30 or 40 feet in length; and with these are boulders of diorite of nearly the same dimensions; but where the ledges appear, the diorite evidently passes into serpentine.

Argillitic Mica Schist with Staurolite. West of the gneiss containing limestone, in Phillips, we have a mica schist which, westward in Madrid, becomes quite argillaceous, and then again, in the south-west corner of Madrid and in Sandy River Plantation, and west as far as Rangeley lake, this rock has more the characteristics of a typical mica schist. The strata are everywhere vertical, or nearly so; and often there are beautiful crystals of staurolite. One of the finest outcrops with these crystals is at a school-house north of Sandy river, three and a half miles west of Madrid village. In the river, below the dam at Madrid village, there is a fine-grained, thickly-bedded mica schist, which contains concretionary nodules of granite from three inches to a foot in length, and from two to eight inches in width. In the larger ones the proportional width is much less than in the smaller ones. Five rods below the dam, the fissile addalusite schist has essentially the same strike and dip as the compact mica schist above. North-west of Madrid village there is a large area of ferruginous schists that probably belong to a different series of rocks from those we are considering. In the west part of Sandy River Plantation, and in the east part of Rangeley, we have mica schist with staurolite. This schist is extensively developed on Saddle-back stream, which flows near the Greenvale house. Following up this stream, we find, for nearly half a mile, both the schist and the conglomerate; and there is such an intermingling of the two, that, unless there have been great changes in the rocks since they were uplifted to their present position, they must belong to the same series of rocks. When the stream turns and comes more from the east, we leave the conglomerate. Above, a deep gorge has been cut in the schist along the strike. On the hill south-east of the Greenvale house, where the steep ascent begins, there is a mica schist with staurolite, and the dip is S. 20° E. 82°. There is a conglomerate included in this, and unconformable with it. On the face of the cliff it was not more than 120 feet in width, but it becomes wider as we ascend the hill. It dips N. 30° W. 75°, and stands on the upturned edges of the staurolite schist: so it is clear that we have two bands of conglomerate. Just south of the inlet of the lake, the schist and conglomerate have the same relations that they do on Saddle-back stream. This schist is more extensively developed in this section of Maine than any other rock, for, with some of the White Mountain gneisses and schists, it occupies the whole country to the north-east as far as Dead river in Flagstaff.

Rangeley Conglomerate. This conglomerate has given rise to much discussion, on account of the flattening and distortion of some of the pebbles of which it is composed, but its stratigraphical relations have received very little attention. This conglomerate is confined to a limited area, extending N. 30° E. and S. 30° W. from the inlet of

Rangeley lake. It is not far from a mile in width, but it becomes narrower northward, and in the middle of Dallas Plantation it is only a few rods in width. In the stream near the Greenvale house there seems to be, on the weathered surfaces, a marked difference between the staurolite schist and the conglomerate; but, breaking the conglomerate, every portion of it, except where there are actually pebbles, resembles in all respects the schist: even the staurolite is not wanting. Going across the stratification, we find places where there is an abundance of pebbles, and then they are wanting altogether, or have been so changed that they are not apparent. There are fine outcrops of conglomerate three quarters of a mile from Greenwich on the road to Rangeley, and at Moxey ledge, near the inlet of the lake. Some of the fragments at the former locality are a foot in diameter. The conglomerate on its north-west border, both north and south of the lake, passes gradually into a rock, which without a lens cannot be distinguished from common gneiss. Looking at this conglomerate now, as a whole, it has the appearance of having been formed from fragments derived from a rock which is now the argillitic mica schist with staurolite, before great metamorphic changes had taken place. The re-formed sediments, which are now the cementing material of the conglomerate, were so little assorted, that in the subsequent changes, in which both the conglomerate and the schist were involved, this material and the schist became essentially the same kind of rock.

Paleozoic.

Wrinkled Argillaceous Schist with hard Micaceous Bands. West of the conglomerate there is a broad area of rock, consisting chiefly of wrinkled argillaceous schists and a few hard micaceous bands. They are found on the hills south of Rangeley lake, and, north of the lake from where the conglomerate ends, it extends nearly to the outlet. In the east part of Rangeley it is limited northward near Gulf pond by an intrusive diorite, but, west, it extends about three miles north of Quimby pond. This band of rocks has one characteristic in common with some of the paleozoic rocks in New Hampshire: the veins of quartz by which it is penetrated, as well as those in the rocks immediately adjoining it, have a decidedly fetid odor. There is a band of this schist in the hill south-east of Greenvale: so it either extends around the Rangeley conglomerate, or there is here a repetition of the band to the west. The conglomerate mentioned as being found on this hill seems to be associated with this schist, rather than with the staurolite schist.

Lower Helderberg and Oriskany. There is quite a large area in the vicinity of Kennebago lake that most probably belongs to the Lower Helderberg and Oriskany. From their fossils, we are sure that some of the rocks belong to these groups. The area of Lower Helderberg and Oriskany in the vicinity of Parlin pond has been known for many years, and its limits on the south-west have been pretty clearly defined. The area in Flagstaff was pointed out for the first time by me at the Portland meeting of the Association for the Advancement of Science; and this now adds another to the many areas of these rocks already discovered.

Slates. There is a band of argillaceous rocks that are unlike, in their physical characteristics, any we have described, which is found on both sides of Kennebago lake. The most southern outcrop seen is on Spotted mountain, south of John's pond; the most northern, on Kennebago East mountain. The rock is generally thick-bedded. Sometimes it has the appearance of an argillaceous sandstone, and it is sometimes a little micaceous; and often the finest and most purely argillaceous bands pass suddenly into a slate conglomerate. The argillaceous rock on the ridge between John's pond and the south end of Kennebago lake breaks up into fragments more like shale than slate. The strike of this rock is N. 40° W.

Slate Conglomerate. The transition of the slate into conglomerate is so sudden that we do not suspect its presence until we see the boulders or ledges where the change occurs. Boulders of slate conglomerate are abundant on the southern shores of Kennebago lake, and outcrop in the vicinity of Flatiron pond.

Calcareous Sandstone with Fossils. Several years ago Mr. H. P. Dill found boulders of fossiliferous rocks along the river in Phillips; hence it has long been known that fossiliferous bands existed somewhere in this section. The rock seen in the vicinity of Kennebago lake is not the same as the boulders of Phillips, though further exploration may show that they are found here; but it seems more probable that the ledges from whence the Phillips boulders are derived are in some other locality, since the Phillips boulders are a pure sandstone, with fossils of Lower Helderberg types, while here the rock is a calcareous sandstone, with some fossils that are found with the Oriskany in the vicinity of Parlin pond. The change, however, does not appear to be any greater than it is between Parlin pond and Moose river. It has long been known that the line of demarcation between the Lower Helderberg and Oriskany in Maine is not so well defined as it is in New York. At Kennebago lake the number of species is quite limited, and they can scarcely be distinguished except upon the weathered edges of the rocks where some of them are well brought out.

The fossiliferous rocks here are probably limited to the area north of Spotted mountain between Flatiron pond and the bridle-path.

Glacial Drift. The study of drift in a region entirely covered by forests is more difficult, even, than the study of the ledges. In the vicinity of Rangeley lake, however, where there are farms, the absence of stratified drift is generally very noticeable. The most common boulders in the country about the east end of Rangeley lake are diorite; and these are derived chiefly from the numerous dykes in the west part of the town of Rangeley. There are very few boulders except of diorite on the bridle-path to Kennebago until we get within three miles of the lake, when we have those of slate conglomerate, calcareous sandstone, fossiliferous, and a few granite boulders.

About ten miles north of Kennebago lake, particularly on the west side of the river, we find a remarkable collection of boulders. They consist of sandstone schist, serpentine, and chlorite, with a few granite boulders; but as we go northward, the granite boulders increase, and soon they begin to predominate, and the others disappear altogether. Some of these boulders are of enormous size, and are probably derived from ledges in their immediate vicinity. There is another great collection of boulders on the Cupsuptic river below the gorge already referred to; and these are derived from the granite ridges on either side of the stream,—for, soon after we pass the granite ridges, these boulders disappear. Elsewhere no great collections of boulders were observed.

The drift striæ on Bald mountain, between Moosetocmaguntic and Rangeley lakes, are S. 55° E.; near Rangeley, on the south side and near the inlet, S. 35° E.; and on the high land south-east of Dodge pond, S. 65° E. The striæ here are in the direction of Saddle-back mountain.

Modified Drift, Kames, etc. A few gravel ridges in the west part of Dallas Plantation were the only gravel deposits resembling kames that were seen in the vicinity of Rangeley lake. On the lower part of the Kennebago river there are some well marked kames; and their absence was also noted on the river till we get about ten miles north of Kennebago lake, where there are some well marked ridges, but these do not extend more than two miles. On Cupsuptic river there is an almost entire absence of kames, as in the other regions we traversed; but on the lower part of the Cupsuptic, for six or eight miles, there are sand and gravel plains extending some distance from the river. These sand plains are characteristic, also, of the Magalloway; but, so far as our observation goes, they are wanting on the Kennebago.

Eruptive Rocks.

Granite. On the north-west branch of the Kennebago river, near its source, there is a band of granite probably two miles wide. It is a typical variety, consisting of quartz, feldspar, and mica in more nearly equal proportions than we often find them.

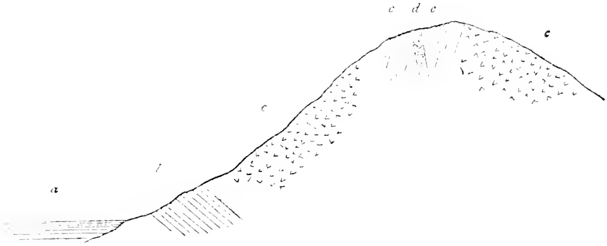

Fig. 64.—Bald Mountain.

a, the lake; *b*, schist on the border of the lake; *c*, granite; *d*, granite,—a narrow band near the top of the mountain; *e*, schist on the summit of the mountain.

There are, however, two kinds of feldspar, the triclinic being more abundant than it is commonly found in the coarser varieties of the New England granites. On the Cupsuptic river, in No. 4, R. 4, we find a similar kind of granite, which extends north and south nearly through the entire range. South-west, in No. 5, R. 1 and 2, there are large areas of granite; but its greatest development we find on Observatory and Aziscohos mountains, and there is quite an extensive outcrop in No. 4, R. 1, on the south-west side of a hill north-west of the upper dam. The top of Bald mountain, between Rangeley and Moosetocmaguntic lakes, except its very summit, is composed of this same coarse granite. The way in which the schist is caught shows better the intrusive character of the Conway granite than any other example we have seen. Fig. 64 shows clearly this feature. To the left, on the border of the lake, we have the schist with an easterly dip; and as we ascend the mountain the granite suddenly appears, and extends almost to the very summit, which is crowned with the same kind of schist as that at the base; but in it is a well defined band of granite, about six feet wide, cutting it so sharply that the dip, which is westerly, is essentially the same as that of the mass on either side. South-east of Moosetocmaguntic lake, in township D on the head waters of Swift river, there is a band of granite, but it is a finer variety than those found northward.

Diorite. The most extensive outcrop of intrusive diorite found in New England has its southern limit near Gull pond, and outcrops are found for more than four miles to the north. South-east of Kennebago lake it forms a sharp mountain ridge, which rises more than 600 feet above the lake. The rock is generally a mica diorite, and it often contains garnets. On the southern limit of this diorite are fragments of schist; and it probably also penetrates the Paleozoic strata in the vicinity of Kennebago lake. There are many dykes of diorite in Rangeley immediately north of the lake, and the rock resembles the great outcrop northward, except that there is more hornblende and fewer garnets.

Felsite. The summit of the diorite ridge south-east of Kennebago lake is chiefly a compact feldspar; and one variety contains a few garnets and a little mica. This forms great cliffs near the summit of the ridge.

APPENDIX G.

THE ATLANTIC SYSTEM OF MOUNTAINS.

Want of time will prevent us from preparing a chapter upon the elevation of mountains and the occurrence of earthquakes, as promised in the preface to Volume I. In its stead, I will describe in greater detail the suggestion made upon page 6, Volume II, in regard to the distinctive features of the Atlantic system of mountains. I hardly need say there is a world-wide difference between the views of the age of mountains expressed in these reports, and those entertained by the metamorphic school of geologists. For this reason, it is important to set forth the correct history of the whole

Atlantic range, in the hope that the public will see that the name Appalachian ought never to be applied to any of the New Hampshire mountains.

The Atlantic system of mountains includes the high lands bordering the Atlantic ocean between Newfoundland and Alabama, bounded westerly by a depression readily traceable from the St. Lawrence and Hudson valleys to East Tennessee and northern Alabama. It may naturally be divided into three sections,—northern, middle, and southern, each entirely encircled by low land, if not the level of the sea.

The northern section is confined to Newfoundland, entirely surrounded by water. The culminating point is about 2,000 feet. The Nova Scotia elevation may be regarded as a branch.

The middle section, with a Green Mountain branch, is nearly encircled by tide-water, having the St. Lawrence gulf and river opposite a great portion, thence following the Champlain depression to the Hudson, the highest divide being 150 feet above the sea. From Albany to New York, and thence around to the starting-point, it is all tide-water. The culminating point is Mt. Washington, 6,293 feet.

The southern section is the longest and highest, reaching 6,700 feet in western North Carolina. The eastern boundary is washed by the sea; and the western is the great valley between the Hudson and Alabama.

The course of the Great Appalachian valley may be traced minutely thus: From the St. Lawrence to Lake Champlain is a rise of 90 feet. Sixty feet more brings us to the highest point in the depression between Lake Champlain and the Hudson river. The valley leaves the Hudson west of the Highlands, strikes across through northern New Jersey to the Kittatinny in Pennsylvania, 10 to 18 miles wide, and from 200 to 600 feet high. There is then a descent to the Potomac, and an elevation to the head of the Shenandoah. Continuing southerly, this valley rises to 2,595 feet at the highest part, near the sources of the Holston river. Following the great valley of Virginia, the altitude is 2,741 feet near the south line of the state, 898 at Knoxville, and 675 feet at Chattanooga. The highest part of this valley in Virginia does not correspond in latitude with the culmination of the mountains, as that point is reached in western North Carolina. This valley is regarded as the western boundary of the Atlantic system, and the eastern limit of the Appalachian ranges.

A section from East Virginia to Cincinnati crosses five different types of orographic structure. First, is the Atlantic plain, nearly 150 miles wide. No mountains exist in it. The elevations are those made by streams cutting into the Cretaceous and Tertiary horizontal deposits, which when protracted display crenulated edges. Second, are the elevations of the Atlantic system known as the Blue Ridge, with obtusely pointed summits. Third, is the valley of the Shenandoah. Fourth, are the long, narrow Appalachian ridges or the Alleghany Mountains. Fifth, is the elevated plateau, called collectively the Cumberland-Alleghany-Catskill plateau, with a quaquaversal arborescent drainage. The Hudson river, with its Mohawk tributary and the Susquehanna river, cut across all these five types of orographic structure.

Most authors call the Atlantic and Appalachian systems by this latter name only. I shall endeavor to show, from a study of their contours, their geological structure and composition, their separation by a great valley, and their identity with the Alps and Jura of Europe, that they are sufficiently diverse to be known by different names.

Distinctive Atlantic Features. These mountains occur as short, sharp ridges parallel to one another in echelon arrangement. Their summit lines are irregular, and their peaks obtusely pointed. The culminating points are higher than those of their neighbors, reaching 6,300 in the middle and 6,700 feet in the southern sections. The rocks are ancient gneiss of Eozoic age, Laurentian, Montalban, and Huronian, with commonly inverted dips. The periods of elevation were mostly pre-Silurian. On the west side of the Green Mountains of Vermont and the Blue Ridge in Virginia, a portion of the earth-masses included with other systems consists of Silurian sediments standing at high angles. These are so involved with the gneiss as to indicate an elevation in Middle Silurian times.

Distinctive Appalachian Features. Contrasting with the Atlantic elevations, the Appalachian ones occur in interminably long and narrow ridges, having level summits curving in the form of loops in the north, and terminating in pairs of straight ridges cut off short by faults in the south. Occasional gaps in them allow of the passage of roads. The elevation is usually 1,000 feet. The variation is from 800 to 2,500 feet; and in the Peaks of Otter in Virginia 4,000 feet is reached, in the neighborhood of the greatest elevation of the boundary valley. The rocks are altogether sedimentary, consisting of sandstones, shales, and a few limestones. They are curved, making the normal and symmetrical folds like a series of ocean waves. None of the dips are inverted. They are Paleozoic exclusively; and pebbles of the sandstone have often been derived from the breaking down of the crystalline schists of the Atlantic rocks to the east. The period of the elevation was at the close of Carboniferous time.

Connected with this is the great plateau, commencing in Alabama and Tennessee, or the Cumberland tableland, with a mean elevation of 2,000 feet, and a width of 30 to 40 miles. This is 3,000 feet high in Pennsylvania. It occupies a considerable breadth in central and southern New York, 2,000–2,600 feet high, and, highest of all in the Catskills, 3,800 feet. Here it terminates. It differs from the Appalachian mountains only in the smallness of the foldings, since in the coal plateau of Pennsylvania six basins, with the anticlinal arches between them, are described, and the same axes are prolonged northwardly into New York.

The Appalachians are divided along the Kenawha river in Virginia by a north-west-south-east fault, coinciding nearly with the highest part of the great valley. The Kenawha is the only one of the rivers flowing into the Mississippi valley that reaches and crosses the great valley. This break was produced by a great strain upon the crust, evidenced in the fall of the land northerly. It will be noted that the Atlantic mountains start with the culmination in North Carolina, and in northern Virginia divide, the one branch becoming the South Mountains in Pennsylvania, and the other sinks to the sea-level near Philadelphia. The low mountains of Staten Island indicate its place near New York. They rise into the White Mountains of New Hampshire beyond New York.

Then there was a sag along Hudson river, which may indicate the course of another break at the lowest part of the mountains just as the other fault shows itself along the Kanawha where the ge-anticlinal ridge is manifest.

Concerning the great valley, Lesley remarks that there is "an unbroken rim of Quebec and Laurentian from Georgia to the extreme eastern end of Canada, contrasted strongly with the plateau of the coal, commencing in Alabama and cut off square by the Hudson, the open valley of the Lower Silurians everywhere keeping the two systems apart."

In Europe, physical geographers refer the Alps and Jura mountains to different systems, characterized by features similar to those just indicated between the two portions of eastern America. The Alps correspond to the Atlantic, the Jura to the Appalachian, and the valley of Switzerland, prolonged into Bavaria and Moravia, to the great Appalachian valley. A section from Italy to the Rhine valley would be very much like the one in our country from eastern Virginia across to Cincinnati.

The Alps are composed of crystalline rocks centrally, with Carboniferous, Mesozoic, and Cenozoic groups corresponding to each other upon both sides. The structure is fan-shaped, but explained by supposing it to have been an anticlinal arch like a loop overhead, long since broken down and removed by denudation. The newer groups are arranged in close synclinal troughs, the older nearest the central crystallines, and consequently sometimes resting upon the newer ones by a species of inversion. The rocks of the Jura are largely Mesozoic, and are the best known exhibitions of the particular belts called for that reason the Jurassic. The Alps and Jura of America are therefore very much like their prototypes in Europe, in all essential particulars.

Authors have variously compared the American with the Swiss mountains. Guyot* says that the western portion is like the Jura,—adding that "there is one feature which distinguishes it [the Appalachian] from the Jura: it is the well-marked division into two longitudinal zones of elevation," or the ones distinguished above as Atlantic and Appalachian. The same author includes the Adirondack mountains with the Appalachians. J. D. Whitney† speaks of the Cordilleras (Pacific highlands) as like the Alps, and the Appalachian (Atlantic highlands leaving out Adirondacks) as like the Jura. The attempts of these distinguished authors to correlate our mountains with the Alps and the Jura, strengthens our conviction of the propriety of using special names for the chains corresponding to them so perfectly as do the two divisions mentioned south of the St. Lawrence.

That the name Appalachian is commonly used to include both these systems, is undeniable. My suggestion is, that we adopt an improved terminology, at least in geological treatises. Two or three considerations may be noted. 1. The desire for a single name to express the mountains along the eastern slope of the continent has led to the undue extension of the name Appalachian. But it should be remembered that, if it is used appropriately, it must include the Adirondacks and Labrador moun-

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* *Amer. Jour. Science*, ii, xxxi, p 166. † Walker's *Physical Atlas*.

tains also, for in the study of geography we are not to be confined to the limits of the United States. So far as appropriateness is concerned, we may as well include the Labrador as the White Mountains under the name Appalachian,—in fact, we must. Guyot, in his *Physical Geography* (1873), has perceived this difficulty in terms, and uses the name Atlantic highlands to include all the elevated region adjoining the eastern coast, and places the Adirondacks with the Appalachians, calling attention to the plain east of them. Harper's School Geography follows Guyot in using the terms Atlantic and Pacific highlands for the mountainous regions on the two sides of the continent. 2. The merging of these two systems under one name has been facilitated also by false theoretical notions. The advocates of the metamorphism of New England rocks legitimately assume the Atlantic to be of the same age with the Appalachians. If their doctrines were correct, this conclusion would follow. 3. The suggestion of the use of the term Atlantic for the eastern portion of this mountainous district is intended to be for geologists, not geographers. The eastern border will then have its Laurentian, Atlantic, and Appalachian systems of mountains formed in three separate sets of periods, the Eozoic, early and late Paleozoic. There will be further sub-divisions of these three systems developed as the subject is further studied.

History of the Atlantic Mountain System.

The place of this system of elevation will be further appreciated after a brief sketch of the several important features of the physical history of the belt of land east of the Appalachian valley from Newfoundland to Alabama.

1. The original sediments of this area, now converted into rocks, were deposited in a basin of Laurentian rocks, the Adirondacks on the west, and near the coast an eastern line of similar age. The breadth of the eastern rim was greater at the south than in the north.

2. Precisely how far our porphyritic gneiss, Bethlehem and Lake Winnipiseogee groups are coeval with the Laurentian, is not certain; but it is clear that the Montalban rocks followed them, and that the first epoch of elevation occurred after their deposition. The first decided evidence of disturbance is afforded by the Franconia breccia.

3. The whole Huronian period next intervened. New Hampshire does not afford any evidence of elevation where the Montalban and Huronian rocks meet. The next upheavals were in connection with the disturbances accompanying the formation and intrusion of the Pemigewasset granites of Conway, Albany, and Chocorua, and the porphyry. This was evidently the epoch of greatest disturbance known in the White Mountains. It is to be compared with the elevation of the Green Mountains, where the Cambro-silurian formations have been folded and faulted.

4. There seems to have been, next, a submergence giving rise to the Gulf of St. Lawrence and to the Appalachian valley, unless this movement was connected with the Green Mountain elevation.

5. There was also a time of depression all over northern New England, to allow of the accumulation of Helderberg limestones. This was followed by,—

6. The last important elevation known in the White Mountains. The forces caused the Helderberg strata to be put into vertical and inverted positions. We have no evidence illustrative of the Appalachian revolution in the Atlantic district, unless it may possibly be represented by the smaller curvatures in the andalusite slates along the Mt. Washington carriage-road. Horizontal Devonian sandstones, resting upon inclined Helderberg strata along the eastern edge of the Atlantic district in Maine, fully confirm us in the belief that the Appalachian revolution, at the close of the Carboniferous period, was principally confined to the formations west of the great valley.

7. The changes in Mesozoic and Cenozoic times have diminished the size of the Atlantic mountains, so that they are scarcely recognizable between Connecticut and Virginia. The deposition of the Triassic sandstones would seem to have required a depression below the present level. Although no marine fossils occur in them, we must believe the basins to have had oceanic connections.

8. There must have been an elevation following the Triassic period sufficiently great to furnish the barriers for the Lower Cretaceous lake extending from eastern Long Island through New Jersey and a part of Pennsylvania. The former extension of the Hudson river channel 80 miles out to sea may have had some connection with the exit of the water from this Cretaceous lake.

9. A later depression is indicated by the presence of shallow water, 100 miles or so in width, between New Jersey and the Great Banks of Newfoundland. (See Pl. I, Vol. II.)

10. There must be added the changes of level described in the glacial and Champlain periods. Authors are not agreed as to their extent, while the current of opinion and the progress of discovery constantly tend to diminish their magnitude.

This review of the history of the Atlantic chain enables us to realize its magnitude, although the northern and middle sections are now partially submerged beneath the ocean.

APPENDIX H.

THE GEOLOGICAL MAP.

Not until the last moment has the geological map in the six atlas-sheets been completed. There are some small changes upon it from the statements of the text of Volume II, which are in all cases improvements. The north-west sheet shows for Quebec the elaborate subdivisions of the Huronian (Quebec), delineated by Sir. W. E. Logan, not yet published in the report of the Canadian geological survey, and kindly furnished us by A. R. C. Selwyn, the present director. From some familiarity with the country south, I have endeavored to carry the same classification into Vermont. I must except the Green Mountain gneiss, which Logan considered to be a metamorphic variety of the Sillery formation, overlying the Lauzon. As shown in my sections in the Vermont geological report (1861), this group everywhere underlies the Huronian, and is therefore older. With this exception, I find no fault with Logan's representation of the formations, but differ from him in placing the Lauzon below instead of above the Levis. Had I occasion to map the ground *de novo*, I should probably not use any of these terms. The limits of these groups have been stated upon page 463, Volume II.

I have elsewhere pointed out the anticlinal structure of the Green Mountains. This fact authorizes the deduction that the formations upon both its flanks are of more modern age, and that the Green Mountain gneiss is essentially Montalban, and underneath the Huronian. Essex county, Vt., is represented very differently from the delineations of the state geological map.

The additions to the Maine part of our sheets are entirely original contributions from our survey. Want of space prevents a description of the details south from the Androscoggin lakes.

I regret much not to have had sufficient time to incorporate all the observations of the position of strata throughout the state upon the map by appropriate symbols. The necessity of having every part of the work completed by a specified date has not given us sufficient time to perform this task. The conclusions to be derived from such delineations have been approximately presented in Pl. XXVI, Volume II.

The maps were executed by Julius Bien, of New York, and are not surpassed, for excellence of finish in the coloring or engraving, by any similar work heretofore issued in the United States.

APPENDIX I.

PANORAMIC VIEWS.

Allusion has been made in Volume I to a number of panoramic views taken from several of the White Mountain summits, by G. F. Morse, of Portland, Me. Owing to a change in the size of the Atlas, it was found necessary to re-draw these hand sketches, and they are all sketched upon two of the large sheets. Upon the first appear panoramas from Mt. Washington and Tremont, covering the entire horizon, divided into two parts by the points of compass. The upper begins at the west, and terminates at the east, the eye looking northerly. The lower view commences where the first leaves off, the eye being directed southerly. The same remarks apply to the panoramic views from Mts. Carrigain and Chocorua upon the second sheet. Both sheets also contain several other profile views, covering only a small part of the circuit, being designed to present the aspect of important or interesting ranges.

Another sheet has been prepared in a different style, by J. Rayner Edmands, with the help of a camera. This is like a photograph, reproducing nature exactly. A comparison of the two styles of profiles will suggest many interesting remarks.

The view from Monadnock is inserted by request, as it completely verifies the correctness of the scout Willard's report in 1725. He "saw Pigwackett lying one point from sd mountain and Cusagee mountain and Winnipesockey laying north East of sd Wannadnock." The mountains now called Pequawket, Kearsarge, and Gunstock may be seen in precisely the positions given by Willard. This fact indicates the correctness of the common application of the names Pequawket and Kearsarge. Within the past two years the people of North Conway and Bartlett are beginning to write the name of their mountain Kearsarge instead of Kiarsarge.

APPENDIX J.

DESCRIPTION OF A SHEET OF PROFILES TAKEN WITH A TOPOGRAPHICAL CAMERA.

By J. Rayner Edmands.

The topographical camera is a portable instrument, a modification of the old camera obscura, by the aid of which one may draw the forms of objects as seen from the point occupied, covering a large horizontal angle without distortion or variation of scale. A description of it will be found in *Appalachia*, Volume I, page 169.

In the summer of 1876, the writer, with the first instrument of the kind, visited several White Mountain summits, to test its performance, hardly expecting at first to obtain material of permanent value. When, therefore, the results proved worthy of publication, it became a matter of regret that they were so fragmentary in their nature; for no view had been drawn throughout the whole circle, and vacant foregrounds or hazy backgrounds rendered much of the work unavailable. During the following summer a few additional drawings were made; but, owing to unforeseen circumstances, the omissions of the year before were not generally supplied. It is also to be regretted that copies of the camera drawings have not been carried, for revision, to the points at which they were made. In presenting the profiles shown upon the accompanying plate in the Atlas, the writer is conscious that much remains undone which would materially improve their appearance, since he has rigidly adhered to the rule of showing nothing which does not appear on the original drawings, except that a few conspicuous omissions are supplied in dotted lines.

The accuracy with which the relative positions of objects can be drawn has been established by measurements upon independent profiles of the same subject, and also by comparison with the readings of a telescopic instrument. In some cases, haze or insufficient illumination may have caused the omission of lines or parts of lines; in some cases, subordinate lines may have been given undue prominence in making or copying the drawing; but in general the forms may be relied upon in considerable detail. No satisfactory means was originally devised, as a part of the instrument, for accurately locating the horizon upon the paper; but fortunately several of the points, at which the fullest or most interesting profiles were drawn, were also occupied by Prof. E. C. Pickering with the micrometer level, thus supplying the missing data without resort to extended calculations.

With the exception of that from Monadnock, the profiles are published on a scale of about five millimeters to the degree; but the scale attached to each is intended to compensate for unavoidable variations. To measure horizontal angles with the greatest attainable accuracy, use an ordinary metric scale; but in addition to the desired angle, measure with it the angular distance upon the attached scale between two graduations nearly under the two points. The difference between the nominal angular distance on the attached scale and its measured angular distance, as given by the scale used, should be applied, with the proper sign, as a correction to the angle measured upon the profile. Horizontal angles may be conveniently measured to tenths of a degree. For readiness of identification, the zero of the attached scale is made to coincide as nearly as may be with the south, so that its readings shall give directly the geodetic azimuth. The profile from Monadnock is on a scale of about one centimeter to the degree, or twice that of the others; but for the part of the view to the right of Belknap, the data are wanting for giving the precise scale. Also, the position of the horizon is not so well known for the second lines of profile from Monadnock and Starr King, as for the others. On the other hand, the distant view from Monadnock, extending between the Franconia and Ossipee ranges, has received more careful treatment than anything else upon the sheet.

Any identified point not on the sky-line may be found on the profile by means of its vertical position, given before the name. For this purpose, mark off from the zero of a short paper scale the distance between the horizon and the bottom of the profile, this distance being shown at either end of the sheet. Then, if this mark be placed anywhere upon the bottom line (the scale running in the direction of verticals), the zero will indicate the level of the occupied point; and the vertical position of the point sought may be read directly upon the scale.

For indicating minor points, and also those whose names are ambiguous or little known, it has been found expedient to use the notation adopted by the Appalachian Mountain Club, and described in *Appalachia*, Volume I, page 7. This consists of a capital letter followed by two numbers. The capital letter indicates one of twenty-six sections into which the state of New Hampshire has been divided; the number before the period indicates a certain mountain in the section; and the figure after the period indicates a special summit of the mountain, as indicated upon the maps of the club,—that is, different summits of the same mountain differ only in the last figure of the designation.

Distances, when given, are expressed in kilometres, the number being enclosed in brackets. One kilometre is a trifle less than five eighths of a mile.

Conspicuous unidentified points are arbitrarily lettered, for convenience in defining future identifications.

APPENDIX K.

PRELIMINARY RESULTS OF SECONDARY AND TERTIARY TRIANGULATION OF THE STATE OF NEW HAMPSHIRE,—1871-'76.

Furnished by Capt. C. P. Patterson, Superintendent of the U. S. Coast Survey.

The results are necessarily preliminary, for the reason that the field work is incomplete, and, in consequence, no final computation can be made at present. The positions of a large number of tertiary objects cannot at present be furnished, for want of a check computation.

NAME OF STATION.	LATITUDE.	LONGITUDE.	AZIMUTH.	BACK AZIMUTH.	TO STATION.	Distance—meters.
	° ′ ″	° ′ ″	° ′ ″	° ′ ″		
Mt. Pleasant, Me.	44 01 35.53	70 49 20.06	....	....	....	....
Agamenticus, Me.	43 13 23.18	70 41 31.83	173 19 33.1	353 14 09.5	Mt. Pleasant	89872.5
Gunstock	43 31 02.98	71 22 10.70	217 43 30.6	38 06 13.3	Mt. Pleasant	71681.5
			300 32 54.8	121 00 49.6	Agamenticus	63002.2
Uncanoonuc	42 58 58.34	71 35 18.83	249 36 13.6	70 12 58.6	Agamenticus	77086.6
			196 35 19.9	16 44 19.9	Gunstock	61902.1
Monadnock	42 51 39.61	72 06 30.49	219 13 05.9	39 43 26.3	Gunstock	94468.6
			252 07 58.4	72 29 13.0	Uncanoonuc	44548.7
Pawtuckaway	43 07 12.21	71 11 50.56	254 15 16.5	74 36 00.8	Agamenticus	42638.8
			64 34 35.7	244 18 34.4	Uncanoonuc	35323.2
Isles of Shoals	42 59 13.32	70 36 49.23	166 19 51.6	346 16 38.5	Agamenticus	26090.7
			107 27 45	287 03 50.4	Pawtuckaway	49791.5
Mason (or Barrett)	42 45 08.21	71 48 45.53	215 28 54	35 38 03	Uncanoonuc	31484.6
			115 37 36	296 25 33	Monadnock	27[illegible]40.8
Crotched	42 59 52.57	71 52 26.70	274 00 50	94 12 31	Uncanoonuc	23342.5
			51 35 36	231 26 02	Monadnock	24441.3
Stewart	43 15 04.29	71 52 04.07	322 35 01	142 46 28	Uncanoonuc	37479.5
			24 25 12	204 15 20	Monadnock	47570.2
Rattlesnake	43 13 41.03	71 34 19.92	2 48 18	182 47 38	Uncanoonuc	27269.2
			96 12 34	276 00 25	Stewart	24143.6
Bean hill	43 23 47.97	71 32 48.91	226 50 33	46 57 52	Gunstock	19647
			4 13 33	184 11 50	Uncanoonuc	46089.7
(Kearsarge) now Kearsarge South Mountain	43 22 58.43	71 51 27.69	3 12 35	183 12 10	Stewart	14653.7
			266 25 06	86 37 55	Bean hill	25223.3
Stoddard	43 05 37 27	72 08 07.40	355 08 07	175 09 13	Monadnock	25939.5
			214 58 26	35 09 50	Kearsarge	39253
(Pequawket house, cupola—1851-'53), now Kearsarge North Mountain house	44 06 19.93	71 05 40.28	220 38 28.7	41 10 04.2	Mt. Blue	91493.6
			266 40 29.7	87 22 56.4	Sabattus	81424.9
Mt. Washington	44 16 12.99	71 18 12.91	3 39 13	183 36 28	Gunstock	83800.5
			304 57 50	125 17 56	Mt. Pleasant	47058.4
Croydon	43 28 53.68	72 13 11.36	290 22.6	110 37.5	Kearsarge	31299
			311 46.3	132 00.8	Stewart	38326
Cardigan	43 38 57.33	71 54 52.54	351 08.5	171 10.9	Kearsarge	29945
			53 02	232 49.4	Croydon	30901

Preliminary Results of Triangulation—continued.

NAME OF STATION.	LATITUDE.			LONGITUDE.			AZIMUTH.			BACK AZIMUTH.			TO STATION.	Distance—meters.
	°	′	″	°	′	″	°	′	″	°	′	″		
Prospect	43	46	41.42	71	36	56.58	24	04.4		203	54.4		Kearsarge	48063
							352	30.5		172	33.3		Bean hill	42745
Cube	43	53	07.59	72	01	26.43	19	27.1		199	19		Croydon	47562
							289	48.4		110	05.3		Prospect	34931
Observatory hill (near Dartmouth college)	43	42	18.52	72	17	07.85	347	55.3		167	58		Croydon	25396
							226	19.4		46	30.2		Cube	29052
Moosilauke	44	01	23.08	71	49	54.97	45	17.9		225	09.9		Cube	21713
							9	07.2		189	03.8		Cardigan	42059
Ascutney	43	26	45 38	72	27	08.36	258	02.2		78	11.8		Croydon	19225
							205	00.9		25	07.8		Observatory hill	31791
Gile	43	47	19 57	72	21	07.12	342	36 1		162	41.5		Croydon	35754
							330	01.5		150	04.2		Observatory hill	10722
Moose	43	44	02.91	72	08	29.56	329	27.5		149	39 3		Kearsarge	45260
							74	31.9		254	25.9		Observatory hill	12040
Bald ledge	44	17	17.12	71	58	33.37	4	56		184	54		Cube	44900
							338	35		158	41		Moosilauke	31616
Whiteface	43	56	00.21	71	24	21.45	106	24.1		286	06.3		Moosilauke	35598
							44	25.9		224	17.2		Prospect	24119
Lafayette	44	09	37.83	71	38	41.03	44	32.2		224	24.4		Moosilauke	21397
							118	17.5		298	03.0		Bald ledge	30019
Black mountain	44	21	45.6	71	45	41.5	8	30.5		188	27.6		Moosilauke	38148
							64	13.3		244	04.3		Bald ledge	19004
Sunapee	43	17	56.2	72	03	50.7	288	21		108	29		Stewart	16792
							197	12.7		17	18.8		Cardigan	40752
Killington	43	36	16.3	72	49	14.4	285	30.3		105	55 1		Croydon	50438
							243	47.2		64	20.2		Cube	71349
Potato hill	44	07	12.7	72	56	12.3	289	17.7		109	55.7		Cube	77705
							256	00.7		76	40.9		Bald ledge	79023
Camel's Hump	44	19	09.6	72	53	13.1	205	36.3		125	12.4		Cube	84248
							272	25.1		93	03.2		Bald ledge	72776
Mansfield	44	31	34.4	72	48	55.9	218	06 2		138	39.3		Cube	95239
							291	17.7		111	52.9		Bald ledge	71915
Harris	44	12	21	72	19	33.5	325	41.3		145	53.9		Cube	43042
							251	46.6		72	01.2		Bald ledge	29411
Colton	43	57	09.1	72	22	03	219	54.8		40	11.1		Bald ledge	48702
							285	00.1		105	14.4		Cube	28573
Burke	44	34	13.8	71	53	36	11	51.8		191	48.3		Bald ledge	32060
							336	24.2		156	34.6		Lafayette	49676
Starr King	44	26	04.5	71	25	59.8	69	34		249	11.3		Bald ledge	46215
							29	03.7		208	54.9		Lafayette	34814
Mt. Washington—kitcheachy	44	16	13.5	71	18	10.8	92	19.8		271	51.6		Bald ledge	53749
							166	01.6		245	47.3		Lafayette	29911
Catamount	43	16	30.2	71	17	45	36	22.4		216	10.4		Uncanoonuc	40259
							77	00.1		256	48.7		Rattlesnake	23040
Trask hill	43	39	51.1	71	07	52.5	143	37.6		323	26 2		Whiteface	37189
							108	08.5		287	48.4		Prospect	41036

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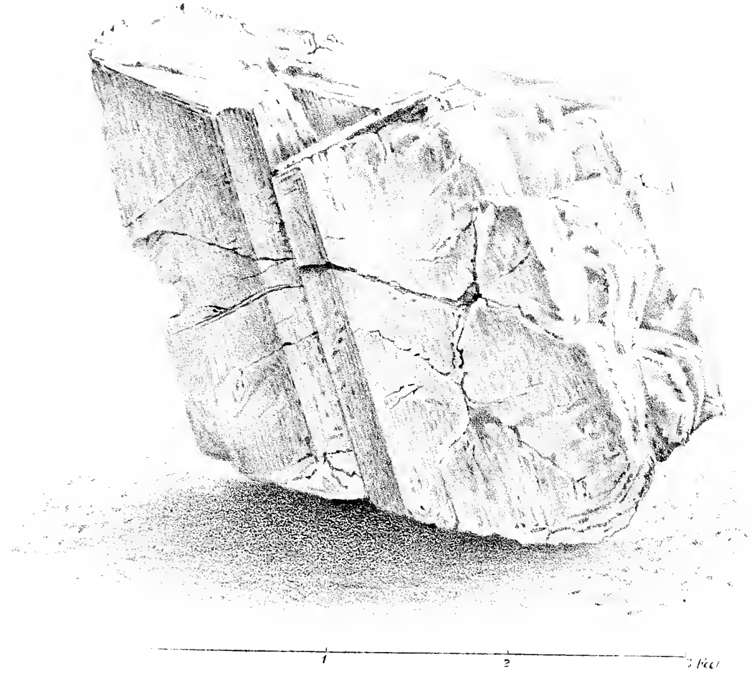

BERYL FROM GRAFTON

PART IV.

MINERALOGY AND LITHOLOGY.

BY GEORGE W. HAWES,
INSTRUCTOR IN MINERALOGY IN THE SHEFFIELD SCIENTIFIC SCHOOL OF YALE COLLEGE.

THE MINERALOGY AND LITHOLOGY OF NEW HAMPSHIRE.

INTRODUCTION.

NEW HAMPSHIRE is widely celebrated for its rocks and minerals. We read much in literature of its granite hills and its rocky peaks. Literary men and artists have, however, generally been satisfied to call the material of every mountain cliff, every boulder, the walls of every ravine, simply rock or granite; but, if one has stopped occasionally to notice the individual appearance of the rocks, and the many and manifest differences in them; has sometimes noticed in them the mineral crystals, often of rare beauty; or has searched among them for substances of value,—he will certainly observe that in New Hampshire a wonderful diversity of minerals and rocks is found. Here are minerals of both economic and scientific interest, and rocks most widely different in composition and mode of formation; and it is the object of this report so to describe and classify the mineral productions of the state, that those who interest themselves in such studies may know and be able to identify the minerals and rocks by which they are surrounded.

Mineralogy and lithology are economic sciences. A knowledge of the first enables one to detect the valuable products which can be extracted from the crust of the earth: a knowledge of the latter enables one to tell the value of rocks for building purposes, and the other uses to which they are applied;—and although the manifest utility of these studies has always given them zest, yet it is hoped that many people, in this state so full of minerals, will be interested in reading the more purely scientific parts of this essay, in which the attempt is made to show, by simple means, the composition, mode of origin, and instructive peculiarities of our rocks and minerals.

A rock is a mineral aggregate. It is a mass that is composed either of one mineral, or of a mixture of several. Hence, in studying the materials of the earth's crust, we must begin with mineralogy; and when we are familiar with the simple minerals, we can then study their aggregations, which form simple or complex rocks. In this work, therefore, the minerals that have been found in the state will first be enumerated, and their noticeable peculiarities will be pointed out. The second part will be devoted to a description of the rocks.

Minerals are often attractive and beautiful as specimens. Natural crystals and gems are admired by all. Rocks are generally admired as forming masses; but rocks are also beautiful when we study them with searching care,—when their minutest structure is brought into view by the aid of the microscope. Moreover, most instructive results are obtained by this method of study. Other portions of this geological report have treated of the age of our minerals and rocks, of their distribution and relations to one another, and of the structure of the country which results from the method of their arrangement. In this part, the results of laboratory work are given; and the methods of physical and chemical mineralogy are introduced as a supplement to the work in the field. Microscopic work has been made prominent, since by this method of study such weighty results have been obtained by foreign laborers, that is has now become indispensable in the prosecution of geological work. The author's aim has been to apply the newer methods of study to our old rocks; to try to show the value of those methods, and how many interesting things can be observed with their aid. He hopes that the many observations new to our section of country, and the variations here furnished on the observations made elsewhere, will be considered of value. He wishes to apologize for the incompleteness of the work, and the injustice done a grand series of rocks. Where the labors of a lifetime could not exhaust the observations that might be made, the work of a very short time, on limited material, can do but little more than draw the attention of students to this field of study.

The author does not wish to enter on this work without paying his tribute to the German lithologists who have developed the methods that he has employed, and so many of whose observations he has repeated. He hopes only to have added some facts of value from our country to the general store.

I wish to thank Prof. Hitchcock for the opportunities and facilities that he has given to me for the prosecution of these studies. The people of the state are much indebted to Prof. George J. Brush, of New Haven, who has so kindly allowed his instruments and books, as well as all the resources of the scientific school, to be freely used for the benefit of the survey. I wish to render my personal thanks to my instructors,—Professors Brush and Dana, of New Haven, and Prof. A. von Lasaulx, of Breslau. The friendliness that these gentlemen have shown the writer made his studies peculiarly pleasant.

In the pages that follow, I think all the things that are referred to and not explained will be found in Prof. Dana's *Mineralogy*. I have, however, been requested, by the chief of the survey, to elucidate my references to microscopic mineralogy, in order to make the work clearly intelligible to all. This will explain the introduction of so much elementary material upon this subject.

METHODS OF STUDY.

In the study of our minerals and rocks, only simple means and appliances have been employed. Many most complicated instruments, and all the appliances of large laboratories, are often employed in such studies; but the means and instruments to which references are made in this work are within the reach of all.

It is unnecessary to say anything about the chemical study. References are sometimes made to the common blow-pipe tests. All the instruments and reactions that are mentioned will be found described in any work on the blow-pipe.* In regard to the physical study it is also almost unnecessary to speak, since we have excellent treatises upon physical mineralogy; and the new work by Mr. E. S. Dana † contains a very clear and concise statement of all those optical principles that are employed in investigating minerals. It is only because the applica-

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* See a treatise upon the blow-pipe, by Prof. Geo. J. Brush, published by Wiley & Son, New York.

† *A Text-Book of Mineralogy*. E. S. Dana. Wiley & Son.

tion of these principles is somewhat different when they are used in microscopic study,—and that, although a number of treatises have been written upon microscopic mineralogy, they are none of them written in English,—that a short description is here given of the methods of preparing specimens for examination, and of a microscope for examining them; to which is added a short statement in regard to what is to be observed, and of those points in which microscopic examination differs from the ordinary optical examination of minerals.

When minerals occur in isolated crystals or masses, or when as constituents of rocks they are in grains or crystals of some size, all their physical properties are easily observed, and they can be subjected to chemical examination; but when minerals occur in complex, fine-grained aggregations, intimately intermingled, as they do in many rocks, none of the physical properties of the minerals can be observed, neither can they be isolated for blow-pipe examination. Hence, when a rock is fine-grained or compact in its structure, and the individual crystals are either invisible or unrecognizable, if we would study their nature, means must be devised to separate and identify them. To accomplish this result, many methods have been devised. A rock is sometimes pulverized, and any magnetic constituent that it contains is withdrawn with a magnet. Sometimes in the powder a heavy constituent is separated by virtue of its superior specific gravity; sometimes the ready solubility of a mineral in acid allows of its separation from the more insoluble constituents. These and other properties of minerals have often been taken advantage of to effect their separation; but the most effective method of discovering the nature and composition of compact rocks is, to make very thin sections of them, and examine the sections with a microscope, aided by certain contrivances for modifying the light. This is referred to at the outset, because this method is not merely employed in rock study, but it is now an essential feature of the study of minerals. By its help, the purity or impurity of minerals is established, as well as the nature and character of their impurities. Moreover, the optical properties of many minerals can be most readily studied microscopically; and the many other useful applications of this method are constantly increasing. As the method of preparing these sections of minerals and rocks for observation is not described in books that are easily accessible to all, it will be here detailed; and it will be seen that, although the cutting of them is often thought to be difficult, it is in reality quite easy, and, with a little patience, can be done with no apparatus;—therefore this beautiful way of studying rocks and minerals is within the reach of all who have access to a microscope.

With a small hammer knock off from the mineral or stone to be examined a fragment nearly an inch in diameter, and as flat and thin as possible. Place some coarse emery (No. 60) upon a flat iron plate; moisten it with water, and then grind a flat surface upon one side of the fragment of stone. When a surface covering the whole extent of the piece has been obtained, grind it further upon another plate with fine emery (No. 120), and finally make the surface still smoother by grinding it with emery dust upon a glass plate; then wash and dry it. Take a piece of glass an inch and a half square and an eighth of an inch thick, and place in the middle of it a large drop of Canada balsam; heat it gently over the smokeless flame of a lamp or a Bunsen burner, taking care that it does not inflame and become blackened by separated carbon. The balsam must be heated till so much of its volatile constituent is driven out, that, when cool, it will be so hard that an impression can be made in it with the thumb-nail with much difficulty. If heated less, it will yield to the subsequent pressure; if heated more, it will be brittle, and break. When the balsam has been sufficiently heated, allow it to cool until it begins to get gummy about the outside edges, then quickly scrape it up into a pile in the middle, and place the dry ground surface of the stone directly upon it, and press it down as firmly as possible against the glass, so that the surface of the stone and the glass may be as nearly in contact as possible. Then allow it to cool. No bubbles of air should be included between the stone and glass; and, if any of considerable size are seen, the operation should be repeated. Now, holding the stone against the iron plate by means of the glass, with coarse emery grind it until it is quite thin, so thin that you fear that the coarse emery will rend it; then grind it still thinner with fine emery, and then with emery dust upon a glass plate grind it as thin as possible, the rule being, that one should be able to read the type of a newspaper through the section. Sometimes, to attain this end with very opaque stones, the size of the fragment will be much diminished, and close watch must be kept upon it during the final grinding, else it might disappear before one expected it. The section is now made and ready to mount.

The most convenient size of a glass slide to mount mineral sections on is 50 m. m. long and 28 m. m. wide. The long glass slides that are commonly used are very inconvenient to revolve upon the table of the microscope. In the middle of such a slide place some Canada balsam, and heat it till it begins to smoke. Having washed and dried the section, place a small drop of Canada balsam upon it, and heat it till it is loosened from the glass; then place on it a very thin glass cover, and with the point of a knife gently push the specimen and glass cover along together over the edge on to the warm balsam on the clean side; then, by pressing it down and working it back and forth with the knife-point, the specimen can be got into good position, and all the bubbles of air can be removed from between the two glasses. When the glass is cold, the superfluous balsam is removed as far as possible with a heated knife-blade, and the balsam that remains is washed away with alcohol, which dissolves it; and the section, on being wiped dry with a clean cloth, is ready for examination.* Fig. 1 represents the natural size of a finished section of one of our diabase rocks.

The microscope that has been used in this work is one which was described by Rosenbusch.† The essential features of a microscope for the examination of mineral sections, beyond those required for ordinary microscopic work, are,—Nicol prisms, so arranged and attached to the instrument that the plane of vibration of the light which passes through them can be determined, and some arrangement by which a section of a mineral can be brought into position in the field of the microscope in any desired relationship to these planes. In the microscope mentioned, this is effected by constructing a graduated circle on the mounting of each Nicol, and by placing a hair cross in the ocular. The tube and ocular of the instrument are not revolvable; and the adjustment for focusing is a vertical motion of one tube that slides up and down within another, but does not revolve within it; and if the zero of the graduated circle on the Nicol below the stage and the zero of the other that is placed over the ocular are both placed at the lines drawn upon the instrument for that purpose, the Nicols are crossed, and the two arms of the hair cross in the ocular correspond to the planes of vibration of the Nicol prisms. If now any section is brought into the field of the microscope, the relationship which the edges or cleavage lines of a crystal bear to the plane of vibration of the light which illumines it is shown by their relationship to the fixed hair lines in the ocular. In the excellent, inexpensive instrument that I have mentioned, a number of beautiful devices are introduced for the sake of making accurate work possible. A basal section of clacite can be placed on the ocular under the upper Nicol, or a quartz plate can be placed in the tube directly over the objective, either of which arrangements makes an excellent stauroscope of the instrument. To the applications of these, reference will presently be made. I have now mentioned the really essential arrangements that can, with a little trouble, be placed upon any microscope.

Examination of Sections.‡ The first point that will be noticed on examining a section of a mineral is its purity or impurity; and very often a mineral that is apparently

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* Those who enter extensively into the study of rocks usually use somewhat more expensive apparatus. A lathe which rotates a plate for grinding, and a disc for sawing, are commonly employed. It may also be mentioned that some persons make a business of preparing such sections, and, with their experience, can make sections in any given direction, through crystals or rocks, and can fulfil any specifications that may be made. Mr. L. Stadmuller, of New Haven, is one who prepares such sections; and Mr. Alexis Julien, of the Columbia College School of Mines, makes most satisfactory preparations.

† *Jahrbuch fur Minereralogie, Geologie, und Palaeontologie*, 1876, p. 504.

‡ For a complete and systematic treatise on microscopic mineralogy, see *Mikroskopische Physiographie der petrographische wichtigen Mineralien, von H. Rosenbusch.* Stuttgart, 1873. See, also, *Die Mikroskopische Beschaffenheit der Mineralien und Gestine, von Dr. Ferdinand Zirkel.* Leipsig, 1873.

homogeneous will be seen to be so filled with matters foreign to its substance as to make a marked proportion of its mass. For example: at Hanover the schists are filled with pretty, perfectly crystallized red garnets. A section shows that these garnets enclose enough quartz, in little colorless grains, to make one third of their mass. Numerous other cases will be described in this work. The minute crystals, that commonly exist as impurities in other minerals, and which are so small that it is impossible to determine the name of the species to which they belong, are called crystallites. The nature of many of these crystals is suspected but not known. Zirkel divides them into bellonites, which are colorless, and trichites, which are black,—terms that have little use in the study of such minerals and rocks as ours. The microscopic crystals which exist as impurities, but which possess either form, optical characters, or other properties by which they can be determined, are called microlites.

The cavities that minerals contain and the contents of them have been studied by many investigators. The microscope shows that crystals, either isolated or imbedded in rocks, are often filled with minute cavities, which contain fluids or crystals, or both. As the presence, and the nature of the contents, of these cavities give important indications of the origin and former conditions of the crystals and the rocks in which they are found, they are worthy of careful attention. Our rocks furnish some remarkable examples of inclusions of this nature. Cavities containing water, and often salt crystals, and others containing liquid carbonic acid, are to be described. I have seen no rock which is so filled with cavities containing the latter fluid as one which has been found in the progress of this study; and sections showing this interesting inclusion may hence become readily accessible to all.

Crystalline Outlines. The first thing that will be noticed when unknown minerals, as they occur in rocks, are microscopically examined with reference to their determination, is the outline of the sections of the crystals. Where crystals are cut at haphazard, as they usually are when scattered through a rock, it must be borne in mind that very variously formed sections can be cut from the same crystal. For example: a square, a rhomb, a triangle, or a hexagon can be cut from a dodecahedron. Yet, as the crystalline forms of imbedded minerals are commonly simple, and not subject to very much variation, the examination of the various sections of the same mineral that are commonly obtained in the same preparation, often enables one to form some judgment in reference to the form of its crystallization. Crystals are, however, often much distorted when found in the narrow confines of rocks; and hence very odd and striking outlines are met with, which are hard to refer to a crystalline form, and though plainly crystalline, as shown by their other physical properties, minerals have often no defined outline whatever, but exist as grains or irregular masses; hence experience and judgment are necessary in drawing conclusions from crystalline outlines. They are, however, very helpful; and sometimes it is desirable to measure the angles of a crystal. In the microscope referred to, the stage is revolvable; the tube of the instrument is capable of being exactly centered, so that the revolution of the stage does not move the centre of the field of view; and then, by means of the spider lines in the microscope, any angle of a crystal section can be measured by bringing first one and then the other side of the angle in coincidence with the one of the lines. The angle of revolution is read off upon the graduated circle that is made upon the outer edge of the disc-formed stage. Angles can be rudely measured by a Leeson's goniometer, or by projecting the image on a sheet of paper, with a camera, and drawing it, and measuring the angle with an ordinary arc of a circle.

Cleavage. One of the most valuable aids in determining a species is the cleavage that minerals show in sections. Minerals that possess characteristic cleavage always show it; for, if it does not exist in microscopic lines originally, it is certain to be developed by the process of grinding. For example: hornblende and augite are easily distinguished by their cleavage; for, as the cleavages of hornblende parallel to the faces of the prism cross one another at 124°, the corresponding cleavages in augite cross one another at a right angle. It is plain that augite might be so cut as to give a section with an obtuse cleavage angle; but, as there are commonly some sections that show the relationship of the section to the form of the crystal, and as there is much difference in the ease and perfection of the cleavage of the two minerals, this feature is very valuable. In other cases, such as in the micas, the observation of the perfect cleavage is equivalent to a determination. Its almost entire absence, as in the case of olivine, is well-nigh as valuable for the identification of a species.

Optical Properties. When a beam of light passes from a lighter into a denser medium, it is broken or refracted, but, when it enters a non-crystalline body in which the particles are arranged about no definite lines, it proceeds on its course with no further modification than an alteration of direction. Such bodies are called single refracting bodies; but crystalline bodies, being formed and held together by certain forces that have acted in certain definite directions, allow the light to pass through them, according to certain laws which are dependent on the structure of the crystal. These laws are very simply applied in the examination of microscopic sections; and by their aid the determination of the crystalline system to which a substance belongs is made easy. The optical principles, as applied to the examination of sections of minerals of the different systems, as seen under the microscope, are as follows:

Amorphous Bodies. It has been stated, that for examination of sections, it is necessary to have a Nicol prism above and one below the stage, so arranged that the planes of vibration of the polarized rays that pass through them can be fixed in any given direction. Suppose the planes of these two prisms to stand at right angles to one another, and to correspond with the spider lines in the ocular of the microscope: the light which passes through the lower Nicol will be reduced to a plane, and this plane will correspond with that plane in the upper Nicol in which light is totally reflected in passing through it. Hence, on looking into the microscope when thus arranged, the field of the microscope will be dark, since the light which passes through the first Nicol is cut off by the second. If, now, the section of any amorphous substance be introduced into the field of the microscope, it having no structural arrangement, cannot modify the plane of the light, and consequently the field of the microscope will remain dark. If, now, the upper Nicol or analyzer be turned about 90°, the field of the microscope will become light, because the light passing through the lower Nicol or polarizer passes through the analyzer, also, under the same conditions. If now, again, the amorphous section is introduced, the field will be still light. In general, place the Nicols as we will, the light will not be modified by placing an amorphous substance between them. Moreover, an amorphous substance shows no definite cleavage lines, or no crystalline outline. In New Hampshire we live in a region of old crystalline rocks; and hence, with some rare exceptions, we have but little to deal with amorphous substances.

Isometric Crystals. Isometric crystals being developed symmetrically in each of their three directions, the elasticity of the ether is the same in all directions; and hence, in isometric crystals, light passes in all directions and planes with equal ease, and this gives to them the same optical character as amorphous substances. Isometric bodies in their sections can, however, commonly be recognized as crystals, since they generally possess either a definite polygonal outline or cleavage lines. These bodies, which possess simply the power of single refraction, are called isotropic.

Tetragonal and Hexagonal Crystals. The case becomes quite different when any other body except those mentioned is placed between the Nicol prisms. Tetragonal and hexagonal crystals are not symmetrical in all directions; and hence the elasticity of the ether is different in different directions. It is either greater or less in the plane of the vertical axis than it is in the plane of the lateral axes; and, if a beam of light passes through a section of one of these crystals, which is cut parallel to the vertical axis, its vibrations will, in passing through the crystal, take place in these planes of elasticity; and, as the elasticity is greater in one direction than the other, that part of the ray, the vibrations of which take place in the plane of greater elasticity, will be retarded less than those that take place in the plane of least elasticity, which is at right angles to the first; hence the ray of light will emerge from the crystal having all its vibrations reduced to two planes, and one of these sets of vibrations will be in advance of the other by a certain amount, depending upon the nature of the substance and the thickness of the section. In other words, the crystal in this direction is double refracting; and the law may here be stated, that the light, by its entrance into any double refracting section, is divided into two rays, each of which is polarized. The planes of vibration of these rays are at right angles to one another; and these planes correspond to the directions of the greatest and least elasticity of the ether in the section. Let us now suppose such a section to be introduced into the field of the microscope while the Nicol prisms are crossed. If we place it so that the vertical axis of the crystal is parallel to the plane of vibration of the light as it issues from the lower Nicol, the light will pass through the crystal without further modification, since the plane of greatest or least elasticity in the crystal section corresponds with the plane of vibration of the light; and, as the light meets the crystal in one of the two planes in which it can pass, the crystal does not alter it, and it is therefore, as before, cut off by the upper Nicol, and the field remains dark. If, now, we revolve the table of the microscope a little, so that the principal axis of the crystal does not correspond with the plane of vibration of the lower Nicol (as shown by the relationship of its edge or cleavage to the hair lines in the ocular), then the light to pass through will be divided into two sets of vibrations, one of which will correspond with the axis of greatest elasticity, and the other with the axis of least elasticity, their directions in this case being parallel and perpendicular to the principal axis. One of these sets of vibration is retarded more than the other; and now these two sets of vibrations, on being again reduced to one plane by the Nicol above the ocular, are in condition to interfere with one another, which they do, producing color. If we continue the revolution of the table till we have turned it 90°, then the other axis of elasticity corresponds with the plane of vibration of the light, and the field of the microscope becomes again dark; hence such a section, on being revolved completely around between crossed Nicol prisms, will be alternately light and dark four successive times, and it will be dark each time that an elasticity axis corresponds with the plane of vibration of the light, which, in this case, means whenever a crystallographic axis corresponds with the plane of vibration of the light in either Nicol.

The case is different if the section is cut perpendicular to the vertical axis. In the ordinary microscope the light reaches the eye in parallel rays; and hence, if such a cut is placed in the field of the microscope, the light passes through it parallel to the vertical axis. Now, as the lateral axes of tetragonal and hexagonal crystals are equal, the crystal is built symmetrically about this axis, and the elasticity in all directions in this plane is equal; and hence in this direction a section of a mineral of either of these systems acts as an isotrope. It is dark between crossed Nicols, and light between parallel Nicols; and revolving it in a horizontal plane between the Nicols produces no effect; hence the direction through these crystals parallel to the vertical axis is called the optic axis; and, as there is but one direction in these crystals that has such peculiarities, these crystals are called uniaxial.

If a basal section of a mineral of these sections is examined with converging light, as is well known, the light no longer passes through the crystal parallel to its optic axis, except in the centre of the field of view, but the rays pass through it more and more obliquely, according to the distance from the centre. Between crossed Nicols this results in the production of a series of colored rings and a black cross traversing it. In the Rosenbusch microscope the analyzer is placed above the ocular; and if now we take out the ocular and then replace the analyzer, of course the light that reaches the eye will be convergent. The field of view will be made small; but, in a basal section of an uniaxial crystal, the ring system and the cross will be seen very plainly, and, although the picture is small, it is very distinct. By the use of the microscope in this way, almost all the effects can be produced that are seen in instruments especially adapted for examination with convergent light; and, although Mr. Rosenbusch does not refer to it, the clearness and accuracy of the image, as seen in his microscope, I consider one of its features. By the use of higher powers, the light is rendered more convergent, and the ring system can be seen in quite thin sections, while with the lower power the optical properties of the plates that are commonly made for optical examination can be very nicely studied. Again: by the use of a quarter undulation mica plate, the positive or negative character of uniaxial and biaxial crystals can be easily determined. This is an advantage for those who, on account of limited means, can possess but little apparatus; for, where, with a little trouble, an instrument can be so easily arranged, which will serve as a microscope, a stauroscope, and for the examination with parallel and convergent polarized light, but little more is needed for optical study. It is of course understood that crystals must have some size, in order to be thus studied. The optical properties of the minutest crystals can often be seen in the microscope; but when the ocular is removed, its magifying power is destroyed.

The peculiarities of the hexagonal and tetragonal systems may then be summed up to be, that all sections, except basal, when revolved in a horizontal plane on the stage of the microscope, the Nicols being crossed, are alternately dark and colored, being dark when the vertical axis corresponds with the plane of vibration of either Nicol, while basal sections are dark in all positions between the crossed Nicol prisms, save when examined by convergent light, when they exhibit a ring system traversed by a black cross. The tetragonal and hexagonal systems are distinguished from each other by the outline of the basal sections: tetragonal crystals having four or eight sides, while hexagonal crystals have some multiple of three as the number of their sides.

Orthorhombic Crystals. As the dimensions of orthorhombic crystals are different in all three directions, so the elasticity of the ether is different in each direction; yet orthorhombic crystals are so built that the axes of elasticity, and consequently the planes of vibration of the light as it passes through them, correspond with the crystallographic axes; that crystallographic axis, in the direction of which the elasticity of the ether is greatest, is the direction of the axis of greatest elasticity; another corresponds to the direction of least elasticity; and a third corresponds to the direction of mean elasticity. Hence the light, as it enters the section of an orthorhombic crystal cut in any direction, is broken and doubly refracted, and passes through the section in two sets of vibrations at right angles to one another, corresponding to the directions of greatest and least elasticity of the section; and these directions correspond with the directions which the crystallographic axes take through the section.

If, now, any section of an orthorhombic crystal be brought into the field of the microscope between crossed Nicol prisms, whenever the direction of a crystallographic axis, as shown by the side of the prism or determined by the cleavage, is brought to correspond with the plane of vibration of the light, the section will remain dark, but will be colored when revolved away from this position, becoming dark again when it has been revolved 90°.

It is to be noted, however, that there are two directions through every crystal, with three different axes of elasticity, in which the two sets of vibrations, taking place at right angles to one another, have equal intensity. These directions lie in the plane of the greatest and least elasticity, and are called the optic axes; and, as there are two such directions, such crystals are called biaxial. If, now, a section be cut perpendicular to one of these axes, it is plain that, in parallel light, it will appear like an isotropic body. No interference of light will take place when it is placed between

Nicol prisms, and consequently no colors will be seen. However, if such a section is examined between crossed Nicols in convergent light, as in the case of the uniaxial crystal, the optic axis will be surrounded by a series of colored rings; but in this case the ring system will be intersected by one black bar, and not by a cross, and when the crystal is revolved, this bar, instead of remaining stationary, as does the cross of uniaxial crystals, revolves, but in the opposite direction to that in which the section is revolved.

The properties of orthorhombic crystals, when microscopically examined, are, then, these: Any section is dark between crossed Nicols, when the direction of a crystallographic axis corresponds with the plane of vibration of the light, as indicated by the hair lines in the ocular. In every other position the sections are colored, with the exception of sections cut perpendicular to an optic axis, which act as if isotropic. Such a section can, however, be distinguished from an amorphous or isometric body, because it will be colored when the ocular of the microscope is removed in order to render the light convergent, and it will be distinguished from an uniaxial section, because the field will be traversed by a black bar that revolves as the stage revolves, and not by a stationary black cross. It may be remarked, that, when examining thin sections, the bar may be seen when the section is so thin that the rings have disappeared, for the number of rings that surround an optic axis depends on the thickness of the plate; and the plate may be made so thin that one ring may spread over the whole field, and then the field will be more or less light, but will still be crossed by a distinguishable bar.

Monoclinic Crystals. Monoclinic crystals have three axes of elasticity at right angles to one another, but they differ from orthorhombic crystals in that, with one exception, these axes do not correspond with the crystallographic axes. One of them always corresponds with the orthodiagonal; hence, sections in some directions through a monoclinic crystal follow the laws laid down for orthorhombic crystals, and others not. Sections parallel to the base, or the orthopinnacoid, or any other sections in this zone, will be dark between crossed Nicols when the crystallographic axes, indicated by crystalline edges or cleavage, correspond to the plane of vibration of the light that illumines them; but all other sections will not be dark under these conditions, and must be revolved a certain number of degrees before they become dark, and this angle through which they must be revolved corresponds to the angle that the axes of elasticity make with the crystallographic axes in the given section. The measurement of this angle is often serviceable. For example: suppose we have sections of augite and hornblende cut parallel to the clinopinnacoid; when placed between crossed Nicols, with the vertical axis indicated by the cleavage placed parallel to the plane of the lower or upper Nicol, the sections will be colored, proving them to belong to an inclined system. In order to make them black, the augite must be revolved 39° and the hornblende 15°.

As the alternations of light and darkness furnish but an inexact method of measurement, its delicacy can be much increased by laying a calcite plate, cut perpendicular to the vertical axis, between the ocular and the analyzer; thus the interference figure of such a plate in converging light is seen in the field; and when a crystal section is laid in the field of the microscope in such a position as to disturb the light, the black cross and rings are distorted, and do not reach their perfection again till an elasticity axis in the crystal corresponds with the plane of vibration of the light. This method of measuring the angle between crystallographic axes and elasticity axes is accurate, but it demands that the crystals have such dimensions as that the black cross can be seen upon them. For the study of long, narrow, and small minerals, Mr. Rosenbusch's microscope has a quartz plate cut perpendicularly to the vertical axis, which can be inserted directly over the objective. The Nicols being crossed, the field will now be brilliantly colored, on account of the revolution of the light by the quartz plate. Any desired color can be obtained by revolving the analyzer; but the color selected will be modified if a section is introduced in such a way as to disturb the light. Suppose the quartz plate to be introduced, and the analyzer to be turned till we obtain a delicate violet color; then, if the section of a mineral is introduced into the field of the microscope, it will appear differently colored at all but at the exact point, when one of its axes of elasticity corresponds with the plane of vibration of the light, when it will be violet. The amount that the section must be turned from this point until the crystallographic axis corresponds with one of the hair lines in the ocular, will be the angle between the crystallographic and elasticity axes.

The same holds true in monoclinic crystals cut perpendicularly to an optic axis, that was said in regard to orthorhombic crystals, save that these axes bear different relationship to the axes of the crystal. As most microscopic observations are made with parallel light, the position of these axes is of less consequence in such study. The principal point is the position of the axes of elasticity.

All the principles that have been stated will become plain on consulting Pl. 2, Fig. 2, which represents two sections of augite from our trap rocks, as they appear in the field of the microscope in the positions to be dark between crossed Nicol prisms. Fig. 2*a* is cut parallel to the clinopinnacoid, and is bounded by the edges of the base and orthopinnacoids. If this section is placed with the vertical axis parallel to the plane of vibration of the light, the section will be colored, showing that an axis of elasticity does not correspond with the vertical axis,—hence the crystal belongs to an inclined system; but, on turning the section about in a horizontal plane 39°, it becomes dark. Now, according to Des Cloizeaux, the optic axes of augite lie in the plane of the clinopinnacoid; they make an angle of 59° with one another, and their bissectrix, which is the axis of least elasticity in the crystal, makes an angle of 39° with the vertical axis; hence, by revolving this section 39°, we have brought one of the axes of elasticity to correspond with the plane of vibration of the lower Nicol, and therefore the light is not broken, and the field remains dark. If, now, from this point we revolve the section, it will again be colored; but, when it has been turned 90°, it will again be dark, because the optical normal, or the axis of greatest elasticity in a crystal of augite, corresponds with the plane of vibration of the light. If, however, we have a section parallel to the orthopinnacoid, this section will contain the orthodiagonal and the vertical axis at right angles to one another; and, as the orthodiagonal is an axis of elasticity, in this position the crystallographic axes fall together with the axes of elasticity, and, on bringing these directions to correspond with the hair lines in the ocular, the section will be dark between crossed Nicols, as would a section of an orthorhombic mineral cut parallel to any pinnacoid. This relation is shown by Fig. 2 *b*, which represents a section of augite cut parallel to the orthopinnacoid. On examining Fig. *a*, we see that one of the optic axes cuts the face of the orthopinnacoid at nearly a right angle. If, then, while examining section *b*, we remove the ocular and replace the analyzer, thus producing convergent light, we shall see this optic axis, not in the centre of the field, for it does not pierce the face at a right angle, but we shall see it off on the side, as represented in *c*. The rings will be traversed by a black bar, which will revolve in the opposite direction to that in which we revolve the section. These three figures will make plain all that has been said in regard to the microscopic examination of crystals with polarized light.

Sections of monoclinic crystals differ, therefore, from those of orthorhombic crystals, in that some sections (those that contain the orthodiagonal) will be dark between crossed Nicols when a crystallographic axis is parallel to the plane of vibration of the light, while the others will not.

Triclinic Crystals. The light also passes through triclinic crystals parallel to three axes of elasticity, which are at right angles to one another; but in no case does one of these axes correspond with a crystallographic axis. Therefore no section of a triclinic mineral is dark between crossed Nicols when a crystallographic axis falls together with the plane of vibration of the light, but all become dark when revolved from this position a certain number of degrees, dependent on the mineral and the relation of the section to the axes of the crystal. This uniform behavior of triclinic crystals serves well for their identification.

Absorption and Pleochroism. Dependent upon the difference in the elasticity of the ether in different directions, through uniaxial and biaxial crystals, are the phenomena of absorption and pleochroism. For example: the rays of light passing through a beryl vibrating parallel to the vertical axis may have some vibrations absorbed, which will give to the emergent light a certain color, as, for example, blue, while that vibrating at right angles to the prism may have no rays absorbed, and thus emerge white. Again: the light, as it emerges from a section of a biaxial crystal, may be of three different colors or degrees of intensity, according as it vibrates parallel to one or the other of the three axes of elasticity. Therefore it is plain that sections of the same mineral may be quite different in color, depending upon their relation to the axes. For example: the hornblende in the schists of the Connecticut valley transmits light of three different colors. The color of any given section will therefore depend upon the resultant of the two sets of vibrations that pass through the section. If, now, we insert the polarizer without the analyzer, we can fix the plane of vibration of the light in any desired relationship to the crystal, and see what colored light is transmitted parallel to a given axis. In the case of this hornblende, we find that the light vibrating parallel to the prism, emerges blue; that parallel to the orthodiagonal, green; and that parallel to the clinodiagonal, yellow; hence, with the polarizer on the microscope in a section that contains several crystals, a crystal may have either one of these three colors, according to which axis corresponds with the plane of vibration of the light. For example, a basal section may be either yellow or green, and a prismatic section may be either blue, green, or yellow; and each one may be made to assume another color by revolving the section on the stage. If, now, we remove the analyzer, and observe with ordinary light, the basal sections will be greenish yellow, the resultant of the two sets of vibrations parallel to the lateral axes, and the prismatic sections bluish green in the plane of the orthodiagonal, or green in the plane of the clinodiagonal, the latter color being made by a union of the blue and yellow vibrations. This may be seen illustrated on Pl. 7, Fig. 2.

The term pleochroism is reserved for the effect produced where certain colored rays are absorbed, as a beam of white light passes through a crystal, producing different colored emergent rays. An isometric crystal can possess no pleochroism. An uniaxial crystal may transmit two differently colored sets of vibrations, and can hence be dichroic; a biaxial crystal may transmit three different colors, and hence may be trichroic.

The term absorption, however, is reserved for that effect where much more light is absorbed in one plane than in the other, producing, not a change in color, but a marked difference in the intensity of the light. This effect can also be best observed in the microscope when the polarizer and not the analyzer is affixed. It is plain that a mineral may exhibit both pleochroism and absorption at the same time, and that, with exactness, pleochroism is but a phase of absorption.

All these principles are very concisely stated by Mr. Rosenbusch in the following form:

I. The substance shows like optical properties throughout, or, if there are differences, the different parts are separated from one another by straight lines (twins).—A HOMOGENEOUS SUBSTANCE.

1. All sections of the same substance, in all positions between crossed Nicols, appear dark. By revolving them on the stage of the microscope the light is not modified, and the interference figure of a calcite plate is not distorted.—ISOTROPE.

1ª. The substance shows no traces of crystalline structure, neither in outline nor cleavage.—*Amorphous.*

1ᵇ. The substance does show evidences of crystallization.—*Isometric.*

2. All the sections, in all positions in a horizontal plane between crossed Nicols, are not dark, and may modify the calcite interference figure.—ANISOTROPE.

2ª. The more or less regular quadratic sections behave like isotropic sections.—*Tetragonal.* Uniaxal.

2ᵇ. The hexagonal sections behave like isotropic sections.—*Hexagonal.* Uniaxial.

2^c. No sections behave as if isotropic, but all of them become dark, and no longer distort the calcite figure when a crystallographic axis falls together with the plane of vibration of the light.—*Orthorhombic.* Biaxial.

2^d. For two of the crystallographic axes, this is no longer true.—*Monoclinic.* Biaxial.

2^e. For none of the axes is this true.—*Triclinic.* Biaxial.

II. Different parts of the substance act differently. In no position is the whole section dark between crossed Nicols; and the different parts bear no determinate relationship to one another.—AN AGGREGATE.

Circular Polarization. Quartz is one of the commonest minerals that come under microscopic examination. A basal section of quartz, as is well known, possesses the property of circular polarization. Now, in microscopic sections, quartz is generally cut so thin that the revolution of the light is too little to be recognized, hence quartz behaves, in thin sections, like any other hexagonal substance. It is to be observed, however, that sometimes it is not necessary to make very thin sections, and, in such preparations, basal sections of quartz will not be entirely dark between crossed Nicols, though they will not show the succession of the prismatic colors.

Of course it will be understood that the preceding pages contain no complete presentation of the principles involved in microscopic study. Enough only has been said to make the figures accompanying this report intelligible, and to draw the attention of those interested in the subject to the principles in accordance with which a microscope must be modified, in order to do satisfactory study upon minerals and rocks; modification which, with little trouble, can be made upon any instrument, though perhaps not with the accurate working of those instruments that are made expressly for use in this now most important and fruitful study. It will be borne in mind, too, that the determination of minerals is not the only application of microscopic study, for most weighty conclusions have been drawn from the arrangement of minerals with reference to one another in rocks, and to the presence or absence of certain characters and ingredients, for the recognition of which any microscope will suffice.

The student of this department of mineralogy will find an extensive literature, and, as it is mostly foreign, he will therefore find in this country a broad field for new investigation, where he will constantly be meeting with new beauties and interesting facts.

CHAPTER I.

THE MINERALOGY OF NEW HAMPSHIRE.

THERE are in New Hampshire some minerals of economic importance. There have here been found many minerals of great scientific interest, which have been studied both at home and abroad, and which have given to our state a world-wide reputation among men of science. In this chapter it is proposed to enumerate the mineral species that have been found in this state; to describe the peculiarities that they possess; and to give the results of whatever labor that has been done upon them.

But little systematic work has heretofore been done upon our minerals. The final report of Dr. C. T. Jackson, the former state geologist, which was rendered to the legislature in 1844, contains what was known up to that time in regard to them. The labors of this geologist were largely devoted to the study of our mineral resources; and he was the first to call attention to many minerals and mineral localities which were formerly unknown. Though the sanguine anticipations of that gentleman in reference to the mining wealth of New Hampshire have scarcely been realized, his labors are of no less value to us.

The location of Dartmouth college in this state has done much for the development of our knowledge of our minerals. There have been in the past, as at present, gentlemen connected with this institution who have searched with great care through our rocks for minerals of new interest. The labors of the present survey have added many names to our list of minerals and mineral localities, and, it is hoped, also something in regard to our knowledge of them.

The minerals will be arranged in the same order as is adopted in Dana's *Mineralogy*. This arrangement, which is based on the chemical composition of the species, is most convenient for a work of this kind. By this arrangement the different ores of the same metal, and minerals allied together by the uses to which they are applied, are often separated from one another; but the chapter by Prof. Hitchcock, on economic geology, treats of the minerals from an economic standpoint.

As this chapter on mineralogy is followed by a short treatise on our rocks, the properties and peculiarities of minerals as rock constituents are referred to under the proper heads. The microscopic characters of these minerals receive attention, since these characters are now of the most importance in the study of lithology. Thus, incidentally to the description of our minerals, an introduction to our lithology will be obtained.

In the consideration of these minerals, it has not been considered necessary to encumber the report with descriptions of their ordinary physical and chemical properties, which can be found in any text-book; and therefore, as a rule, nothing more than the formula of a mineral is given before proceeding to the mention of its individual characters as occurring in our state. The following species of minerals have been identified, and are referred to in the following order:

Native Elements.

1. Gold.
2. Silver.
3. Copper.
4. Iron.
5. Arsenic.
6. Sulphur.
7. Graphite.

Sulphides.

8. Stibnite.
9. Molybdenite.
10. Argentite.
11. Galenite.
12. Bornite.
13. Sphalerite.
14. Chalcocite.
15. Pyrrhotite.
16. Pyrite.
17. Marcasite.
18. Chalcopyrite.
19. Arsenopyrite.
20. Tetrahedrite.

Fluoride.

21. Fluorite.

Oxides.

22. Water.
23. Melaconite.
24. Corundum.

25. Hematite.
26. Menaccanite.
27. Spinel.
28. Magnetite.
29. Chromite.
30. Chrysoberyl.
31. Cassiterite.
32. Rutile.
33. Pyrolusite.
34. Limonite.
35. Psilomelane, Wad.
36. Molybdite.
37. Quartz.
38. Opal.

Anhydrous Silicates.

39. Hypersthene.
40. Pyroxene.
41. Rhodonite.
42. Spodumene.
43. Anthophyllite.
44. Amphibole.
45. Beryl.
46. Chrysolite.
47. Garnet.
48. Zircon.
49. Vesuvianite.
50. Epidote.
51. Zoisite.
52. Iolite.
53. Chlorophyllite.
54. Biotite.
55. Lepidomelane.
56. Muscovite.
57. Anorthite.
58. Labradorite.
59. Andesite.
60. Oligoclase.
61. Albite.
62. Orthoclase.
63. Microcline.
64. Tourmaline.
65. Andalusite.
66. Fibrolite.
67. Cyanite.
68. Sphene.
69. Staurolite.

Hydrous Silicates.

70. Prehnite.
71. Analcite.
72. Talc.
73. Serpentine.
74. Kaolin, clay.
75. Pinite.
76. Margarodite, sericite.
77. Ripidolite.
78. Penninite.
79. Prochlorite.
80. Delessite, Diabantite, Viridite.

Columbate.

81. Columbite.

Phosphates.

82. Apatite.
83. Triphylite.
84. Autunite.

Tungstate.

85. Wolframite.

Sulphates.

86. Barite.
87. Melanterite.
88. Kalinite.

Carbonates.

89. Calcite.
90. Dolomite.
91. Ankerite.
92. Siderite, spherosiderite.
93. Rhodochrosite.
94. Malachite.
95. Azurite.

1. GOLD.

Gold is a metal which, though widely distributed in New Hampshire, is not very often to be seen, since it has generally been found to exist in very minute scales or combined in sulphurets. The knowledge of the probability of its presence has led to the most careful search, and to its detection long ago in Canaan and Lisbon. From Canaan Dr. Jackson first obtained two recognizable spangles of gold by carefully washing 2,000 grains of the quartz powder. It is also found, by assaying, in the pyrites of the same place. The most promising gold assay that I have seen, is one made by myself upon an arsenical ore from Crook & Brown's mine in Lyman. The assay yielded 20 ounces of silver and 2.5 ounces of gold to the ton. Several other so-called gold ores were assayed at the same time, but with negative results, so far as proving them to be ores workable for gold. The appearance of these ores was certainly such as to excite suspicion of the presence of gold, and to make them well worthy of assay; but when such promising appearances are really so deceptive, all owners of such property cannot be too careful in the investment of means for working the claims. The assay mentioned shows the possibility of the discovery of workable deposits in our state. Productive gold mines have been operated at points on our coast from Canada to Georgia; but the history of gold mining in our section shows the necessity for much caution.

Beside the gold contained in veins, the alluvial deposits over the whole course of the Connecticut river are liable to contain a little gold. Prof. Hitchcock has obtained it by washing the deposits at Hanover, and Mr. Huntington found it on the northern boundary of the state. At Pope's mine, which is over the boundary in Canada, pieces have been found that weighed two grains. The region, however, that has excited the most attention, is the so-called Ammonoosuc gold field. This field was first reported on by Prof. Wurtz.* It contains gold not only in the alluvium, but also in the quartz veins in the rock. In Lyman specimens are found in which the gold is sprinkled through the quartz in grains that are visible to the naked eye, and in these veins it was first discovered. It is commonly accompanied in the quartz veins by ankerite and galena. Lisbon,

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* *Am. Jour. Mining*, Sept. 12, 1868.

Littleton, and Enfield are other localities where gold is found. The whole subject of the explorations for gold and its distribution over the state is elsewhere given in detail by Prof. Hitchcock. It is evident, however, from what has been said, that gold is distributed and is liable to be found all over the western area of the state.

Gold will flatten out when hammered, and will not dissolve or change color in nitric acid. These two simple properties of malleability and insolubility are very well known, even by those who forgetfully allow themselves to be deceived by yellow sulphurets and shining mica. It may be mentioned that the analysis of New Hampshire gold, which was made at the United States mint, shows that it is exceptionally pure, containing but one half of one per cent. of silver. Gold so pure is rarely found.

2. SILVER.

Native silver has been reported as found in New Hampshire, but still the occurrence of this mineral is not without doubt. Filaments of silver were found in an iron ore which occurs on West River mountain, and thus this place was put upon record as a locality of native silver; but it has been questioned whether the silver was really native.* A piece of native silver, three or four inches in diameter, was found on a stone wall near Portsmouth, and this, too, was publicly reported. It may be stated, however, that the occurrence of native silver in this state has not been demonstrated.

3. COPPER.

Native copper is often found in connection with eruptive rocks. At Jackson in this state, on Eastman's hill, while blasting for tin ore, some native copper was blown out by Jackson. It occurs at the junction of an eruptive mass of sienite with the slaty country rock. It was found in connection with other copper ores. Native copper, in dendritic forms between layers of the rock, has been observed by Prof. C. H. Hitchcock in Lyman and in Orford.

4. IRON.

The existence of native iron on the earth, save in the meteoric masses

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* *Am. Jour. Science*, i, vol. 3, p. 74.

which have fallen from above, has been often affirmed and often doubted. The subject has, however, received new interest from its proved presence in basaltic rocks, and from the discussion in regard to the origin of the numerous immense masses of iron which have been found in Greenland. My attention was called to this subject by observing a bright particle which was embedded in the midst of a grain of magnetite in a thin section of the chrysolitic gabbro from Mt. Washington. This particle possessed a lustre so resembling metallic iron, that I tested it with a solution of sulphate of copper, and found that, like metallic iron, it became covered with a film of copper, which proved it to be iron. On testing numerous other specimens, I was but twice able to repeat the observation; hence, though no very great weight can be attached to the experiment, it may be said to exist in these rocks, and, if the undecomposed trap rocks from Waterville, or from the Mt. Washington river, are pulverized, the magnetic constituents withdrawn by a magnet, and these constituents treated with a solution of sulphate of copper, on examining with the microscope, occasionally one will see bits of reduced copper, which is evidence of the presence of metallic iron. The efficacy of this reäction has been doubted; but my observation of grains of iron, though minute, is sufficient to call the attention of those who may study these rocks in the future to the possibility of finding it in more abundance, and under such circumstances that conclusions can be safely drawn from its occurrence.

No meteoric iron has, so far as I know, been found in this state. I might mention that a supposed meteorite, which was found in Concord, has been considered important from the circumstance that it contained no iron, this absence rendering it unique among meteorites. This stone was described by Prof. B. Silliman, Jr., in 1847,* and was shown to consist of tersilicate of magnesia and silicate of soda; but although the circumstances of its fall seem to be well authenticated, it is but fair to state that in the cabinet of Yale college, where the specimen is preserved, it is put among the doubtful specimens. The reason of this doubt is, that its very peculiar composition, and its slaggy, artificial look, are thought to weigh seriously against its celestial origin.

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* *Am. Jour. Science*, ii, vol. 4, p. 353.

5. Arsenic.

Though ores of arsenic are common, native arsenic is a rare mineral in the United States, and almost its only localities are in New Hampshire. It has been observed by Jackson on the estate of Francis Kimball, in the town of Haverhill, and also at the tin mine in Jackson. In both these places it occurs in thin layers in a dark blue mica schist, associated with iron and arsenical pyrites.

Native arsenic is volatile at a low temperature, and, when volatilized, gives forth its disagreeable but characteristic order of garlic. Dr. Jackson, in describing its occurrence at Haverhill, states that on hot days it is somewhat volatilized by the heat of the sun striking upon the rocks where it is found, so that on such days the odor of arsenic is perceptible when one is near the locality. The garlic odor is evolved when the ore is struck with the hammer; but other arsenic minerals are like it in this respect.

6. Sulphur.

Native sulphur occurs sparingly in some places, and results from the decomposition of iron pyrites. Pyrites, by exposure, is oxidized to iron sulphate, and this process is sometimes attended by the separation of sulphur. It is in connection with pyrite and sulphate of iron that it is found. Thus associated, it has been observed in the iron ore beds at Brentwood. It has also been found in Chester in small quantities in a bed of tremolite, into which position it was probably conveyed by a process of sublimation.

7. Graphite.

Graphite or plumbago is widely distributed through our rocks, as it is all over New England. Sometimes it forms large deposits; and sometimes, in the form of scales, it is an ingredient of the rocks, at times forming a considerable proportion of their composition, and at times a mere microscopic impurity. In the towns of Nelson and Goshen it has been mined, although the quality is not of the best.

Large specimens are found at Bristol. In Chester, it is found in veins in the mica slate. On the north side of Monadnock mountain, nodules with a coarse texture are found. At Sutton much is found, and of good quality. Other localities are Barrington, Bedford, Troy, Walpole, Washington, Hillsborough, Campbell mountain, Keene, Wentworth, Swanzey, Andover, and Orford.

This mineral possesses no peculiarities of note in this state. It is essentially pure carbon; it is opaque in the thinnest microscopic sections of the rocks which contain it. Caution must be exercised not to confound the molybdenite, of which we have an abundance, with the graphite. They both soil the fingers, and leave a mark on paper. They are both infusible; but molybdenite, when heated before the blow-pipe, imparts a characteristic green color to the flame, while graphite imparts none.

The presence of graphite in the oldest rocks is regarded by many geologists as affording evidence of the existence of some form of life, either vegetable or animal, in those remote ages when the rocks were accumulated in which no fossils at present are to be found, since, by vital forces, free carbon is readily separated from its oxidized condition, and it is difficult to obtain it by other methods. The stages of transition of vegetable matter to coal, and finally to graphite, are well understood; and the presence of animal remains, in considerable variety at some points in the Connecticut valley, renders it not at all improbable that sea weeds and other low forms of vegetable life may have had a great development in those previous ages in which the old schists were accumulated in which graphite is now so abundant.

8. STIBNITE [Sb_2, S_3].

This important ore of antimony has not been found in deposits of any economic importance in this part of the country. It has been obtained from Cornish and Lyme, though neither place should be recorded as a locality for the species, since no one is able to find it at present. Dr. Jackson assayed the specimens that he obtained from citizens in Cornish, and found they were very rich in silver, which was suspected to be due to an admixture of argentite. The specimens also contained copper pyrites. Prof. O. P. Hubbard found crystallized specimens in loose blocks of quartz in the town of Lyme, and though he supposed it to be in place near by, he was unable to find it. Hence it may be stated that there is evidence of the existence of this mineral, and a possibility of the discovery of localities. It is best recognized by heating a bit in an open glass tube, when it will be seen to fuse without difficulty, and to emit white fumes, which condense as an amorphous sublimate, while fumes of sulphurous acid emerge from the end of the tube, recognizable by their reaction on litmus paper, and by their smell.

9. MOLYBDENITE [Mo, S_2].

This mineral, though not elsewhere common, has been found in abundance in this state. At Westmoreland there is a large vein of the massive mineral occurring in the crystalline rock, from which large amounts have been taken, and which has furnished specimens for every mineral cabinet in the country. At Landaff and Franconia it is often found in beautiful tabular hexagonal crystals, but ordinarily it is in a more massive condition. Fine crystals are found at Whitefield, Lyme, New London, and Alstead. Other localities are Orford, Newport, Warren, Jackson, Effingham, and Grafton.

This mineral, when first found, was by some confounded with graphite, and, as graphite, the attempt was made to utilize it; but the crucibles that were made of it fell to pieces in the process of baking. Its lustre and streak are somewhat different from graphite, but it is easiest recognized by the green flame that it imparts to the blow-pipe flame. Molybdic acid is sometimes found associated with it as a decomposition product. This acid, which is a very valuable chemical reagent, is made by roasting molybdenite.

10. ARGENTITE [Ag_2, S].

A silver mineral once found at Cornish by Jackson was suspected to be argentite, but it was not proved. As silver sulphide exists in our galenas, it may possibly be found.

11. GALENITE [Pb, S].

Galena is a very common mineral in New Hampshire. It occurs in small beds and veins, and though it has never been found in such large quantities as to make it a profitable lead ore, yet the uniform presence in it of varying amounts of silver has always made it a mineral of great interest, and numerous attempts have been made to mine it. It is well to bear in mind that no marked success has ever yet attended these operations. The galenas that are found in these highly crystalline regions are often quite rich in silver; and, as rich ores have been found in this state, the zeal in searching for them has always been active. The trouble has never been that the ores were poor, but that the amount of ore was small and its extraction difficult; hence there are many places, as, for example, Shelburne, Warren, and Madison, where the surface indications were flattering, and extensive operations were begun, but where the money expended was lost, and the workings long since abandoned. All over New England such abandoned mines are to be found. These facts should be remembered by those who are tempted to place great expectations upon every new discovery of silver-bearing ore, for experience teaches that the success of silver mining in New Hampshire is so doubtful that no money should be expended in working veins, unless it is done under the advice of skilled and experienced scientific men.

As localities where galena may be found, may be mentioned, in particular, Madison, Shelburne, Warren, Enfield, Haverhill, Lebanon, Bath, Orford, near White pond in Tamworth, Meredith, Surry, Orange, Woodstock, Rumney, Lyman, Lisbon, Dalton, Pittsfield, Loudon, Ellsworth, Alton, Connecticut lake, and Gardner mountain; and it may be stated to be common in small quantities scattered through the rocks in general.

Galena can be recognized by its bright cubic cleavage planes, though at times it becomes nearly massive and intimately mingled with other sulphides, and at times it is merely seen as shining particles in the rocks. The following is an analysis of galena from Warren, by Jackson:

Lead,	83.48
Silver,	.20
Sulphur,	16.32
	100.00

The ore of which this was a sample would yield 58 ounces of silver to the ton. Such an ore, under favorable circumstances, can be profitably worked. The galena from Madison was assayed by Mr. C. A. Seeley, and from that he obtained 94 ounces to the ton, a quite favorable result, so far as the quality of the ore is concerned. Assays of the ore that has been extracted from the Newburyport mine have been reported as much higher, and others much lower than this. Galena from Monroe, Conn., yielded Mr. P. Collier 874 ounces of silver to the ton. Thus these ores vary much in their value, and, though widely distributed, it may be quite safely affirmed that New England will never add any very great amount to the world's production of silver.

12. BORNITE [Cu_3, Fe, S_3].

This sulphide of copper occurs sparingly associated with other copper ores in this state. At Jackson it is found associated with the copper pyrites and the tin oxide. Large specimens of it are obtained from a metallic vein in Dalton; and at Shelburne it is associated with copper and zinc ores. At Littleton it is found in what is called the White Mountain mine, associated with chalcopyrite. It has not been found in crystals, but is generally in a massive condition, mixed with the yellow copper pyrites, from which it is easily distinguished by its color, which, on a fresh fracture, is between copper-red and brown; but, where it has been exposed, it is always tarnished to a purple color, on account of which it is called purple copper, or variegated copper ore.

13. SPHALERITE [Zn, S].

There are some large deposits of sphalerite or zinc blende in New Hampshire, although thus far they have not proved themselves to be of economic value. At Warren there is a large vein of black blende. Blende, when pure zinc sulphide, is nearly colorless, but it usually contains some iron, which replaces a portion of the zinc, and the black color of this blende at Warren results from the presence of much iron. There is also a deposit of this black variety of blende in Shelburne, and another in Lyman, while at Madison there is a large vein of a much lighter colored blende, which, as might be supposed, contains very much less iron. Haverhill, Rumney, Monroe, and Croydon are other localities of note; and this is a mineral that one is constantly meeting in small quantities, in veins and crevices of the rocks, recognizable by its resinous lustre, though this property, usually so characteristic, is not easily seen in the black ferruginous varieties that are so common with us. In them, this resinous appearance is best seen on the spot, where a piece is struck with a hammer, or in the partially pulverized mineral. It has been predicted that, at some future time, these deposits can be profitably worked.

Some specimens of zinc blende from New Hampshire have been analyzed by Dr. Jackson, who obtained the following results:

	Madison.	Lyman.	Warren.	Shelburne.
Sulphur,	33.22	33.40	26.60	32.60
Zinc,	63.62	55.60	62.50	52.00
Iron,	3.10	8.40	9.60	10.00
Cadmium,	.06	2.30	1.30	3.20
Manganese,	.....	.....	.....	1.30
	100.00	99.70	100.00	99.10

The blende from Madison was yellow, while, owing to the amount of iron present, the others were all nearly black. All the analyses, save the one of the blende from Warren, correspond very nearly with the correct formula (Zn, Fe) S. In the analysis of the Warren blende, the amount of sulphur is too small, and this indicates some alteration of the mineral. The uniform presence of cadmium is very noticeable; and the Lyman and Shelburne blendes would be considered as very rich in this metal.

The blende in New Hampshire is not often found in good crystals, but in its massive condition it usually shows on fractured faces the characteristic dodecahedral cleavage.

14. CHALCOCITE [Cu_2, S].

This sulphide of copper is not common. At some places it accompanies other copper minerals, though in small quantities. At Oxford it occurs associated with the green carbonate of copper and with copper pyrites. It is not in crystals, but in noncrystalline masses and grains, recognizable by their dark gray color on a fresh fracture, and by the malleable copper globule, which is obtained by heating the mineral on a piece of charcoal with the blow-pipe.

15. PYRRHOTITE [Fe_7, S_8].

This mineral is found in some places in veins forming large deposits, and it is also scattered all over the state as a constituent of the rocks. It has not been found in crystalline form, but it occurs in bronze colored masses, associated with other kinds of pyrites, from which it is distinguished by its lustre, and the property of being attracted by the magnet in small particles, whence it is called magnetic pyrites. A large deposit of pyrrhotite occurs at Croydon, where there is a vein of the sulphurets of iron and zinc, having a width of several feet, two feet of the thickness of which is occupied by a very solid, compact pure pyrrhotite, and nearly two feet more by a less compact variety. It is also found in considerable quantity in Enfield, Orford, Haverhill, East Hanover, Lyman, Grafton, and at Mt. Misery. Small deposits are found almost everywhere. At Copperas hill, in Vermont, it is utilized in the manufacture of copperas. Dr. Jackson mentions that the Franconia Iron Company attempted to work the magnetic iron ore of Landaff, but that they failed to extract good iron on account of the large amount of magnetic pyrites that the ore contained, for sulphur in iron ore is very deleterious.

When pyrrhotite is present in a section of a rock prepared for microscopic examination, it can be detected by shutting off the light which is transmitted through the section from below, and examining it by the light reflected from the surface of the section. Pyrrhotite, being a metallic mineral, will then appear bright in the dark field of the microscope, and can be recognized by its bronze color. Sometimes a little microscopic grain in our dioritic rocks will be partly pyrite, partly pyrrhotite, and partly magnetite; and their lustres are brought into sharp contrast in the field of the microscope.

Sulphide of iron is commonly a very deleterious ingredient of building stones; but the magnetic pyrites does not decompose so readily as ordinary pyrites. I have seen some gneiss from our state, in buildings, and though the stone was sprinkled with particles of magnetic pyrites, it had not become stained by long exposure to the weather.

Pyrrhotite, in certain localities, contains such a percentage of nickel and cobalt that it forms a valuable ore of these metals. I have examined some of the pyrrhotites of the state, and, although by a careful test nickel was detected in them, I have as yet seen none that would be considered as an ore of that metal.

16. PYRITE [Fe, S_2].

Iron pyrites is another mineral that is very common, both in masses and as a constituent of the rocks. It forms a large proportion of the material of some metallic veins, as, for example, at Croydon mountain. Shelburne, Unity, Warren, Haverhill, Red hill in Moultonborough, Richmond, Lebanon, Lyme, Lyman, Gardner mountain, and Monroe may be mentioned as places where it is to be obtained in abundance, while hundreds of square miles of the state are covered with pyritiferous rocks, and it is common everywhere in little veins. It is often found in crystals, the prevailing forms being, as usual, the cube with the planes of the pentagonal dodecahedron. The crystals are often much distorted by the oscillation between these two forms.

Pyrites is a very common ingredient in rocks; and, as its presence is very deleterious in stones that are to be used for building purposes, a careful examination of them is advisable, as, if pyrites be present, it decomposes on exposure, and stains the stone. When present in considerable amount, it can be recognized with the naked eye, since its brassy yellow metallic lustre makes it conspicuous; and the minutest particles of it can be recognized in microscopic sections by turning away the light from below the stage of the instrument, when the pyrites, with its bright yellow reflection, is very evident. In the slates and greenstones of the Connecticut valley, it is often found in the most minute microscopic and still perfect cubes.

17. MARCASITE [Fe, S_2].

This, the dimorphous form of iron bisulphide, has been found at Haverhill, associated with ordinary iron pyrites and the various other sulphurets that occur there. Marcasite is orthorhombic, has a lower specific gravity than pyrite, and, on account of its lighter yellow color, is called white iron pyrites. The Haverhill mineral is found in fibrous radiated masses. The crystalline form is not evident, but it is plainly prismatic. It decomposes more readily than common iron pyrites; and the outside of the fibrous masses is often changed into the hydrous oxide of iron. All these characters make it easy to distinguish, though its chemical reactions are like those of pyrites.

18. CHALCOPYRITE [Cu, Fe, S_2].

Chalcopyrite is widely distributed over the state in varying amounts, but never in such quantity as to make workable deposits, although openings have been made with the hope of profit in view. Chalcopyrite is found associated with other sulphurets in metallic veins, and also in little deposits on the walls of dykes, and in the surrounding rocks. It is usually massive, but at times it shows evidences of crystallization; and at Copperas hill, across the Connecticut in Strafford, very pretty crystals, formed by the twinning of two tetrahedrons, are found. As localities for copper pyrites that are noteworthy, may be mentioned Bath, Franconia (in gneiss rock), Madison, Haverhill, Warren (on Davis's farm), Lyme (east of the east village), Jackson, Shelburne, Unity, Westmoreland, Littleton (with bornite in White Mountain mine), Connecticut lake, Croydon, Plainfield, Orford, Gardner mountain, and Monroe.

A number of specimens of chalcopyrite from New Hampshire were analyzed by Dr. Jackson,[*] but, as most of the analyses are of impure specimens, which were selected as ores, they possess no value for a report on mineralogy. It is sufficient to say that Dr. Jackson found, by his analyses, a number of ores sufficiently rich to be profitably worked. Analyses of ores of copper from New England are, however, not at all conclusive as to the value of mines. The following is Dr. Jackson's analysis of chalcopyrite taken from H. Lang's estate in Bath. The analysis agrees very well with the formula, and indicates quite pure copper pyrites:

Copper,	32.5
Iron,	33.
Sulphur,	31.2
Silica,	3.2
	99.9

When occurring as a microscopic impurity in the rock, chalcopyrite is recognized by the lustre, which is given to the light reflected from its surface. Its deeper yellow color distinguishes it from iron pyrites. It is not often met with in rock study.

19. ARSENOPYRITE [Fe As S].

Arsenopyrite or mispickel is not an uncommon mineral in our state.

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[*] *Geology of New Hampshire*, 1844, p. 215.

It is found massive, and also in beautiful crystals, that are well known to all mineralogists.

The ordinary massive variety occurs abundantly. The quartzite and schists along the Connecticut river are often full of it, and it is sometimes an associate of the ores that have been proved to be auriferous. In these localities crystals of the ordinary form are also found. Large masses of the non-crystalline variety are found at Jackson. Francestown, Haverhill, Lebanon, Weare, Groton, Lisbon, Lyman, Middleton, and Alton are localities of note for this mineral. It is abundant in Rockingham county. The mineral, when crystallized, is commonly found in forms resembling Fig. 1 on Pl. 3.

Arsenopyrite is orthorhombic in crystallization. The crystals that are found at Franconia are very remarkable for their form and for their perfection. Some of them are represented on Pl. 3. The figures are taken from Dana's *Mineralogy*. Figs. 1 and 1 *a* represent the ordinary crystals as there found, while 1 *b* is an exceptional variety, both in form and composition. It was analyzed in 1833 by A. A. Hayes,[*] who, on account of the cobalt that it contained, considered it to be a new mineral, and named it danaite, in honor of Prof. J. F. Dana, who made known the locality, and who first detected the presence of cobalt in the mineral; but it having been shown that cobalt is at times present in varying amounts in arsenopyrite, where it replaces a portion of the iron, Prof. J. D. Dana, in his *Mineralogy*, considers it to be merely a variety of that mineral, which is very evidently the case. The following is the analysis of the Franconia danaite, as made by Mr. Hayes:

Arsenic,	41.44
Sulphur,	17.84
Iron,	32.94
Cobalt,	6.45
	98.67

These rare crystals are found isolated in the gneiss rocks, associated with chalcopyrite, and are highly prized by mineralogists and crystallographers.

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[*] *Am. Jour. Science*, vol. 1, xxiv, p. 386.

20. TETRAHEDRITE [$Cu_8 Sb_2 S_7$].

This mineral, elsewhere so important, is very rare in New Hampshire. It has been found in Cornish, associated with stibnite; but the place from which the specimens were obtained is now unknown.

21. FLUORITE [$Ca Fl_2$].

There are several noteworthy occurrences of fluor spar in our state. At the Notch it is found in beautiful sea-green octahedrons, of the size of hickory nuts and of perfect form. It occurs in the quartz veins. In the more exposed portions of these veins octahedral cavities are found, from which the fluor spar has been dissolved, and often these cavities are partially refilled with quartz, thus showing the process of the formation of pseudomorphs by replacement; for, if the process of filling had been complete, we should have octahedrons of quartz just like those that come from Cornwall. These green octahedrons are found on Mts. Crawford and Webster, at Bemis brook, and, indeed, all along the White Mountain Notch. Fluor spar forms a vein of considerable size at Westmoreland, from which crystals weighing several pounds have been obtained. The color is light green, and the crystals are cubic. It is also found at the tin mine in Jackson, where crystals of various colors—green, white, and purple—are found. A pretty purple variety is found associated with albite at Grafton, and also at Newbury.

Fluor spar, when treated with sulphuric acid, is decomposed with the generation of fluor-hydric acid; but if a crystal with bright faces is placed in the cold acid for a short time, and then is removed, washed, and examined with the microscope, it will be seen that it is not uniformly eaten by the acid, but that its surface is covered with little depressions bounded by crystallographic faces, which bear a definite relationship to the outlines of the crystal, and are supposed to indicate certain structural lines according to which the crystals are built. If, now, one of these green octahedral crystals from the Notch is broken so as to obtain a fine bright cleavage surface, and is then submitted to the action of sulphuric acid, it is etched by the cold acid with the greatest ease, much quicker than any other crystals that I have ever tried; and, when examined with the microscope, its surface is seen to be covered with depressions, one of which, with its relationship to the octahedral face, is shown in Pl. 3, Fig. 7*a*. These etch figures on fluor spar are considered by H. Baumhauer[*] as being made by the faces of a tetragonal trisoctahedron, because, if the cubic faces of fluor spar are etched, four-sided pyramidal depressions, first observed by Wyrouboff, are found on them, the sides of which are parallel to the combination edge of the cube and octahedron, and which can consequently also be explained by referring them to the same figure. These same figures were obtained by A. von Lasaulx,[†] in his studies on Silesian fluorite, and referred to the same crystalline form. Both these gentlemen also obtained more complicated figures, which were referred by them to the combination of the same figure, with a trigonal trisoctahedron.

These simple etch figures on the octahedral faces can with equal propriety be referred to the faces of a cube, since they bear the proper relationship to the octahedron; and to this form I refer the figures obtained on our octahedrons, for the following reasons. Although they are not capable of measurement, the faces look as though they stood at right angles to one another. Some of the larger and more isolated depressions possess more facets. One of these depressions is represented in Fig. 7*b*. This figure, somewhat different from any obtained by Baumhauer, corresponds to the combination of a cube and dodecahedron. Now, octahedrons of fluor spar are found in a great many places that need no etching to bring out this structure. Octahedrons are found that are entirely made up of little cubes, and these cubes possess at times the dodecahedral modification. Hence I think it may be inferred that there are structural directions in these perfect, smooth octahedrons at the Notch which are parallel to the faces of a cube and dodecahedron, just as there are in those common cases, which are made so evident by the more predominating influence of the last named figures over the octahedron.

These crystals, when heated, phosphoresce with a very beautiful violet light; they also, under the influence of heat, decrepitate violently at a comparatively low temperature. Possibly this may be due to the fact

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[*] *Neues Jahrbuch für Min*, 1876, p, 605.

[†] *Zeitschrift für Krystallographie*, vol. 1, p. 360.

that they are filled with innumerable cavities containing water. When a thin cleavage piece is examined under the microscope, these cavities are seen in immense numbers and of every conceivable form, two of the larger of which are represented in Fig. *7 c* and *d*. These cavities always contain a bubble, which is not diminished in size by heating, which indicates that the fluid is water. The presence of these cavities, containing water and a certain amount of empty space represented by the bubble, is regarded as evidence that minerals containing them were formed at elevated temperatures and pressures, since, in minerals suitable for experiment, the bubbles disappear when the minerals are heated to a certain temperature, showing that the bubble is an empty space formed by the contraction of the fluid after the formation of the crystal.

Fluor spar also occurs as a microscopic ingredient of some of our granites and sienites, as for example, on Chocorua mountain. It is recognized in thin sections of the rocks by its very perfect octahedral cleavage, and by revolving the section in a horizontal plane between the crossed Nicol prisms, when it remains in every position uniformly dark.

22. WATER [H_2O].

Some of the purest waters in the world run in the streams and come up in springs in New Hampshire. Pure spring waters are not common; but in the northern part of the state, some of the springs that come through the slate rocks are well-nigh pure, and a large amount of water when evaporated, leaves an inconsiderable residue. The spring waters in the Dixville Notch are most remarkably pure. The reason is, that the slates in these regions are composed almost exclusively of insoluble constituents. There are, however, a large number of mineral springs in various parts of the state, common in which are chalybeate waters. The springs of this kind, at Amherst, Charlestown, Pittsfield, and Unity, are best known. When occurring near beds of pyrites, these springs contain both sulphur and iron, evidently obtained from the decomposition of that mineral. Near Mt. Pleasant, just over the boundary in Maine, there is a spring of this nature.

23. MELACONITE [CuO].

This mineral has been formed in some places by the decomposition of copper pyrites. At Orford, where the copper ores are decomposed at the surface, some green carbonate of copper has been formed, and also some black oxide. As there observed, it is an earthy, black substance, easily reduced on charcoal with the blow-pipe to metallic copper. It is a mineral of little importance to us.

24. CORUNDUM [$Al_2 O_3$].

When this substance is impure, from the presence of oxide of iron, it is called emery. It is stated, in the old lists of mineral localities, that emery has been found at Lancaster and Lyman. The present survey has not detected it, and is not able to verify the statement.

25. HEMATITE [$Fe_2 O_3$].

There are large deposits of this oxide of iron in some parts of the state, and in some places the effort has been made to extract it. Of the most mineralogical interest, the ore, as it occurs at Piermont, may be mentioned. There it is found in a micaceous form, made of a mass of the brightest scales. This ore has been analyzed by Jackson, with the following result:

Iron sesquioxide,	93.5
Titanic acid,	3.8
Impurities,	2.7
	100.0

A part of the iron ore in the beds at Bartlett and Jackson is hematite. Franconia, Lisbon, and Rindge are other localities; while in insignificant amounts it is found in many other places, and, as a microscopic ingredient, it is scattered through all our bedded rocks.

It is most natural to find this oxide of iron so widely spread in our old crystalline rocks; for, as has been often shown, beds of iron ore are in general accumulated by the agency of water, which brings together deposits of the hydrous iron sesquioxide, as can be seen in certain boggy places where similar deposits are being formed to-day; and, when beds have been subjected to such heat as we may suppose has operated in the crystallization of our granitic rocks, the water has been driven out, transforming them into hematite; when, at the same time, some reducing agent acts upon the deposits, magnetite is produced, or sulphuretted hydrogen may, under the same circumstances, convert them in part into pyrites. These three minerals are very often associated together in our state.

The presence of quite a percentage of titanium, in some of the large deposits of hematite, discourages the hope of their utilization.

Hematite, as an ingredient of the rocks, is recognized by the circumstance that in quite thin sections it is not opaque, but transmits light of a blood-red color. Sometimes in the older rocks it is seen in very minute hexagonal scales, so thin as to be quite transparent, and of a fine red color.

26. MENACCANITE [$(Fe, Ti)^2 O^3$].

This is a very common mineral, and in almost all the localities that have been given for iron ores some of it is to be found. Besides these places, it is found at Littleton, at Wilton in micaceous crystals on quartz, at Orford, and at Franconia in noticeable specimens.

The proportion between the titanium and the iron varies greatly in this mineral. At times, half its weight is titanic oxide; and, again, we have hematites, in which only a small proportion of the iron is replaced by titanium. Thus, the Unity iron ore contains 6.8 per cent., and the Piermont ore contains 3.8 per cent. of titanic acid (Jackson). As titanium is such a common ingredient in our ores, any magnetite or hematite ores that are found in the state should be examined for titanium before any estimate is placed on their value or money expended in their extraction, since the presence of this element is very deleterious.

Titanic iron is well-nigh universally distributed through the rocks of the state, almost every rock analysis that has been made showing some titanium. When the rocks contain magnetic iron, the analyses usually indicate that it is somewhat titanic. The green slates, diorites, etc., that occupy the Connecticut valley, uniformly contain titanic iron. For example: the diorite at Littleton contains 7.53 per cent. of titanic acid, while it contains but 16 per cent. of iron, a part of which belongs to the hornblende; therefore it is evident that the iron oxide is a highly titanic menaccanite.

This mineral, as seen with the microscope, in thin sections of a rock is always opaque. It very rarely appears crystallized, but is generally in bits and patches of very irregular and indeterminate outline. It is often seen in staff-like, club-shaped, and other elongated forms, and often in indented and diffuse forms, which, although not sufficient to distinguish it from magnetic iron, are certainly quite characteristic of titanic iron. When crystallized, it is hexagonal; and in some of our rocks hexagonal and rhomboidal plates are found which are suspected to be of titanic iron.

Although menaccanite is difficult to dissolve in acids, yet it undergoes a peculiar kind of decomposition in the rocks, which is quite characteristic of it. This decomposition is very often seen in microscopic study of basic rocks. Its beginning is shown in grains that have a gray, translucent edge. Then, again, this gray substance traverses the black grain in straight lines, following the cleavage or planes of composition; then, but a faint skeleton of black mineral is seen traversing the white decomposition product; and, finally, every trace of the titanic iron has disappeared, leaving a gray, translucent mass, which by reflected light is white, and which possesses a structure dependent on the mode of its decomposition. The white product resulting has been determined by Prof. A. von Lasaulx to be a compound of titanic acid and lime resembling perofskite [$CaTiO_3$]. It is supposed that the lime of the hornblende or feldspars reacts on the titanic iron, producing the titanate of lime; and sometimes, when silica also takes part in the decomposition, sphene may be produced. Where the iron goes to is not explained, but it is likely that it enters into the composition of the ferruginous chlorites, which are so usual in these basic rocks where this mineral is most common.

The forms that the decomposition product takes, are most remarkable; and in our New Hampshire diorites are some more strange than have been seen elsewhere. When the decomposition goes on regularly from the circumference till it reaches the centre, the result is a mere irregular patch of translucent material, but when it follows the cleavage or lamination the forms are quite fantastic; and at times these forms possess such a very strange similarity to organisms, that they have deceived observers into the belief that they were the fossilized remnants of microscopic forms of life that existed in the original sediments.* Fig. 5 on Pl. 2 represents one of the most remarkable. It is drawn from a section of a diorite from Connecticut lake. It appears in the microscope as composed of a dark gray, translucent substance traversed by lines of greater transparency; and nothing could resemble more closely the structure of a coral, or of a fragment of some rhizopod. By reflected light the whole appears white, traversed by faintest black lines. Fig. 6, though less organic in appearance, is fully as remarkable as a decomposition product of titanic iron. It represents a form found abundantly in the diorite of Hanover. Persons are naturally interested in finding organisms in old rocks; and besides the cautionary value that may be attached to these figures, they are illustrative of a method of decomposition, which, in our greenstones, is characteristic of the titanic iron.

27. SPINEL [$Mg\ Al_2\ O_4$].

The mineral spinel has been found in pretty little bright red octahedral crystals in a limestone rock on Saddleback mountain.

28. MAGNETITE [$Fe_3\ O_4$].

This ore is found in deposits of such magnitude that efforts have been made to mine it. It is widely distributed in smaller amounts. At the Franconia iron mine, in Lisbon, there is a vein from 5 to 8 feet thick in the gneiss rock, which was worked for some time. Fine dodecahedral crystals are found there. The ore is compact, fine grained, and of a bluish gray color. Jackson's analysis is as follows:

Iron proto-sesquioxide,	96.20
Titanic acid,	1.50
Silica,	2.30
	100.00

When the vein was worked, several other minerals in fine crystallized condition were obtained from the mine, and it was an often-visited locality. Garnet, epidote, and hornblende were found in crystals remarkable for their beauty. Magnetite occurs in large beds in Unity; but in this

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* See Hawes, *American Journal of Science*, iii, vol. xii, p. 134. The other gentlemen who have seen these specimens, and have published opinions in reference to them, are very excusable, on the ground that they saw but single specimens, and are not professed experts in microscopic mineralogy. The author has paid some attention to the subject, under competent instruction, since the paper referred to was published.

ore there is a considerable percentage of titanic acid. Large amounts of magnetite are associated with the hematite at Bartlett. At Swanzey large crystalline masses are found in a granite vein. In Amherst, fine crystals having the planes of a cube and octahedron occur; and rhombic dodecahedral crystals are also found. The crystals at this place are sometimes two inches in diameter. At Winchester there is a large vein that was once worked; it is contaminated with pyrites. Other localities are Berlin, Piermont, Jackson (on Thorn mountain), Lebanon, Benton, and Easton, besides many smaller deposits unnecessary to mention. There are, moreover, many localities in the state, on approaching which the magnetic needle is very strongly deflected; and the presence of large bodies of ore is suspected but not proved.

Native lodestones are found on Gunstock mountain in Gilford.

Magnetite is one of the most commonly occurring minerals in rocks of all kinds, and offers some interesting features for microscopic study. In almost all our rocks it is present either as an essential or an accessory ingredient. Even in the thinnest sections of the rocks it is perfectly opaque, but it is evident that, could it be made thin enough, it would be translucent, since in our mica quarries at Alstead it has been found in such thin films, between the layers of mica, as to be plainly transparent. These films have been shown by Prof. Brush to be magnetite.* When the light from below the stage is shut off, the surface of a section of magnetite has a bluish metallic lustre by reflected light. As a constituent of the rocks, it is often in wholly irregular grains, and, again, it is often in minute crystals of perfect form. In our trap rocks it is quite generally crystallized; and the little crystals are often grouped together in various ways, sometimes forming quite complicated figures.† The magnetite in sections of these rocks is seen in little squares or triangles, which are sections of octahedrons; and in more complicated right-angled forms, which result from the compounding of its isometric crystals. On Pl. 2 are represented some of the groups of crystals as seen in the rocks. Figs. 4 and 4*a* are from a section of the diabase at Bemis brook; 4*b* and 4*c*, from the same rock at the Lincoln Flume; and 4*d* is a more delicate form, which is drawn from a section of the porphyritic diabase of Con-

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* See *Dana's Mineralogy*, p. 150.

† See Pl. iii, in *Zirkel's Basaltgesteine*.

cord, Vt. All these forms are, however, quite common, and are often observed in the trap rocks. The delicate arborescent forms like the last appear, with high magnifying power, to be composed of crystals; but the form of the crystals is disguised by the presence of myriads of minute translucent crystals that have attached themselves to them.

These skeletons of magnetite, so regularly formed, indicate that the magnetite was the first mineral to form in these rocks, since such delicate yet determinate forms could only develop in a quite plastic mass. Sometimes hexagonal sections are found, which may be sections of dodecahedrons; but in such cases it is not easy to decide whether it is magnetite or titanic iron. It may be stated, however, that magnetite is more often crystallized than titanic iron, and is usually easy to recognize by its form; and when without definite form it is more often in compact grains, and does not show the peculiar decomposition to which titanic iron is subject.

At times, particles of magnetite are grouped in regular forms not dependent on its own crystallization, but on that of some other mineral. For example: in sections of some of our diorites we see that the hornblende has been well-nigh entirely decomposed, and though possessing still its original form, it is now composed of an aggregate of three or four other minerals, among which magnetite is at times predominant. When magnetite has thus resulted from the decomposition of a ferruginous mineral, like hornblende, the individual particles are often grouped together in forms resulting from the outline or the cleavage of the hornblende. Fig. 3 on Pl. 2 is drawn from a section of the eruptive diorite from near the Profile house. This section is cut parallel to the base of the original hornblende crystal; and the magnetite is arranged along lines parallel to its cleavage. In other crystals the magnetite surrounds the edge, in a regular line, and is irregularly scattered through the interior. Sometimes, again, a row of magnetite grains surrounds the outside boundary of an apparently intact crystal. The figure given is, however, sufficient to illustrate this subject. A high magnifying power does not show that these particles are crystalline.

Magnetic iron decomposes with difficulty; but its grains in rocks are often seen surrounded by a yellow ring of the hydrous sesquioxide of iron.

The beds of magnetite, such as exist in our state, are supposed to result from the combined action of heat, resulting from metamorphic action, and some reducing agent. This action has converted beds of hydrous iron sesquioxide, which were accumulated by the action of water, into the magnetic oxide.

29. CHROMITE [$Fe\,Cr_2\,O_4$].

Chromic iron has been found in several places in Vermont. In New Hampshire, a small amount has been found in the soil of Dublin. It is most often found associated with serpentine rocks, of which we have none that is readily accessible.

30. CHRYSOBERYL [$Be\,Al_2\,O_4$].

This rare mineral has been found in a narrow vein, which was opened in making the deep cut through the granite rocks at Orange summit.* The form of the crystals was compound, like that of the crystals from Haddam in Connecticut, which are well known; but none were found with terminal planes to the crystals, and all were more or less imperfect.

31. CASSITERITE [$Sn\,O_2$].

Dr. Jackson, thinking that circumstances were favorable for the discovery of tin mines, made a most careful search for this mineral in our state, and at last succeeded in finding it; since which discovery much time and money have been expended in the hope of turning the discovery to practical advantage, but thus far with no success.

It was first discovered in 1841, in the town of Jackson. It occurs in little veins at the junction of a dyke with the schistose rocks. Large excavations have been made with the idea in view of extracting the ore, but no quantities sufficient to yield metal of consequence were met with. This was the first discovery of tin ore in the United States.

Cassiterite, as found at Jackson, is sometimes crystalline and sometimes massive. Fig. 6 on Pl. 3 represents one of the crystals. The figure was drawn by Mr. J. E. Teschemacher for Dr. Jackson. It is a twin crystal, the twinning plane being parallel to the plane of a pyramid of the second order. It is much enlarged, for the best crystals are very small. I have seen no perfect crystals from there; but those that I have found appear

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* Prof. O. P. Hubbard, *American Journal of Science*, ii, vol. xi, p. 424.

to be twins, like the one figured. The cassiterite at Jackson is dark colored and opaque, except in the thinnest fragments. The veins are from half an inch to several inches wide, but they are mostly filled with arsenopyrite, chalcopyrite, and other minerals. The veins are in mica schist. Tinstone has also been found in the town of Lyme, but in much smaller amount than at Jackson.

32. RUTILE [TiO_2].

Rutile has been found at several places in our state. A red, massive variety occurs at Merrimack, on the Souhegan stream; and a considerable amount has there been extracted for economic purposes. Crystals have been obtained from the soapstone quarries at Richmond, where many other interesting minerals have been observed. In the rocks accompanying the limestone at Orford, crystals have been found; also, at the same place, quartz crystals are obtained, which contain acicular crystals of rutile. Such quartz crystals were first found in Orford by Dr. Horsford; but masses and crystals of quartz, penetrated through and through by delicate rutile crystals, have been found at several localities. Handsome specimens have been found near Hanover and at Cornish. In the last named place, a large, smooth, round pebble of quartz, as large as a man's head and filled with little needles of rutile, was found a long time ago, and was broken up and distributed among mineralogists. Rounded pebbles of quartz, with needles of rutile, have been found in the river-bed at Lebanon. These loose pieces may all have been brought from Orford, which lies to the north. The little crystals penetrating the quartz vary from a delicate straw color, when very small, to jet black when larger. Some of the finer specimens are cut as jewels. Lyme, Merrimack, Richmond, and Warren are other localities for rutile.

The microscope reveals the presence of rutile as a frequent constituent of our granites and schists. It is most often seen in very minute needles piercing the quartz, thus forming microscopic specimens of the same nature as the macroscopic ones. These needles are often very long; and frequently those that appear short will, on changing the focus of the instrument a trifle, be found to go on to surprising lengths. They are often straight and often curved, and almost always in clear quartz. Sometimes, with the hand on the thumb-screw, in order to be able to focus deeper into the specimen, a needle can be followed in its curving course through a distance two or three times the width of the field.

The most interesting microscopic occurrence that I have observed is in the actinolite schist of Pittsburg. The rock is a compound of actinolite and quartz, in which the quartz is penetrated by the delicate black needles, to which I have already referred, while the actinolite contains much larger and more perfect yellowish-red crystals of rutile, which show very well the tetragonal, crystalline form of the species. The crystals are apparently eight-sided; and some of them possess the geniculations so characteristic of the species. The crystals lie scattered about indefinitely in the actinolite; and, as all the large crystals are in that mineral, it may be assumed that the circumstances for the formation of crystals of rutile were more favorable in that mineral, or at the time that it was made, than in the case of the quartz. Fig. 1 on Pl. 4 represents a much magnified section of this rock, in which the condition of the rutile, both in the actinolite and in the quartz, is shown.

33. PYROLUSITE [$Mn\ O_2$].

This ore of manganese is found at Winchester and Hinsdale, associated with the manganese silicate that occurs there. At Northwood, tuberous and mammillary specimens have been found in the granite. It is not an abundant mineral, but as a black incrustation, soiling the fingers when touched, it is quite widely distributed. It is not found crystallized in the state.

34. LIMONITE [$H_6\ Fe_4\ O_9$].

Under this head, besides the pure mineral, the deposits of bog ore will be noticed. In several places these bog ores have been extracted for reduction; and it is reported that excellent iron has been made from them. In Lancaster, bog iron ore was found constituting the hardpan of a meadow, and was easily extracted. In Bedford, Amherst, and Merrimack are deposits that have been worked. In Bath, a swamp deposit was found beneath three feet of mud, and was easily broken up and drawn out. In Madison, Dr. Jackson discovered a deposit in the bottom of Six-mile pond. It is found in the low lands of Grafton and Lebanon, where it has been deposited by sluggish streams. On Black mountain in Haverhill there is a deposit of the compact botryoidal limonite. Barrington, Gilmanton, Kingston, Mason, Lyndeborough, New Boston, Chesterfield, Nottingham, West River mountain, Orange, Pembroke, Salisbury, Jaffrey, Moultonborough, Orford, Surry, and Plainfield are other towns where deposits of the hydrous iron oxide are found. As may be inferred, it is generally distributed all over the state, either as the compact, dark mineral limonite, or forming ochrey beds of a foot or more in thickness, and again, as a mere ferruginous deposit in the gravel, where it cements the pebbles together.

The mode of origin of limonite has been treated of by many writers. The beds in this section of the country were shown by Percival * to have resulted from the transportation and redeposition of the iron from decaying pyritiferous rocks. Other writers have followed, showing the same to be true of the other deposits that occur along the Atlantic coast. The exact source of the iron can generally be ascertained by studying the rocks of the region. The method of transportation has also received much attention; for, as the sesquioxide of iron is insoluble, if it were transported in solution it must have been in some other condition. There are many chalybeate springs in our state, several of which are found near by the deposits of bog iron, and which show that here as elsewhere the iron has in part been transported in the state of carbonate. Sometimes by oxidation pyrites is converted into a sulphate of iron, and thus transported, and, again, it is transported as a salt of an organic acid, as suggested by Berzelius, and verified for our ores by Jackson, † who analyzed these ores, and found varying amounts of organic acids in them. Hunt, in the ochre of Pointe du Lac in Canada, found fifteen per cent. of humic acid; and Jackson's analyses show varying amounts from none to eighteen per cent. of vegetable matter, which he refers to organic acids; but what proportion of this resulted from the vegetation of the swamps in which the ores were deposited is not with certainty determined. Iron transported in any of these ways is liable to be deposited as the hydrous sesquioxide, as soon as it is subjected to oxidation, though a portion of it may remain as carbonate; and more or less of the carbonate of iron

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* *Rep. Geol. Conn.*, p. 132.

† *Geology of New Hampshire*, Dr. C. T. Jackson, 1844

exists in most of the bog ores of iron, as is proved by treating them with hydrochloric acid. In some of our bogs this ore can be seen in process of formation. A sluggish stream, flowing perhaps from a chalybeate spring, runs into a marshy spot, and the top of the water is seen covered with an iridescent slime,—a result of the oxidation of the iron in solution to the insoluble sesquioxide,—while the bottom is covered with a yellow deposit of sesquioxide of iron.

Limonite is a common constituent of rocks. Sometimes it exists as an original constituent, as where it forms the cementing material of conglomerates; or, again, it results from the hydration of other oxides of iron, under which circumstances it appears as a yellow, semi-transparent substance surrounding an opaque, unaltered core, if the decomposition is incomplete.

I would refer to a number of analyses of hydrous iron ores in Jackson's report; but, as they have no mineralogical significance, they are not reproduced here.

35. Psilomelane, Wad.

Impure, hydrous manganese oxides. Wad is found in many of the deposits of bog iron ore. Sometimes it is sufficiently compact and pure to be called psilomelane, but most of it is very impure, being much contaminated with iron oxides, organic matter, and other impurities. It is recognized as a manganese oxide by its black color, and its manganese reactions before the blow-pipe. Psilomelane is fonnd at Winchester, with the other manganese minerals.

36. Molybdite [MoO_3].

This mineral is a result of the oxidation of the sulphuret of molybdenum or molybdenite, and occurs in connection with it. It is found in the cavities of the veins of molybdenite in Westmoreland in considerable amount, and less abundantly with the other deposits in Landaff and Franconia. As it occurs in our state, it is an earthy, yellow mineral, filling cavities or incrusting the sulphuret.

This mineral is easily recognized by heating it with the blow-pipe upon a piece of charcoal, when it is volatilized, coating the coal with a white sublimate, which, when touched for an instant with the reducing flame, is changed to a beautiful blue color.

The molybdite of Westmoreland contains six tenths of one per cent. of oxide of uranium,* which makes the mineral from this locality remarkable, and which gives to it a deeper yellow color than is common in specimens of molybdite.

37. QUARTZ [SiO_2].

This mineral, which forms the larger part of the crust of the earth, is of particular importance in those parts of it that are occupied by old crystalline rocks like New Hampshire.

Common transparent, glassy quartz forms a large proportion of our rocks, and is, moreover, found in the most grand and beautiful crystallizations. On Moose mountain some very fine and large crystal masses have been found. A group of these crystals in the Dartmouth College cabinet weighs 147½ pounds. It contains forty-eight crystals, four of which are from five to five and a half inches in diameter. Fine, large, clear crystals are also found at Benton, Littleton, Bartlett, Hanover, Warren, Westmoreland, the White Mountain Notch, and Raymond.

The crystals in some localities have a smoky tint. Smoky quartz is found at Bartlett, Cornish, and the Notch. The Cornish specimens are penetrated with rutile; and the presence of titanic acid is supposed by some to impart the smoky color to this variety of quartz.

Quartz of a delicate rose color, called rose quartz, occurs in mica schist rocks in the White Mountains, at Acworth, Raymond, Andover (on Ragged mountain), and Keene. It is quite abundant on Mt. Washington; and much of it is annually carried away by tourists.

Amethyst or purple quartz is found at Surry, Mt. Crawford, Waterville, and Westmoreland,—at the latter place in fine crystals. Moreover, some fine, large crystals have been ploughed out of the soil in Amherst. Some of these were three inches in diameter and eight inches long. Fine, rolled pieces are found at Hampton Falls. Quartz with a purplish tint is common.

Among other occurrences of note may be mentioned beautiful green crystals, colored by epidote, at Franconia and Enfield; fine red and yellow crystals, colored by oxide of iron, at Francestown, Gilmanton, and

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* Jackson. *Geology of New Hampshire*, p. 230.

Hanover; jasper, also, at the same places; quartz, penetrated through and through with tourmaline needles, at Sullivan and on Moose mountain, besides numberless occurrences of local interest.

The white translucent variety of quartz is found in large beds at Alstead, Hancock, Bedford, Amherst, and Lyndeborough; and Prof. Hitchcock has traced a system of veins of it which extend for more than fifty miles through the gneissoid rocks. At times, a kind of quartz filled with cavities, making what is called buhrstone, is found in veins. This kind of quartz occurs at Littleton.

At Grafton a very large, interesting crystal has been found, which is in the collection of the survey. It consists of a huge crystal a foot long and eight inches in diameter, but which is entirely made of little crystals with their planes all parallel to the planes of the large crystal. This complex form of a quartz crystal is not uncommon, but such large, fine specimens are rarely seen.

The microscopic characters of quartz are so fully illustrated in the lithological part of this report as to need little explanation here. It may be briefly stated, however, that basal sections of quartz differ from other hexagonal minerals, in that a beam of light passing through them parallel to the vertical axis is rotated to a certain degree; and hence quartz between crossed Nicols exhibits the phenomenon of circular polarization. The amount of rotation of the light depends upon the thickness of the plate; and also the different colors of the spectrum are rotated to a different degree. Hence, if a plate of quartz thus cut, and of some thickness, is inserted between crossed Nicol prisms, the plate will not be dark, as in the case of ordinary hexagonal minerals; and neither will the plate be dark, whatever be the position of the Nicols with reference to one another; but as the upper Nicol prism is revolved it will meet the different colors of the spectrum in succession, and the amount that it must be turned to intercept all the colors from red to violet will depend on the thickness of the plate; and whether the polarizer must be turned to the right or the left, in order to intercept the colors in the order of their arrangement, beginning at the red end of the spectrum and proceeding towards the violet, determines whether the crystal is right- or left-handed. If, now, the section of quartz be cut very thin, it is plain that the revolution of the light may be so small as to be imperceptible, and then, between crossed Nicols, it will not show colors, but will approach towards the behavior of other hexagonal minerals. If the section be a little thicker,—of the thickness of ordinary rock sections,—the light will not be rotated to such a degree as to separate the prismatic colors so widely from one another as that one can see that the mineral exercises circular polarization; but still the section will not be entirely dark between crossed Nicols, and will not become so on rotating it in its plane. Sections cut at all varying from the basal plane polarize the light, giving the most brilliant interference colors.

It may therefore be said that, in microscopic sections of rocks that are of the proper thinness, quartz, although optically peculiar, does not differ essentially from ordinary hexagonal minerals, and that its colors in polarized light are peculiarly brilliant. Other microscopic characters are the uniformity of these interference colors over its whole surface, except at the edge of its crystals or grains. The edges are differently colored, on account of the varying thickness at these points. The almost uniform presence in it of little cavities filled with fluid, and containing bubbles and often little crystals, is noticeable. These cavities are often hexagonal. Figures of them will be found in the plates.

As quartz was, as a rule, the last mineral to crystallize in our rocks, it is more often in rounded or irregular grains than almost any other mineral. As it is very difficult to decompose, it is ordinarily clear and transparent in thin sections, while the minerals that surround it are more or less decomposed. It possesses no cleavage, and when in large particles is usually traversed by irregular fractures. In a fine-grained mixture of quartz and orthoclase, the two minerals are not easily distinguished from one another, as they both give brilliant colors in polarized light, and the cleavage and other properties of the feldspar cannot be recognized. In such cases, in examining sections of our old rocks, the presence of the two minerals together is best recognized in the microscope by shutting off the light from below, and examining by reflected light, when the quartz, which is clear and undecomposed, appears black, while the feldspar usually appears as a white, opaque, snowy substance, this effect being produced by its impurities, minute fissures, and partial decomposition.

38. OPAL.

An amorphous and usually hydrous form of silica.

This substance exists in large quantities in New Hampshire, in the condition of infusorial earth, or mountain meal, as it is often called. In trade it is called tripolite. The deposits of this substance are large, especially in the northern part of the state; and it is in that condition of purity that makes it the best polishing powder. The following is my analysis of a specimen from Lake Umbagog:

Silica,	80.53
Alumina,	5.89
Iron sesquioxide,	1.03
Lime,	.35
Water,	11.05
Organic matters,	.98
	99.83

The analysis indicates that this substance is essentially hydrated silica. It is found forming layers in the muddy bottoms of ponds, and in bogs as a sub-peat deposit, and often it exists in such a state of purity as to be white and soft when dry, and thus it often attracts attention.

These infusorial earths were first investigated by the Count Ehrenberg, and he found them to be nearly entirely made up of the siliceous remains of diatoms and infusorial animalculæ, which, although of such minute size, possessed forms of great beauty. From a large bed of this earth near Richmond, Va., over one hundred species of these microscopic organisms have been obtained and described by Ehrenberg and Bailey. The New Hampshire deposits are, however, all fresh water deposits, and, in common with such deposits all over New England, they are entirely composed of diatoms, and contain no foraminiferal forms. Specimens from our state have been investigated by nearly every one who has interested himself in the study of infusoria, but no better idea can anywhere be obtained of the appearance of these deposits under the microscope, and of their average composition, than by an examination of the figure which was drawn long ago by Ehrenberg, from a specimen of such an earth from our state. His work is not now easily accessible, and therefore I reproduce the figure here. Fig. 6, on Pl. 4, represents the field of Ehrenberg's microscope, as it appeared occupied with a sample of New Hampshire infusorial earth.* The species represented are as follows:

Polygastern.

Fig. 1. Chaetophila Saxipara.
1.* 2. Discoplea Coscinodiscus.
3. Eunotia icosodon.
4. “ monodon.
5. “ octonaria.
6. “ quatuordenaria.
7. “ septenaria.
8. “ serra.
9. “ tredenaria.
10. “ triodon.
11. “ “
12. “ undenaria.
13. Fragilaria constricta.
14. Gallionella distans.
15. Gomphonema gracile.
16. “ truncatum.
Fig. 17. Himantidium arcus.
18. “ gracile.
19. Navicula amphioxys.
20. “ dilitata.
21. “ lineolata.
22. “ Legumen.
23. Pinnularia Semen.
24. “ viridis.
25. Stauroneis Phœnicenteron.
26. 27. Tabellaria trinodis.
28. Trachelomonas? lævis.
29. “ pyrum.

Phytolitharien.

30. Lithodontium furcatum.
31. Spongolithis aspera.

Soft parts of Plants.

32. Pollen Pini.

These organisms are excessively minute, and a cubic inch of this earth contains many millions of individuals.

Dr. A. M. Edwards has studied these earths, and in Vol. I of this geological report will be found a lengthy treatise on the diatomaceæ in general, with illustrative plates.† The small figures here reproduced are sufficient, however, to show those interested in the subject from a mineralogical stand-point, the nature and composition of these interesting deposits.

This substance is also of considerable economic value. It is burned till it is white, whereby the water and organic matters are removed, and it then constitutes the best kind of polishing powder; for, although they are quite hard, the grains are so extremely minute that they scarcely feel gritty between the teeth, and consequently the substance is eminently adapted for polishing wares. This earth is soluble in caustic

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* *Ehrenberg's Mikrogeologie*, T. xxxiii X. Also, *Monatsbericht der Berliner Akad. der Wissenschaften*, 1845, p. 60.

† Mr. H. L. Smith, of Geneva, N. Y., has also examined these earths, and is prepared to furnish a typical series, embracing all the different species, properly mounted for microscopic study.

potash or soda, making a silicate, which is called soluble glass. This substance is a valuable cement. Wood, when coated with it, is fireproof; and eggs, after being dipped in it, will remain fresh. It is, beside, a great purifying agent, and nothing else put in the water will give that pure whiteness to linen that can be obtained by the use of this substance. There are many deposits in this state, which are too small to be of commercial value, but which might be much more generally utilized by the people of the neighborhood. The substance has been latterly employed as the basis of dynamite.[*] It is a bad conductor of heat, and serves as a good protection for boilers and steam-pipes. A detailed list of localities for this substance in this state is given in the report above alluded to, by Dr. Edwards.[†]

These deposits are still being accumulated. If the material at the bottom of any stagnant pool of long standing is carefully examined with the aid of the microscope, these minute plants will be found in immense numbers.

Dr. Jackson obtained seven and one half per cent. of phosphates of lime and magnesia from a specimen from Hooksett.[‡] Any such material would make an excellent fertilizer for fields near at hand. I have myself seen no such phosphatic infusorial earth, and attribute the presence of such an amount as indicated by Dr. Jackson's analysis to some accidental cause.

39. HYPERSTHENE [$(Mg, Fe)\ Si\ O_3$].

This mineral is distinguished from other minerals related in composition to pyroxene by its orthorhombic crystallization. It occurs in the gabbro of Waterville. It is a constituent not often visible to the naked eye, but is easily recognized by its optical properties observable in microscopic sections, and by the circumstance that it possesses the same peculiar interpositions that make it so noticeable elsewhere.

The most remarkable occurrences of hypersthene in America are at St. Paul's island, Labrador, and at one or two points in Canada. As there observed, it has a deep brown color, and easy cleavage parallel to the brachypinnacoid, and the microscopic sections show that, inlaid in

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[*] See Ann. Rep., G. H. Cook, State Geologist of N. J., 1874.

[†] *Geology of New Hampshire.* Hitchcock. Vol. I, p. 502.

[‡] *Geology of New Hampshire.* Jackson, p. 185.

planes parallel to this plane, are immense numbers of little brown scales or rhombic plates. The true nature of these scales has not been determined, but they have been suspected to be brookite by some—a conclusion doubted by others. It is only known that they impart the metallic copper color to hypersthene, and that they are inlaid in the determined plane in three directions, one of which is nearly parallel to the vertical axis, one at right angles to it, and one making an angle of about 30° with it.

Turning now to our hypersthene, it may be noticed that in thin sections it is much lighter in color than that occurring elsewhere, and, indeed, it is nearly colorless in thin sections. It occurs in irregular fragments and grains in the rock, giving no sign of external crystal faces; but when in a microscopic examination of a thin section, the vertical axis, as indicated by the cleavage, is brought parallel to the plane of vibration of either one of the crossed Nicol prisms, the section is dark, and does not disturb the interference figure of a calcite plate put on the ocular under the upper Nicol prism. Hence, it is orthorhombic. The interpositions are like those in the St. Paul's Island hypersthene. It contains magnetite in irregular fragments irregularly distributed, and brown scales much darker in color, however, than those in most hypersthene, and which are symmetrically arranged. The larger part are nearly parallel to the vertical axis, but not exactly, for, as was observed by Kosman, the plane of the interpositions builds an angle of 7° 45′ with the cleavage plane. The second part are inlaid, with their long edges making an angle of about 30° with the cleavage lines, and a few scales are apparently inlaid at right angles to the first. A peculiarity of this hypersthene is the large number of interpositions making the oblique angle to the vertical axis. Fig. 2, on Pl. 4, represents the appearance of the hypersthene in the Waterville rock, and the mode of arrangement of its characteristic interposition. It is not abundant, but it is very conspicuous in some sections of the rock, and is very easily distinguished from the pyroxene, olivine, etc., with which it is associated.

40. PYROXENE [R Si O_3].

R standing for Ca, Mg, Fe, or Mn.

Pyroxene is found at some localities in fine large crystals, and it is also a prominent ingredient in some of our most interesting rocks. In the town of Amherst, fine and much sought specimens, containing pyroxene, vesuvianite, and cinnamon garnets, associated together, are found in the limestone. Fine crystals are also found at Warren; and at Haverhill there is a locality where beautiful green crystals of pyroxene are found associated, as at Amherst, with cinnamon garnets.

Pyroxene is one of the most important minerals that plays a part as a rock constituent. It is most common in basic rocks, though it also enters at times as an essential into the more acidic rocks, as, for example, the augite sienites. Hence, the study of the mineral as a rock ingredient is most important in our state; and its constant recurrence in various forms renders this study interesting.

In our rocks, augite occurs both in crystals and grains. When of sufficient size to be macroscopically examined, it is either black or dark in color, and the cleavage surfaces that it shows are at right angles to one another, so that it is without great difficulty distinguished from hornblende; and when it sinks to smaller proportions, the microscope determines it with certainty. At times it is well crystallized in the rocks, as, for example, in the olivine diabase of Campton Falls. The outlines that are obtained in cutting a section of a rock where the augite is crystalline are such as would be obtained by cutting a crystal of the most ordinary and common form, for the rare and complicated forms that are found on free crystals do not occur on ingrown crystals. Fig. 3, on Pl. 4, is drawn from a section of the Campton Falls rock as an illustration, and a common augite crystal is introduced into the figure for comparison. It is seen that sections parallel to the base (section *a*) will be eight-sided, those parallel to the orthopinnacoid (*b*) will be six-sided, while those parallel to the clinopinnacoid (*c*) will be four-sided, and modified and distorted figures will be obtained in oblique directions, but which can usually be identified. The cleavage is parallel to the faces of the prism *I;* hence the basal sections show a right-angled cleavage, which is sometimes nearly perfect, as in this case, but more often it is interrupted, though it can almost always be recognized. The mineral being monoclinic, those sections that contain the orthodiagonal (sections *b* and *a*) will be dark between crossed Nicols, when a side of the prism is parallel to the plane of vibration of the light, while all other sections will show a variation from this deportment, and if a clinodiagonal section (*c*) is examined it will be found that if the vertical axis is placed parallel to the plane of a Nicol prism, the section must be revolved 39° (or the complement of this angle in the other direction) in order to reach the point where the section will be dark between crossed Nicols, and not distort a calcite interference cross; thus showing that an elasticity axis makes this angle with the vertical crystallographic axis.

Augite is more often in grains, showing no crystalline faces, and then its cleavage serves to distinguish it from other minerals with which it is liable to be confounded; and it is to be noted that the mineral is not markedly dichroic, and hence when revolved with simply the polarizer on the microscope, no marked variation in color is seen, as it comes into different positions with reference to the light; but when revolved between crossed Nicols, the interference colors that are obtained are very brilliant.

Pyroxene is sometimes foliated, the laminæ being parallel to the orthopinnacoid. Pyroxene of this structure characterizes the rock gabbro.

The alterations that augite undergoes, as developed by microscopic study, are quite interesting. The most evident one in our rocks is the alteration of augite into hornblende, of which examples are common. This change is merely a molecular one, since the two minerals have the same composition; but it becomes very evident by the alteration of cleavage, and all other physical characters. Sometimes the change is complete, giving us hornblende in augitic forms; and sometimes it is partial, when we have hornblende with a core of augite. This change was first noted by Gustav Rose, who named the hornblendic product *uralite,* and the rocks containing it uralite porphyry, &c. The resulting uralite has usually a fibrous structure. I have never seen so pretty an illustration of this kind of change as is furnished by the augite sienite of Jackson, in our state. Here the augite is not altered into a fibrous green uralitic mass, but into fine, compact brown hornblende, which contains, as a rule, a core of augite. The cleavages of the two minerals also bear a definite relationship to one another. If we lay out the lateral axes of a crystal of augite (see Pl. 7, Fig. 1) and connect their ends, we shall have a nearly square figure, which is the base of the prism of augite, and the sides of which are parallel to the ordinary cleavages of that mineral. If, now, we double the length of the orthodiagonal, and connect the ends with the ends of the same clinodiagonal, we obtain the base of the hornblende prism to the sides of which the ordinary cleavage of hornblende is parallel. Now, in these altering grains of augite in this sienite from Jackson, the cleavages of these two minerals bear the exact relationship to one another that these two figures do when thus constructed, as is shown in Pl. 7, Fig. 1. This is a basal section, and the cleavage of the outside hornblende is seen to be parallel to the outside figure of the accompanying diagram, while the inside augite exhibits a cleavage parallel to the inner part of the little diagram. The hornblende is strongly dichroic, as is shown by the yellow bit above, which is cut parallel to the prism, while the augite is not dichroic. This case of alteration furnishes a most instructive illustration of the relationship that exists between these two minerals.

Another kind of change has been effected by that slow weathering that has converted the pyroxene into a green hydrous mineral. Pyroxene is very subject to this kind of alteration. This green product is known to be a kind of chlorite, and viridite is a name that has been proposed for it when its nature is unknown. This is a convenient word to apply to the green unknown results of decomposition; but several persons have attempted to determine the nature of this viridite, which plays so important a role in basic rocks, and Dr. K. L. Th. Liebe determined it to be a kind of chlorite, with the composition of an unisilicate, a conclusion confirmed by an analysis made by myself on pure material gathered from diabase. Now, the change from the calcareous bisilicate pyroxene to the magnesian unisilicate chlorite involves the separation of a definite amount of lime and silica, and hence, as a rule where this decomposition has taken place, we find lime carbonate and silica as associations of the green chlorite. Other kinds of decomposition take place, resulting in the production of epidote and various hydrous silicates; and sometimes augite crystals are decomposed into a heterogeneous mixture with the mere outline preserved.

41. RHODONITE [$MnSiO_3$].

Rhodonite is abundant in some localities in the south-western part of the state. It forms beds in the gneissoid rocks. It is found sometimes of the rose color characteristic of the pure, unaltered mineral, but usually of various shades of brown, the color being dependent upon the degree of oxidation or decomposition. A bed of it is situated on the top of Stony mountain near Winchester, and another on a hill a mile south-east of Hinsdale. The latter bed is seven feet thick, and quite extensive. Smaller deposits are found at other points in these same neighborhoods.

This mineral is subject to easy alteration, for the lower oxide of manganese is unstable, and has a constant tendency to oxidation. This change results in the production of a brown or black silicate of manganese sesquioxide, which is called marceline. On the exterior of the mineral the silica is sometimes removed, leaving a coating of manganese oxide, or pyrolusite, and when water containing carbonic acid acts upon the mineral, a carbonate of manganese is formed which is rhodochrosite. Products resulting from one or all of these methods of decomposition are common at the localities mentioned, as at all other localities of this ore. Such products have been often analyzed, and names have been given to them, but the decomposition is not usually so complete as to produce a perfectly homogeneous product, and hence they are usually mixtures of minerals.

The following is an analysis, by Dr. Jackson, of this mineral from Winchester:

Silica,	26.4
Iron oxide,	4.
Manganese oxide,	68.
Loss,	1.6
	100.0

Pure rhodonite is composed of 45.9 of silica, and 54.1 of manganese protoxide. Comparing this with Jackson's analysis, we see that he analyzed a decomposition product. His analysis is just like many others that have been made upon such products, and proves it to be the variety marceline, in which the manganese exists for the most part in the state of sesquioxide.

Rhodonite, when crystallized, is isomorphous with pyroxene; but our mineral is massive. It fuses easily, and imparts a deep violet color to a borax bead, the color becoming red-brown when the bead is cold.

42. SPODUMENE [$3\ Li^2\ Si\ O^3 + 4\ Al^2\ Si^3\ O^9$].

This is another silicate isomorphous with pyroxene. It is found in good crystals at Winchester. Its crystals are white in color, and usually flattened by the wide development of the orthopinnacoid. The ingredient that characterizes this mineral is its lithia. The crystals resemble those from Huntington, Mass., which Prof. Brush found to contain more than five per cent. of that oxide. The mineral is easily recognized by its large, tabular crystals, its easy cleavage parallel to the orthopinnacoid, and the carmine color that it imparts to the blow-pipe flame.

43. ANTHOPHYLLITE [$(Mg, Fe)\ Si\ O_3$].

This mineral occurs in a talcose rock at Richmond. It is characterized by its fibrous structure, its brown color, and its infusibility before the blow-pipe. It is the orthorhombic species of the hornblende group, and hence may be distinguished in a thin section by the circumstance that it is dark between crossed Nicol prisms when its fibres are parallel to the plane of vibration of the light; but it has no significance in our petrography, although Brooks has found it as a common constituent of rocks about Lake Superior, which occur in formations lithologically related to some of ours.

44. AMPHIBOLE [$R\ Si\ O_3$].

R standing usually for Ca Mg and Fe. It also often contains alumina and alkali.

Amphibole here, as elsewhere, is one of the commonest minerals. Fine crystalline specimens are found. It is a very common ingredient of the rocks, and forms rock masses by itself.

The common dark colored variety, which is usually called hornblende, has been found abundantly in superb crystals at the Franconia mines in Lisbon. Long-bladed crystals are also found there, and at Warren. Hornblende is found in fine crystals at Exeter, Hanover, Winnipiseogee lake (on Red hill), and Moultonborough.

Actinolite is the lighter green variety that usually occurs in smaller, longer crystals. It is found at Unity and Lisbon, and is common in unremarkable occurrences.

Tremolite is the white variety containing no iron. It is noticeable at Bedford (near the Devil's Den, abundant), Gilmanton, and Warren.

When this variety of amphibole crystallizes in fine capillary form, it is called asbestus. This variety is found at Franconia in masses or sheets which are from one to two inches thick, and composed of the finest interwoven fibres. This is called mountain leather. It is noticeable, also, on Monadnock mountain. A fibrous, dark colored variety, resembling fossil wood, is found at Lebanon.

Hornblende is a most important mineral as an ingredient of the rocks. In combination with feldspar, it forms our sienites, and with a triclinic feldspar or with quartz, it forms that wide expanse of diorites and amphibolites that occupies so much of the Connecticut valley. It is also a prominent ingredient of the eruptive rocks. It is common in works on lithology to divide it into two kinds,—basaltic and common hornblende. Basaltic hornblende is that very deep colored ferruginous hornblende that occurs in the basic eruptive rocks. The sections must be made thin, in order to make it transparent. It is usually deep brown, and strongly dichroic. Such is the hornblende of the eruptive diorites at Campton falls, Dixville Notch, etc. The common hornblende is lighter in color, contains less iron, is more often green, and is not in such compact crystals, being very often in fibrous masses or crystals made up of numerous others. It is more or less dichroic, according to the depth of its color. Such varieties as actinolite, which in thin sections become white, of course are not dichroic.

Hornblende is most easily recognized by its cleavage, which is so perfect, parallel to the sides of its first prism, that all basal sections appear divided up into rhombs with an obtuse angle of 124°. This characteristic serves for the determination of hornblende in all cases, save in those in which it exists in aggregations of minute crystals too small to exhibit cleavage, as it often does.

The pleochroism of hornblende is so remarkable that it aids in its determination. Hornblende is monoclinic, and hence it is possible that the light traversing the crystal parallel to its three varying planes of elasticity may be differently colored, and this is markedly the case with this mineral. This is illustrated in Pl. 7, Fig. 2, which is drawn from the hornblende schist of Cornish. The plane of vibration of the light determined by the lower Nicol, which alone is on the microscope, is indicated by the arrow, and it is seen that, when the light passes through a basal section parallel to the orthodiagonal axis, the crystal is green, and, through a like section parallel to the clinodiagonal, it is bright yellow, while a prismatic section, with the vertical axis parallel to the plane of vibration of the light, is blue. With ordinary light, the predominant color of these crystals is green, only varying in shade because blue and yellow make green, and green and yellow make green, as do also green and blue. In this figure it will be noticed that the crystals are not terminated, while the prismatic faces are well developed. This is quite characteristic of ordinary hornblende in the rocks. The basaltic hornblende shows a very strong absorption of the light, rather than a marked pleochroism. The characteristics given distinguish hornblende very well from augite, which is not pleochroic, is right-angled in its cleavage, and very different in crystalline outline.

When a section of hornblende is revolved between crossed Nicol prisms, the interference colors are not bright, especially in the basaltic varieties. Bright colors are obtained, however, with the lighter colored kinds. As with augite, sections containing the orthodiagonal axis are dark between crossed Nicols when a crystallographic axis falls with the plane of vibration to the light. With other sections, this is not true; and a section cut parallel to the clinopinnacoid, and placed with the vertical axis parallel to the plane of vibration of the light, must be revolved 15° before it becomes dark, showing that one elasticity axis makes an angle of 15° with the crystallographic vertical axis.

It has been shown that augite and hornblende are frequently associated together in our rocks as a result of alteration; but it is also true that at times they are associated together in the same rock, apparently both being simultaneous formations.

It has been pointed out, first by G. Rose, that these two minerals are referable to the same fundamental form; that is, if the prismatic planes of pyroxene making an angle of 87°.5 are called I, then the plane i-2 will correspond to the I of hornblende. In other words, the orthodiagonal of the hornblende crystal has twice the length of that of pyroxene. This makes the two minerals isomorphous in form; but since the minerals have different cleavages and habits of crystallization, they must still be considered as dimorphous. Now it is well known that there is no variety of pyroxene of which there is not a corresponding variety of hornblende; and so it may be inferred that only difference in condition is necessary to make one or the other species out of the same components. But where we see, as in the case of our diorites, both minerals made in a place where the conditions were necessarily the same, it is plain that the chemical conditions have also influence, and that the species are not strictly dimorphous, but different chemical compounds. This cannot be proved in the case of our rocks, since they are fine in texture and the materials inseparable; but as the point is of interest, I have looked about for materials which can be substituted. At Edenville, N. Y., there is an association of pyroxene and hornblende apparently analogous. At this place cavities in the rocks are filled with crystalline masses of the two species placed upon one another in all kinds of ways,—hornblende upon pyroxene, and *vice versa*, sometimes in large crystals, and again in small. The crystals take the commonest forms of the two species, and present no peculiarities of note. A study of these specimens brings one to the same conclusion as does the study of our rocks. The minerals being so intimately associated, the conditions under which they were formed must have been the same; and hence it must be inferred that some chemical differences have determined the crystallization. Material was carefully selected, and analyses were made, to test this point, with the following results:

	Hornblende.	Pyroxene.
Silica,	42.97	51.05
Alumina,	11.90	2.02
Iron sesquioxide,	3.08	1.30
Iron protoxide,	13.84	12.18
Manganese protoxide,	.48	.12
Lime,	11.63	22.07
Magnesia,	11.49	10.02
Potash,	.88	.....
Soda,	2.73	.....
Ignition,	.38	.34
	99.38	99.10

These analyses show that there is a marked difference in the composition of the associated pyroxene and hornblende; and indicate that the presence of alumina favors the formation of hornblende, although the difference in these two analyses in other respects is very wide,—the large percentage of lime in the pyroxene being marked; and it is known that pyroxene much more uniformly possesses a larger percentage of lime than does hornblende. The presence of alkali in the hornblende is also noticeable. Hence we see that when these minerals are associated, analysis shows them to be different chemical compounds.

The occurrence of associated pyroxene and hornblende in the cavities of the lava at Vesuvius has been described by Vom Rath.* He has shown that these minerals have been deposited in these cavities by a process of sublimation, and hence, both were formed under the same conditions. His analyses were necessarily imperfect, since the very small amount of material that he possessed did not allow of the determination of all the ingredients; yet the same distinctions between his analyses of pyroxene and hornblende are prominent,—a larger percentage of alumina, a smaller of lime, and the presence of alkali in the hornblende.

Moreover, some of our igneous rocks contain pyroxene, and others hornblende, and some both. Now, since these rocks form well defined dykes, and possess those characters which make it perfectly evident that they reached the surface in a molten condition, it might be inferred that the minerals in them were formed under essentially the same conditions. At Dixville Notch the traps are in part diorites, which contain hornblende in such large and well formed crystals that the separation of pure material for analysis is easy. Now this compared with my analysis of pyroxene, picked from the triassic trap of the Connecticut valley,† gives us the results that follow:

	Hornblende. Dixville Notch diorite.	Pyroxene. New Haven trap.
Silica,	40.79	50.71
Alumina,	17.36	3.55
Iron sesquioxide,	3.83	.....
Iron protoxide,	15.04	15.30
Manganese protoxide,	.30	.81
Lime,	10.83	13.35
Magnesia,	6.97	13.63

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* *Pogg. Annalen Erganzung*, Bd. vi, p. 229.

† *American Journal of Science*, iii, vol. ix, p. 187.

Alkali (by difference), . . .	4.17	1.48
Ignition, ...	.71	1.17
	100.00	100.00

Here, again, the same results are evident, the preponderance of alumina in the hornblende being the most striking difference.

But in the case of the pyroxene at Edenville, and also in some of our igneous and metamorphic rocks, the pyroxene has changed its cleavage and optical properties, and become hornblende. The minerals have not become hydrated, or the iron oxidized, as in ordinary decomposition; but a change has been effected without any alteration of composition, forming the mineral which was called by Rose uralite, which is pyroxene having the inner structure and optical properties of hornblende. In this case it is evident that pyroxene and hornblende are dimorphous forms of the same composition; that is, the molecules of the original pyroxene, under the subsequent influences, have reärranged themselves. Tschermak has noticed that crystals of pyroxene with crumpled ends are the ones most liable to this kind of alteration. This is the case with the Edenville crystals, but whether it be a result or a cause of the alteration is not plain.

From these analyses, it appears that any given composition capable of forming pyroxene, may, under different circumstances, form hornblende, and hence the two minerals are dimorphous forms of the same material; but that under uniform conditions, chemical composition will determine what species shall be formed, and alumina is an important agent in this determination.

Now, in the decomposition of rocks and the redeposition of sediments, the lime that is held in their composition is most apt to be dissolved and carried away in solution, and thus we obtain those immense beds of limestones, whereby the sediments are left more aluminous; and so in metamorphic rocks there is a much greater tendency to the formation of hornblende; and our stratified basic rocks are mostly diorites and amphibolites, while the amount of metamorphic pyroxenic rocks is small. As a confirmation of this, see the following analysis of hornblende from the diorite of Littleton:

Silica,	49.03
Alumina,	13.72
Iron protoxide,	9.84
Manganese protoxide,	.40
Lime,	11.22
Magnesia,	11.96
Soda,	2.40
Water,	.90
	99.47

This is the variety of hornblende that is called pargasite, and which oft-repeated analyses have shown to be the common hornblende of green diorites, in all localities. This hornblende, the analysis of which is given, is a foliated variety, and by some is supposed to be a mixture of hornblende and pyroxene. In our rocks, at least, it is all hornblende, and its aluminous nature is what I wish to call attention to in this connection.

Hornblende is subject to decomposition, perhaps not so readily as augite, but yet in an analogous way. In the rocks it is liable to be hydrated, and to be changed into chlorite, and sometimes it breaks up into a variety of products at once; and although the external form remains, microscopic sections show that it is composed within of the most heterogeneous mixture. Fig. 3, on Pl. 7, represents such a crystal drawn from a section of the diorite which forms a dyke near the Profile house, Franconia. It has the form of a quite perfect crystal of hornblende, but now it is composed of magnetite, biotite, and calcite, with remnants of hornblende. In many of the crystals in this rock the alteration has been complete. I am inclined to think as Zirkel does, in his consideration of analogous augite crystals, that the biotite was an enclosure, as calcite encloses sand, for crystals, apparently undecomposed, are often penetrated by it; but the magnetite and calcite are products of decomposition.

45. Beryl [$Be_3 Al_2 Si_6 O_{18}$].

The largest beryls of the world are found in New Hampshire; indeed, our beryls are cited in every text-book to illustrate to what proportions crystals can grow under favoring circumstances. Grafton and Acworth are the most celebrated localities for great beryls. It is a hexagonal mineral, and some of the large crystals have very perfect hexagonal forms, though they lack the lustre and transparency possessed by the small crystals from the same localities. The form and dimensions of two of these large crystals from Grafton are shown in Figs. 4 and 5 on Pl. 3, which represent the outlines of the bases and the dimensions in inches. The measurements were made by Prof. O. P. Hubbard,* who attempted their extraction, in which effort one was destroyed. The other one has since been broken up and scattered abroad. These crystals are among the largest that any species of mineral has ever afforded, and it is sad that the best specimens should have been destroyed. Their form is as regular as hexagonal crystals of smaller size will average. The crystal, the base of which is represented in Fig. 4, was originally six and a quarter feet long. These beryls, when of this enormous size, are apt to have subordinate planes, as is shown at *a* in the drawing. The crystal from which Fig. 5 is drawn, weighed over two and a half tons. One beryl extracted from the Acworth quarries is four feet long, and two and a half feet in diameter. The one that is preserved in the rooms of the Boston Society of Natural History is represented in the frontispiece, with a scale below it representing its dimensions in feet.

These large crystals are of a pale green color, and many of them have been extracted, and are exhibited as great curiosities in the museums of the world. Some very large crystals still remain in the quarries, where they can be seen; but their extraction is a matter of considerable expense, since much rock must be moved in order to obtain them, and, moreover, it is very hard to get them out whole, since the material of which beryl is composed is very brittle, and filled with rifts, and a jar is sufficient to break them when they are not well supported. The large crystals have always been securely hooped before any attempt was made to move them. Prof. Hitchcock has obtained one for the state museum, weighing half a ton.

Smaller but much more perfect and beautiful crystals are found in the quarries from which these large beryls are obtained, and also in other localities. They are usually terminated by a smooth basal plane, but often have in addition the planes of an hexagonal pyramid. Canaan, Wilmot, Springfield, Danbury, the islands of Lake Winnipiseogee, the northern part of Rumney, Chatham (in the stream near the path to Baldface), Campton, New Ipswich, Sullivan, Plymouth, Wilmot, New London,

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* Hubbard, *Am. J. Sci.*, ii, vol. xiii, p. 264.

Millsfield, Groton, and Warren, are localities. They are found at many places in the White Mountains, and less noticeable crystals occur elsewhere. The crystals obtained from the places mentioned are fine, the predominant color being green; but yellow and blue crystals are also common. The larger crystals are filled with impurities that make them cloudy, or even white and opaque like feldspar; but often crystals are obtained which are so clear, and of such a fine color, that they have been cut into gems of rare beauty. The green color that predominates has been shown by analysis to be due to a trace of chromium, which, when present in greater amount, gives the green color to the emerald. Clear crystals, when found in the quarry, are difficult to extract without producing flaws in them, and hence the stones from which the most beautiful jewels have been cut, have been dug up from the neighboring soil, where they were deposited by being washed out from the decomposing granite. There is a theory among the people, that by lying a long time in the soil they acquire a heightened brilliancy. The rare beauty of these specimens is rather to be attributed to the fact that they have not been subjected to the jars produced by sledges and powder.

The beryls are found in granitic veins. These veins are easily recognized by the very large crystals of quartz, feldspar, and mica, which are the constituents of ordinary granites; and the general presence of beryls in them is interesting, as substantiating the theory of their formation. These granitic minerals occupy large fissures, and it is thought that water, which had filtered through the surrounding rocks, and which, under a high pressure, and at a high temperature, had become saturated with their soluble constituents, deposited these great crystals of the various minerals in these fissures, until they were finally filled with this extremely coarse granitic mixture. In this way, the rarer elements, such as glucinum, which exist in such minute amounts in the surrounding rocks, became concentrated in these veins, forming the beryls that are so common there. These veins are worked at various points, in order to obtain the great crystals of mica, which are very valuable.

Some beryls from New Hampshire have been analyzed. The analyses are both made upon specimens from Acworth. The first is by Prof. C. A. Joy.* The second is by M. B. Williams: †

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* *Am. J. Sci.*, ii, vol. xxxvi, p. 91.

† *Geology N. H.*, C. T. Jackson, p. 182.

	I.	II.
Silica,	68.84	68.35
Alumina,	16.47	17.60
Glucina,	13.40	14.00
Iron oxide,	1.70	trace.
Chromium oxide,		trace.
	100.41	99.95

The analysis by Prof. Joy is the result of an extended series of experiments which were made with the view of finding the best methods to analyze this species, and to obtain glucina in a state of purity in order to study its properties and its salts.

The fracture of beryl is vitreous. It sometimes shows a basal cleavage, and this cleavage is very marked and perfect on the very large specimens.

A thin section of one of the large beryls from Grafton shows that the crystal is filled with microscopic impurities. Its appearance under the microscope is represented in Fig. 4 on Pl. 4. There are amorphous substances that have filtered into the cracks; and there are crystalline substances. These latter are all prismatic, and are arranged with an edge of the prism parallel to the long axis of the beryl. The minerals are those that are common in the granite veins. There are little black tourmalines, and scales of black mica. Beside these there are minute particles that polarize the light like quartz, and numerous cavities that are filled with water, each one containing a bubble of air. These cavities are generally wholly irregular, but others have a perfect hexagonal outline, with the long axis and the sides parallel to those of the large crystal. Like the other cavities, they contain a fluid and a bubble. Most of these cavities probably contain water; but one that I examined apparently contained two fluids, and the bubble disappeared at a temperature of 30° centigrade. It therefore contained liquid carbonic acid, which has been shown by Sorby and others to be common in beryls.

The expansive force of liquid carbonic acid at 0°, C. is 36 atmospheres, and increases one atmosphere for every added degree of temperature. If, as is likely, the temperature was an elevated one under which these minerals were formed, the pressure must have been immense.

46. CHRYSOLITE (OLIVINE) [$(Mg, Fe)_2 Si O_4$].

This mineral is a prominent ingredient of some of our igneous rocks. It was first noticed as an ingredient of the trap at Campton falls by Prof. O. P. Hubbard,* who also found it forming masses of some size in a very coarsely crystalline diabase, which is found in boulders (the original locality for which is not known) at Thetford, Vt. It was identified in the gabbro from Waterville † by Mr. E. S. Dana. When visible to the eye in the rocks it has a vitreous lustre, and a greenish yellow color. The easy decomposition to which it is subject makes it conspicuous; and rocks like our gabbros, which, when broken, show the clearest and freshest grains of chrysolite on a fresh fracture, are externally covered with iron-stained pits, from which the chrysolite has rotted away. It has been found, also, in granite boulders near the Crawford house.

The following is an analysis of the chrysolite from the Waterville rock, by Mr. Dana.

Silica,	38.85
Alumina,	trace.
Iron protoxide,	28.07
Manganese protoxide,	1.24
Lime,	1.43
Magnesia,	30.62
	100.21

The analysis shows this to be the variety of chrysolite which commonly occurs in rocks, and which is usually called olivine. It contains an unusually large amount of iron,—as remarked by Mr. Dana, the proportion between the iron and magnesia being as 1 : 2. Hence the formula for this olivine is

$$\left\{ \begin{matrix} 2\ Mg^2\ Si\ O_4 \\ Fe^2\ Si\ O_4 \end{matrix} \right\}$$

When present in sections of rocks prepared for microscopic study, chrysolite is easily recognized. When crystalized, its sections are either six- or eight-sided, the figures being the sections of the most common form of the crystals of this species. This form is made by a combination of two prisms and a macro- and brachydome. In the rocks that I have examined, the sections at right angles to the vertical axis appear

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* *Am. Jour. Science*, i, vol. xxxiv, p. 110.

† Id., iii, vol. iii, p. 48.

quite imperfect, indicating a poor development of the prismatic planes, while the sections parallel to the vertical axis show beautiful six-sided forms, being combinations of the edges of a prism and dome. The appearance of the olivine in the olivine diabase of Campton falls is represented in Fig. 4 on Pl. 7. Beside these crystalline outlines, the microscopic peculiarities of olivine are very characteristic. As a rule, its cleavage is wholly irregular, though cases are not wanting in our rocks where it gives evidence of a very perfect cleavage parallel to the plane of the macropinnacoid. The crystals are dark between crossed Nicol prisms when a prismatic edge or a cleavage, when evident, is parallel with the plane of vibration of the light. The interference figures produced by olivine, when revolved between crossed Nicol prisms, are very brilliant.

The decomposition of olivine is very characteristic. As before stated, it decomposes with great ease; and almost always, in microscopic sections, decomposition products of one kind or another are found about the fractures or cleavages, which have admitted the reagents that act upon it. In the olivine of our gabbros, alteration has not progressed far; but in the diabases the alteration is almost complete. For example: in the crystals figured from Campton falls, the material about the cracks is a different substance from the olivine, and is of a light yellow color. By its action on the light, it is recognized as serpentine, the common product that results from the hydration of olivine. This shades off into a greenish yellow fibrous serpentine, while only the centres of the larger crystals are still intact. All these different products are brought into the strongest relief by the aid of polarized light. Many crystals have been observed and described by Zirkel and others, that are entirely altered into serpentine; and the well known crystals from Snarum, in Norway, afford excellent macroscopic illustration of this change of olivine into serpentine, which the microscope finds so common.

47. GARNET $[R_3 \dot{R} Si_3 O_{12}]$.

R, in our species, standing for lime, protoxide of iron, and manganese; $\dot{R}$ for alumina and sesquioxide of iron.

Garnet is a common mineral in our metamorphic rocks. It is found usually in very perfect crystals, the forms being the dodecahedron and the tetragonal trisoctahedron or trapezohedron, and, again, it is found in large masses, which are destitute of any crystalline form. We possess quite a variety of garnets, the prominent varieties being the red iron alumina garnet called almandite; the manganese iron alumina garnet called spessartite; the lime alumina garnet called cinnamon garnet or grossularite; and the lime iron garnet called andradite.

The red almandine garnet is common in the hornblendic rocks of the Connecticut valley, and also in the gneiss and mica schists all over the state. Sometimes, as at Hanover, the crystals are nearly clear, and resemble the stones from which the gems are cut, but more commonly they are only translucent. They vary in size from microscopic grains to crystals an inch in diameter. They are commonly dodecahedral, though the edges are often replaced by small planes of the trapezohedron. They are found in the most perfect forms in chlorite rocks; but small and very perfect crystals are found in the greatest profusion in some of the hornblende rocks. This variety of garnet is found in a chlorite rock at Haverhill, in large crystals 1½ inches in diameter. Newington, Lisbon, Unity, Orford, Dorchester, Dalton, and Windham are localities for it, and it is common in some of the mica schists and granitic rocks of the mountains, though the crystals are not so often perfect. Sometimes fine crystals are dug from the soil where they have been deposited after the disintegration of the rocks; and from this source the finest pieces for cutting have been obtained. This variety of garnet is common in the great granite veins like those at Acworth and Grafton. Clear and beautiful little crystals, and large imperfect ones, are abundant. Very large and perfect crystals have been found in the granite veins at Winchester. They are trapezohedral in form, but have the planes of the rhombic dodecahedron.

Spessartite—the silicate of manganese, iron, and alumina—is most common in the mica schist rocks. Its crystals are usually larger. It commonly crystallizes in trapezohedrons, though the planes of the dodecahedron are often seen. A great many of them have been obtained by mineralogists from the mica schist at Springfield, where they are very abundant, and very perfect in their crystallization.

Andradite—the lime iron garnet—is very dark in its color, being deep blood-red, and often nearly black. It has been identified by W. Fisher*

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* *American Journal of Science*, ii, vol. ix, p. 84.

as occurring at Franconia. Massive garnet in large pieces is found here, in the geodic cavities of which beautiful blood-red crystals are found associated with calcite and magnetic iron. The following is an analysis, by Fisher, of a nearly black specimen from this locality:

Silica,	38.85
Iron sesquioxide,	28.15
Lime,	32.00
	99.00

The analysis shows, as he remarks, that it is a pure iron lime garnet, remarkably simple in composition, the analysis of which corresponds very exactly with the formula.

The most beautiful garnets that have been found in New Hampshire are perhaps the cinnamon or alumina lime garnets which are found associated with green pyroxene at Warren and at Amherst. They are of a cinnamon-brown color; and the ones at Warren are very perfect in their form. The Amherst crystals reach a very large size, some of them being three or four inches in diameter; but when so large they do not often have perfect and smooth crystalline faces. These crystals are found in the limestone, and also in the crystalline rocks, at their surfaces of contact with the limestone. They are mostly simple dodecahedrons. They are associated with pyroxene and vesuvianite, which are other lime and alumina minerals. Dr. Jackson, in describing these rocks, has followed some others in thinking that the occurrence of these lime silicates at the junction of the limestone with the siliceous rocks, or primary rocks, as they were termed, is sufficient evidence to prove that all these rocks were of igneous origin, since the siliceous rocks on eruption would inevitably generate such silicates of lime and alumina as garnet and vesuvianite, on coming into contact with the limestones. But this is not a weighty argument. Garnet and vesuvianite are minerals which, although unaffected by acids in fine powder, are decomposed by hydrochloric acid with ease if they are ignited before treatment, and the solution, if evaporated, will gelatinize. This shows that some chemical change is effected by heating a garnet, and therefore a garnet would not be likely to be formed at a high temperature; and, as is well known, it is not often found as a constituent of igneous rocks, save as a product of their decomposition. It is very probable, however, that by metamorphic and other agencies garnets might be formed, as they so often are, on the junction of siliceous rocks and limestones; but it is on account of the proximity of the chemical elements which by reaction on one another may form garnets, and is not any proof of the igneous condition of either mass.

Garnet is often present as a microscopic constituent of our rocks. It seems likely to exist anywhere, save in the basic eruptive rocks. When present in microscopic preparations it is recognized by its optical deportment, since, owing to its single refraction, its sections, in whatever direction they are cut, are dark in all positions between crossed Nicols. In the schists the garnets are usually crystalline; and then their sections are commonly six- or eight-sided, being sections of dodecahedrons, but often they are nearly round. In the granites, on the contrary, the garnets frequently have no crystalline outline, but have a most irregular and eccentric structure, and look like melted bits of glass. Garnet has no cleavage, and its sections are usually traversed by rifts, which go in all directions.

Some beautiful specimens of garnets, all mounted and in readiness for microscopic study, are found in our granitic veins. These are garnets which, having crystallized between plates of mica, are flattened out, and, instead of appearing as natural crystals, look like thin flat discs fastened in the mica. They form very pretty objects, and are thin enough to be studied with the microscope. Lasaulx* mentions one of these garnets which was all penetrated by little crystalline needles of tourmaline. Other microscopic impurities, such as quartz, magnetite, and epidote, are often present in garnets, and sometimes a garnet will have cavities in it of crystalline form.

The garnets that occur in the hornblende schist at Hanover are very interesting as a microscopic study. They are well crystallized in perfect dodecahedrons, and to all appearance are perfectly pure, many of them being quite clear, and of a beautiful wine color; but when a thin section is cut through one of these, it is seen to be filled with grains of quartz, which in many cases constitutes at least one third of the whole. Fig. 5

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* *Elemente der Petrographie*, Dr. A. Von Lasaulx, p. 80.

on Pl. 4 is drawn from one of these garnets, and shows it as it appears when magnified twenty diameters. When this section is examined between crossed Nicols, the garnet becomes black, but the quartz springs out into brilliant colors. The garnet does not enclose any of the hornblende of the rock, but it does sometimes enclose a piece of magnetite. This seems to be a remarkable case of impurity, which reminds one of the Fontainebleau limestone, which is carbonate of lime, the crystals of which sometimes contain half their weight of sand. In our garnets, however, the quartz, being transparent, does not become evident until a thin section is made; and no better illustration than this can be found, to show the value and necessity of microscopic work in connection with mineral determination, since experience shows that analyses made on apparently pure material may be worthless, on account of the presence of weighty impurities.

Garnets are common in the clay slates of the Connecticut valley. In them a very pretty process of pseudomorphism can be seen in progress, which is represented in Fig. 5 on Pl. 7. Here a garnet perfect in outline is slowly changing into chlorite. The chlorite in this specimen is arranged concentrically about the garnet in foliated masses. In other specimens that I have seen, from other localities, the foliæ of chlorite were arranged radially. Prof. R. Pumpelly* has described and figured garnets from the Lake Superior region that were almost entirely changed into chlorite. The garnets in these slates also contain some quartz, but not as much as the Hanover crystals.

48. ZIRCON [$Zr\ Si\ O_4$].

This mineral is found as a microscopic constituent of some of our granites and sienites, but I am not aware of its occurrence in macroscopic crystals. Zircons in the granite are not very common, but the crystals, though very minute, are often perfect in form. Fig. 1 on Pl. 5 represents some crystals of zircon in the Fitzwilliam granite. They are highly magnified. As is seen, some of the crystals show the perfect quadratic base, and others show the prism. Again: some of the crystals are rounded, and yet approximate to the form of zircon. The dark mineral on the sides of the figure is biotite. The zircons are bedded in

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* *American Journal of Science*, iii, vol. x, p. 17.

quartz. Some of these little crystals exist in the sienite at Sandwich, and are there very perfect in form.

49. VESUVIANITE (IDOCRASE) [$Ca_8 Al_4 Si_7 O_{28}$].

Large and fine crystals of vesuvianite have been found at Amherst, and also at Warren. These crystals occur on the surfaces of contact of the limestones and siliceous schists that are there associated. One of the crystals from Amherst is represented in Fig. 2 on Pl. 3. It is taken from the second edition of Dana's *Mineralogy*.

50. EPIDOTE [$H^2 Ca^4 (Al^2, Fe^2)^3 Si^6 O^{26}$].

We have epidote both in isolated crystals and in our rocks. It is found at Lisbon in light yellow acicular crystals, and in larger, finer forms. Very pretty twin crystals, and also a massive variety, are found there. It occurs at Warren, associated with quartz and pyrites. It fills a vein in Jackson, from which immense crystals have been taken, some of which were eight inches in diameter and of a fine green color (Jackson). Smaller but better crystals, and also twins, are more common. It is found at Bedford, Gilmanton, Hanover, Portsmouth (radiated acicular crystals in hornblende), Exeter (very beautiful groups of radiating crystals), and Benton (in boulders).

As a rock constituent, epidote is preëminently characteristic as a decomposition product in certain basic rocks. It is found in seams and cracks in the metamorphic diorites that are so common in the Connecticut valley, and is an almost constant microscopic ingredient of the rocks themselves. The same is true of some of our eruptive rocks. In microscopic sections it is trichroic; but the colors are often so faint as to render the recognition of this difficult. It may be said, however, that it is usually yellow in color, and, when revolved between crossed Nicols, the colors obtained are perhaps more brilliant than those shown by any other mineral.

Where the rocks contain the most basic feldspars, and where this feldspar is dull by decomposition, there epidote is most often found. In our light green feldspathic diorites, epidote seems to be the mineral most commonly found in and about the triclinic feldspar as a product of its decay. At times, this process of alteration has proceeded so far that nearly all traces of the triclinic feldspar has disappeared, and a green rock, with nearly the composition of epidosite, is the result. Examples of this are to be found in Cornish and Stewartstown, where all stages of the progress of alteration can be seen. In the eruptive diabases, epidote, resulting from alteration, often fills amygdaloidal cavities. Products that result thus from decay rarely possess any definite crystalline outlines in the rocks; and this is the case with epidote, which commonly exists in very minute grains, or aggregates of grains.

51. ZOISITE [$H^2 Ca^4 Al^6 Si^6 O^{26}$]

Zoisite differs from epidote in containing but little or no iron. It has been found in ash gray, much compressed, and deeply striated crystals at Westmoreland. It has also been found at Hanover, Franconia, and Lisbon.

52. IOLITE [$Mg^2 (Fe^2, Al^2)^2 Si^5 O^{18}$].

Very fine specimens of this beautiful mineral are found at Richmond. It occurs in the quartz rock and mica schist. Its color is blue, but its dichroism is very marked,—one species being blue when the light passes in the direction of the vertical axis, and brownish-violet when it passes at right angles thereto, the two colors obtained parallel to the two lateral axes being not markedly different. This mineral was found in opening a soapstone quarry. Iolite is also found in Unity and Croydon. This mineral alters with the greatest ease, the first result being the hydration of the mineral, then the separation of the prism by planes parallel to its base, and, finally, the production of a hydrous silicate, which varies much in composition.

Iolites from Richmond and Unity have been analyzed by Dr. Jackson, with the following results:

	Richmond.	Unity.
Silica,	48.00	48.15
Alumina,	35.	32.50
Iron protoxide,	6.	7.92
Magnesia,	10.	10.14
Manganese protoxide,	1.	.28
Water,	.....	.50
	100.00	99.49

These analyses agree closely with the formula given. The iolite is usually found in large, flat pieces, with no crystalline planes except the base. Crystals with prismatic faces are not rare, but they are commonly much decomposed.

53. CHLOROPHYLLITE.

Iolite, as already stated, is a mineral that is very easily altered, and many of its decomposition products have been analyzed, and given distinctive names. When Dr. Jackson made his geological survey of this state, he discovered at Unity (where iolite, also, is found) a hydrated silicate, to which, on analysis, he gave the name of chlorophyllite. This substance was also analyzed by Rammelsberg, who places it along with several other like substances in a supplement to iolite. Dana classes all these substances together under the name of fahlunite, a species belonging with the hydrous silicates. The following are the analyses of chlorophyllite from Unity:

	Jackson.*	Rammelsberg.†
Silica,	45.20	46.31
Alumina,	27.60	25.17
Iron sesquioxide,	9.17	10.99
Manganese protoxide,	4.08	tr.
Magnesia,	9.60	10.91
Lime,	.....	.58
Water,	3.60	6.70
	99.25	100.66

Rammelsberg remarks that his analysis gives, on calculation, a quantivalent ratio, which is that of a definite hydrate of the species iolite, or a species with the same formula as iolite, plus three or four molecules of water. As Jackson's analysis, when compared with Rammelsberg's, shows wide variations, chlorophyllite must be regarded as a product resulting from the decomposition of iolite.

MICA.

Mica in our state is an important mineral from an economic standpoint, and a very interesting mineral from a scientific. We have some

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* *Rep. Geol. N. H.*, 1844.

† *Rammelsberg's Min. Chem.*, 1875, p. 653.

of the finest mica quarries on the continent, and much mica of the best quality is extracted from them. Mica is, moreover, a most common and interesting rock constituent.

We have four species of mica,—biotite and lepidomelane (black micas), which are uniaxial, and muscovite and lepidolite (white micas), which are biaxial. These micas often occur together; but when their crystals are in contact, there is usually some simple relationship between the axes of the two crystals. It may be stated in general, before describing the species, that all these micas have the same prismatic angle. Biotite and lepidomelane are hexagonal and uniaxial, and have a prismatic angle of 120°; and muscovite and lepidolite are biaxial and orthorhombic, but have the same prismatic angle of 120°. The color of our granites, as well as of many of our schists, is largely due to the kind of mica they contain. Granites that contain the white biaxial micas are light colored, while the black micas make the granite dark colored, and the darkness is proportional to the quantity. Some granites are nearly black, on account of the large amount of black mica they possess.

54. BIOTITE [K_2 (Fe, Mg)^7 Al^4 Si^7 O_{28}].

Black magnesia iron mica.

This mica varies very much in color, according to the proportion of iron that it contains. It is usually nearly black. It is of no economic value; but as has been already stated, it makes dark-colored granites, which, by some, are more admired than are the white granites. The mica in granite is generally in very small scales; but in the great granitic veins that occur at Grafton, Alstead, Acworth, etc., all the ordinary constituents of granite are found in very large crystals, and among them are interesting specimens of biotite. The biotite of these veins is very rich in iron, and is black by reflected light, though thin flakes of it are brown by transmitted light. I analyzed a specimen of it at one time from a granite vein in Middletown, Conn.,* and found it to be an unisilicate, containing 35.61 per cent. of silica, 20.03 of alumina, 21.85 of iron protoxide, 5.23 of magnesia, and 9.69 of potash, with quite a list of accessory elements, among which were lithia, fluorine, and titanic acid; and, as the physical appearance of the micas in all our granite veins is

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* *American Journal of Science*, iii, vol xi, p. 432.

exactly the same, it may be assumed that this is the composition of our black mica.

Biotite is hexagonal. In our quarries imperfect crystals are sometimes found, though pieces with an irregular outline are most abundant. It is quite common to find it united by the edges of its laminæ with muscovite or white mica; as if the muscovite, after reaching a certain size, had gone on increasing itself with the substance of biotite. Moreover, when the two species have thus grown together, it is found that their prismatic faces are parallel to one another. Although we do not often have the prismatic faces to study, still we have the means for finding their directions. When one takes a tolerably thin piece of mica, and strikes it quickly with a sharp point, lines of cleavage are developed about the hole made by the point; and thus a figure is produced called a strike figure (schlag figur). Now Reusch has shown * that this cleavage in hexagonal mica is parallel to the sides of the prism, and that in orthorhombic micas it is parallel to the rhombic prism and the shorter of the lateral axes. Therefore the strike figure is exactly the same in the orthorhombic mica that it is in hexagonal, and in each case is composed of three cleavages, which cross one another at an angle of 60°. If, now, we strike with a pointed instrument upon a piece of this mica, which is composed of the two species, near the line upon which they are united, we shall produce these cleavage lines, which will run from one species into the other without interruption, and without any change of direction. This shows that there is some simple relationship between the positions of the crystalline planes of the two species; and, if we draw lines to represent the faces of the crystals parallel to these lines of cleavage, we shall obtain the correct positions of the crystals, and see their relationship to one another. Fig. 2 on Pl. 9 represents one of these pieces of mica with two of the strike figures,—one on the black mica and one on the white; and the lines are seen to run without interruption from one into the other species. The faces of the crystals are drawn parallel to these lines, and the relationship of the two crystals is shown.

Biotite is easily determined by the aid of the microscope. All sections, save those parallel to the basal cleavage, are very strongly dichroic;

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* *Monatsbericht der Königl. Akad.* Wissensch. Zu Berlin, 1868, p. 428, and 1869, p. 84.

hence those that show the very evident basal cleavage, when revolved on the stage of the microscope with only the lower Nicol fixed upon the instrument, are light yellow when the vertical axis of the crystal is parallel to the plane of vibration of the light, and very dark brown or black when the cleavage, which corresponds to the lateral axes, is parallel to this plane. Sections that show no cleavage are basal sections, and, as basal sections of hexagonal minerals do not possess double refraction, they show no dichroism. It is possible to confound biotite with basaltic hornblende, since their colors and dichroism are much alike, though the cleavage of mica is different. Between crossed Nicol prisms all sections of biotite will be black when the cleavage corresponds with the plane of vibration of either Nicol, since the cleavage corresponds with an axis of elasticity. With hornblende this is not the case, and in the larger number of its sections the point of maximum darkness will be obtained when the cleavage makes a certain though not great angle with the plane of the light.

Biotite is constantly met with in our rocks, and in many cases it requires no microscope to detect it; but in many other cases it is only microscopic.

Biotite is fusible before the blow-pipe; but the ease with which it fuses depends upon the amount of iron that it contains. Our black biotites in the feldspar quarries are very rich in iron, and hence fuse without much difficulty to magnetic globules. Some specimens impart the bright crimson color that is characteristic of lithia. There was one per cent. of lithia in the biotite from Middletown that I analyzed. Some of the biotite in the granites contains lithia; and the lithia-bearing varieties seem to be much more easily fusible than those which contain none.

If an ordinary cleavage piece of biotite, sufficiently thin to be translucent, is put on the stage of the microscope, the ocular removed, and the two Nicol prisms placed at right angles to one another, the field will be traversed by a black cross, the arms of which do not alter their positions on revolving the stage. The mica is thus easily seen to be uniaxial.

55. LEPIDOMELANE.

From an examination of the analysis of biotite that precedes, it is easy to see how readily a mineral so composed would alter. Such highly ferruginous minerals, when the iron is present in the state of protoxide, are very subject to oxidation. A number of such micas have been analyzed, and they show no essential difference from such a biotite as that last described, save that they contain a large proportion of iron sesquioxide, and are black and opaque, and more or less brittle. The optical properties, when they can be made out, are identical with those of biotite. These micas, containing sesquioxide of iron in the place of protoxide, are called lepidomelane. Many specimens of mica which are found in the granite quarries and rocks of New Hampshire would be referred to this species. It is distinguished from pure biotite by its opacity, its lack of elasticity, and its black shiny lustre. It fuses before the blow-pipe to a magnetic globule, and is easily decomposed by acids. In the microscope it has the same optical properties as biotite, and it is common in some of our granitic rocks. Prof. J. P. Cooke* describes a variety from Cape Ann, which has been named annite, which differs from what is considered typical lepidomelane in containing a less proportion of iron sesquioxide, and a greater of protoxide. We have, in some of our granites, micas which exactly answer to this in physical properties; a granite from Farmington contains mica like this, which gives the reaction for lithia that is obtained from annite. Prof. Cooke, thinking this to be owing to an impurity, deducts the percentage of lithia obtained; but as my analysis shows that lithia exists in pure biotite, I think that our micas that I have examined, and which give a lithia reaction, doubtless contain it in their composition.

The optical properties of lepidomelane under the microscope are identical with those of biotite. It is quite likely that a large proportion of the black mica in our rocks might be referred to this species; but in lithology no distinction between lepidomelane and biotite is recognized, and all the black dichroic micas are called biotite.

56. MUSCOVITE [$K^2 Al^2 Si^2 O^8$].

Muscovite, or common mica, is one of our most valuable minerals. Besides its universal distribution over the state as a rock constituent, large amounts of it are extracted from the granitic veins, where valuable plates, sometimes a yard across, are found. Grafton, Alstead, Acworth,

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* *Am. Jour. Science*, ii, vol. xliii, p. 22.

and Springfield, are towns where large granitic veins have been worked with profit for the mica, and the Grafton mica mines are still in very successful operation. Alexandria, Orange, and Groton are other localities. Much further reference to these occurrences of mica will be found in the chapter on economic geology.

Muscovite is orthorhombic, and the angle of its prism is 120°. The crystals appear sometimes nearly hexagonal, on account of the development of the brachy-pinnacoid. In Wilmot, large crystals, six inches in diameter, are found, which by the combination indicated appear nearly hexagonal. Gilmanton, New London, and Hinsdale, beside the mica quarries already mentioned, furnish fine crystalline varieties of muscovite. This mica is usually colorless, or smoke color in thicker plates; but green and yellow muscovite is found at Bedford, rose-colored at Walpole, green, white, and brown at Piermont, and green at Unity. All shades of yellow result from alteration, and an opaque gold color is often the last product of change.

The association of minerals with muscovite in our granitic veins is very interesting. Its union with biotite according to a definite rule has been already mentioned under that species. The simplest case of that association is where plates of black and white mica are united by their edges, as illustrated in Fig. 9 on Pl. 2. The cleavages developed by a blow with a sharp point are parallel in the two species, and, as shown by Reusch, these cleavages are parallel to the prismatic faces of the two species. The sides of the hexagon on the biotite may therefore be drawn, but the prism of muscovite might be drawn with its long axis in three different directions. If now we remove the ocular from the microscope, on looking through the biotite with the Nicol prisms crossed, the strictly uniaxial character of the mica will be seen by the clear black cross, the arms of which cross one another in the centre of the field. (Biotite is not always so strictly uniaxial.) Muscovite is orthorhombic, and the vertical axis is the acute bissectrix; and in our crystals the plane of the axes appears always to be that of the macrodiagonal. If now, with the ocular removed, we look at the muscovite, we see its two optic axes, and the direction of the line connecting them is the longer diagonal of the rhomb. These observations are represented in the figure; *a* and *b* are the cleavages produced by blows, and the appearances of the optic axes of the two micas, as they appear between crossed Nicols without the ocular, is also shown. These data give us the position of the crystals, which are seen to be connected by their prismatic edges.

In addition to that union of plates by a simple edge, there are also found specimens in the mica quarries where plates of muscovite partially or wholly surround a crystal of biotite; and here the same symmetry in the arrangement of the prismatic planes is made evident by a determination of the positions of the planes of the muscovite. This was investigated by Gustav Rose,* and Fig. 9 on Pl. 3 is the one drawn by him from a specimen from Alstead in our state. In this figure, *a* represents the direction of the cleavage induced by a blow with a sharp point, and *b* represents the direction of the plane of the optic axes, and the relationship of the two figures is thereby easily identified.

Every one who has seen the mica as it comes from these quarries must have noticed how it is traversed at times by a straight crack, and that on breaking it in two, this straight cleavage crack is filled with a multitude of little fibres which are parallel to the direction of the line. At times these natural divisions spoil a fine large sheet of mica, and at times a piece of mica is divided by these divisions into a number of long strips. Now Reusch and Bauer, who have studied the little cracks produced by striking mica, have demonstrated that in muscovite a sharp blow with a hard point develops a cleavage parallel to the sides of the prism and to the shorter diagonal, as already shown; but it was also found that by pressure with a rounded point a little six-rayed star could be formed, the arms of which were cleavages not parallel to the sides of the prism, but at right angles to them. If, now, we take one of our sheets of mica with a straight edge produced by natural division, and strike upon it with a sharp point near the edge, we shall find that this edge is never parallel to any of the little cleavage lines, but always stands at right angles to one of them, and hence corresponds with one of the cleavages that can be induced in the mica by pressure. This is illustrated in Fig. 10 on Pl. 3. At *a*, a cleavage induced by a sharp blow is shown, which indicates the direction of prismatic planes; and at *b*, a cleavage induced by pressure is shown, and the natural edges of this strip of mica stand at right angles to a blow cleavage, and parallel to a pressure cleavage; and hence

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* *Monatsbericht der Konigl. Akad. der Wissenschaften*, Berlin, April, 1869, p. 339.

we can conclude that these divisions in this mica are cleavages that were produced in it by pressure resulting from some dislocating agency after the mica was formed. The fibres that lie in these cleavages are only much smaller cleavage strips.

Beside enclosures of a different species of mica, other minerals are found between or attached to plates of mica, and these minerals have all the peculiarity of being flattened out into discs, ribbons, or net-works,—forms induced on them by the crystallization of the mica. For example: garnets are found in the mica, which, instead of being ordinary dodecahedrons or trapezohedrons, are flattened discs; and when the mica is scaled away till it is of the same thickness as the garnet, it forms a natural setting around the crystal, which, with its fine wine color, looks very pretty in its yellow mica surroundings. Flattened crystals of tourmaline are very common. The crystals are often so thin by reason of this flattening, that they are quite transparent, and the effects of polarized light can be observed by using two of them. The minute crystals that are best seen with the aid of the microscope are the most perfect, and must be extremely thin. Two little crystals, that by chance cross one another at right angles, are shown in Fig. 10 on Pl. 2 as they were found in a piece of mica from Grafton. Nature has here prepared for us the experiment which is tried by every one in the beginning of the study of optics,—to show the beautiful principle of polarized light. Other minerals are also found. Magnetite, so thin as to be translucent; quartz, in little net-works of flat crystals; feldspar, in thin, white plates; and beryls flattened into ribbons are not uncommon.

Muscovite is easily recognized in microscopic sections of the rocks by its white color and its ready cleavage, which, in all but basal sections, is very plainly evident in the straight lines which traverse it in but one direction. Its sections are always black between crossed Nicols when its cleavage is parallel to the plane of vibration of the light; and all its sections, whether basal or not, are four times dark in a complete revolution between the crossed Nicols. It has hence all the properties of an orthorhombic crystal. It commonly is found in rocks in irregular bits destitute of crystalline outline; but in the granites it does make efforts to crystallize, as is often macroscopically evident. In the Roxbury granite, the microscope detects the most innumerable, very minute, yet most perfect crystals. This granite contains both muscovite and biotite in comparatively large scales, with no crystalline form; but some of the grains of quartz are filled with the finest little muscovite crystals. A section of this rock is represented in Fig. 2 on Pl. 5. On changing the focus, many more of these crystals are brought into view. The large mineral above is muscovite, and the black one on the right is biotite.

FELDSPAR.

In a state like ours, which is covered by crystalline rocks, feldspar is, next to quartz, the predominant mineral. All the feldspars of lithological importance are well represented, the species being,—

Anorthite, $Ca\ Al^2\ Si^2\ O^8$.
Labradorite $(Ca\ Na^2)$, $Al^2\ Si^3\ O^{10}$.
Andesite $(Ca\ Na^2)$, $Al^2\ Si^4\ O^{12}$.
Oligoclase $(Ca\ Na^2\ K^2)$, $Al^2\ Si^5\ O^{14}$.
Albite, $Na^2\ Al^2\ Si^6\ O^{16}$.
Orthoclase, Microcline, $\Big\}\ K^2\ Al^2\ Si^6\ O^{16}$.

It is useless to give localities for specimens of the species; and hence the space will be given to a discussion of those properties that are of the most importance in the approaching study of the rocks. The feldspars are all triclinic, with the exception of orthoclase, which is monoclinic, and hence easily distinguished from the others by its optical properties. Microcline, though not very evidently monoclinic in external form, is very plainly so in its inner structure, as will be shown. These two species stand isolated from the others, which are triclinic, and which all in common are subjected to a peculiar method of twinning. This twinning is not the simple revolution of one part of a crystal about the other, but is what is called polysynthetic twinning, which consists in the repetition of this process so many times that a small crystal may consist of many hundred laminæ, each one of which is revolved 180° from the position occupied by the neighboring one. To make the effect of this twinning plain, Fig. 8 on Pl. 3 is introduced. Let the figure represent a section of a feldspar crystal cut parallel to the plane of the macro-pinnacoid, and suppose that an axis of elasticity makes some given angle with the vertical axis; then, if this section is placed between crossed Nicol prisms, it will be colored, except when the elasticity axis corresponds with the plane of vibration of the light, which is when the vertical axis makes a certain angle with this plane. But, suppose the crystal to be divided up into the laminæ 1, 2, 3, and No. 2 revolved 180° about an axis at right angles to the edge *ii*, and then No. 3 revolved in the same way about No. 2, bringing it into its original position again, as illustrated in Fig. 8 *a*. It is plain that the effect of this, if often repeated, would be in the first place to cover the base O with striations running parallel to the edge of the brachy-pinnacoid, and to bring the axes of elasticity into such positions that, when they corresponded with the plane of vibration of the light in one set of the laminæ, they would not in the other set in which they occupy the reversed position; and that in two consecutive laminæ the axes of elasticity would make double the angle with one another that they do with the vertical axis of the crystal; and hence in polarized light the consecutive laminæ would be differently colored, and the section would appear banded.

The extent to which the twinning may go on is illustrated in Fig. 6 on Pl. 7, which is drawn from a basal section of a crystal of oligoclase from the Antrim granite. This section is so placed in the figure that one set of laminæ is dark, which, in a basal section of oligoclase, happens when the plane of the laminæ makes an angle of from three to four degrees with the plane of the vibration of the light. A millimetre is placed in the figure for comparison, and it is seen that there are forty repetitions of the twinning in one millimetre, or over a thousand to one inch. The yellow crystal to the right is orthoclase. All triclinic feldspars have a basal cleavage; and, as the striation is there plainly shown, they are sometimes called striated feldspars. In polarized light, the effect of twinning would be seen in all sections save those parallel to the brachy-pinnacoid, which is the plane of the laminæ. As the basal cleavage of feldspar is so easy, sections large enough for microscopic examinations are easily obtained from sizable crystals without labor; and mineralogists are thankful to Des Cloizeaux* for giving the position which the axes of elasticity bear to the brachy-diagonal axis of the crystals in basal sections of the different feldspars, and which furnishes a most ready way for their determination.

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* *Des Cloizeaux Annales de Chemie et de Physique*, 5th series, vol. iv, 1875, and vol. ix, 1876.

It is of course plain that a basal cleavage piece of orthoclase, if put on the stage of the microscope between crossed Nicol prisms, would be dark when the straight edge formed by the meeting of the brachy-diagonal and the basal cleavages was parallel to the plane of vibration of the light, since it is monoclinic. If a section of any other feldspar is obtained in the same way, and put between the crossed Nicols, it will appear as if made up of a series of bands parallel to the edge of the brachy-pinnacoid; and when these bands or this edge is placed parallel to the plane of vibration of the light, none of the bands will be dark, since no crystallographic and elasticity axes coincide in triclinic crystals; but, on turning a certain number of degrees to one side, a part of them will be dark, and, on turning the same, or nearly the same, to the other side, the rest will be dark, while the first become again brightly colored. The amount of the revolution necessary to produce these results varies with the different species, and furnishes the most ready way to discriminate between them. That is the angle that an elasticity axis makes with the brachy-diagonal can be determined, or the angle that the section must be revolved from the position, when one set of bands is dark, till the others become dark, (which would be just twice as much as the first angle, and is the angle between the elasticity axes in two parts of a twinned crystal) may be determined. These angles for the different species of feldspar, as fixed by Des Cloizeaux, are as follows:

	Angle between the brachy-diagonal and elasticity axes.	Angle between the elasticity axes in two consecutive bands.
Oliogoclase, ...	2–4	4–8
Labradorite, ...	5–7	10–14
Albite, ...	3.5–4	7–8
Anorthite, ...	27–37	54–74
Microcline, ...	15.	30.

Fig. 6 on Pl. 7 may be taken as an illustration. It is drawn from a basal section of oligoclase from Antrim. In oligoclase a plane of elasticity cuts the base, making an angle of 3° with the brachydiagonal, and hence when these striæ are placed parallel with the hair line indicating the plane of vibration of the light none of the striæ are dark, but when the section is revolved three degrees one set of bands becomes black, while the other takes a higher color. If now the section be revolved from this position six degrees in the other direction, the other set will be dark and the first set bright colored. Hence this is oligoclase, since the elasticity and brachy-diagonal axes make an angle of 3° with one another in a basal section. Now since these angles are small, and the necessity of very close measurements is evident, the mere alternations of light and darkness furnish a rather crude method of measurement. It is plain that the calcite plate put between the ocular and upper Nicol would be of no assistance since the alternations of crystals in different positions would distort the interference cross of calcite, no matter how the crystal might be placed; hence the quartz plate which Mr. Rosenbusch places over the objective in the tube of the microscope, is here of the greatest value. This quartz plate produces circular polarization, and rotates the planes of vibration of the different colors to different degrees; hence, by turning the upper Nicol we can intercept any given color that we desire. The violet color is thought by most workers to be the most delicate. If now we have the lower Nicol in its primary position with the plane of the light corresponding with one of the hair lines in the ocular, and the upper Nicol so placed as that the field of the microscope is a delicate violet, on interposing a section of a triclinic feldspar, one set of the bands of the feldspar will be of this violet color, when an elasticity axis in them corresponds with the plane of the vibration of the light, while the very slightest variation in the position will modify this color. Hence this microscopic method of measurement is very accurate, and gives a means with small basal cleavage splinters to determine the species of the feldspar. This method has been extensively used in the study on the composition of our rocks.

It has been advanced as a theory that orthoclase, albite, and anorthite are the three well defined feldspars, and that all others may be derived from them by supposing them to be composed of a mixture of a certain definite number of molecules of these admitted species. These intermediate species,—labradorite, andesite, and oligoclase,—have been classed together under the common term plagioclase, and the individual members of the group considered as subspecies. This is the theory advanced by Hunt and Tschermak, and which Des Cloizeaux's determinations are regarded as disproving. It seems to be that careful measurements can with certainty determine to which species a feldspar, of which a basal section can be obtained, should be referred; and thus the species possess sufficiently distinctive properties. But in fine-grained aggregates, where the nature of a feldspar can be only approximately determined, and where the difference between these kinds of feldspars is of no lithological importance, plagioclase is a good general term for use, and it has become so rooted in lithology that it is liable to maintain its foothold, though perhaps in this modified sense. It seems that species of feldspar may grade into one another as other minerals do, where no theory is considered necessary to account for it; so, as referring to a subgroup of the triclinic feldspars, it must be granted that the word plagioclase is convenient, and in this sense it will be used. The three kinds of plagioclase will be treated of as distinct species whenever the composition of a feldspar is known with certainty, and plagioclase will refer to imperfect or approximate determinations. The question, whether these three members of the plagioclase group should be merged into one mineralogical species, is of little practical importance, so long as the subject is so well understood as at present.

57. ANORTHITE [$Ca\,Al^2\,Si^2\,O^8$].

This kind of feldspar is a constituent of some of our diabase rocks and greenstones. It is contained in some of the calcareous diorites in the Connecticut valley, but the most notable specimens are found in the diabase at East Hanover. There a rock occurs that is filled with large crystals of this species. They are dull on their surfaces, but they possess quite a number of planes, the prominent ones being the base, the domes 2 ĭ, 2 ī, and the prismatic faces I and i ĭ; and some edges are rounded off as if an effort were made to form other planes. These crystals are often an inch in length and breadth. Some are flat, and others, by a greater development of the prismatic planes, are thick and short. The rock is so full of them that it is an anorthite porphyry.

These crystals are no less interesting because they have undergone an almost complete alteration. Before referring to this, it will be well to recall that anorthite is commonly subject to the polysynthetic twinning, which makes its base striated, and its sections, in polarized light, banded. A basal section, when placed between crossed Nicols, with its bands parallel to the plane of vibration of the light, must be revolved through a much larger angle than any other feldspar, the angle for anorthite being from 27° to 37°, through which it must be turned in order to produce in either of its sets of laminæ a maximum of darkness.

If, now, a section of one of these fine anorthite crystals is cut, nothing of the kind is to be seen. The section placed between crossed Nicols appears made up of the most immense number of minute particles; the field is uniformly light; and, on revolving the section, no effect whatever is produced, and no point of maximum darkness is obtained. In other words, these crystals possess aggregate polarization, and are no longer feldspar; but the large crystal is made now of an immense number of little ones lying in every possible direction. I analyzed this feldspar product, with the following result:

	Anorthite. Hanover.	Typical anorthite.
Silica,	52.52	43.10
Alumina,	30.05	36.90
Iron sesquioxide,	1.10	.....
Lime,	2.20	20.
Magnesia,	.30	.....
Potash,	7.11	.....
Soda,	3.77	.....
Water,	2.67	.....
	99.72	100.00

Here is seen the progress of a change, which may result in the conversion of a basic into an acidic rock. Lime is removed, alkali is gained; and, while other minerals decompose, losing all their bases, and leaving residues of silica, here we see how this most basic feldspar is approaching to that composition, which, with the addition of some silica and a recrystallization, can form the orthoclase of our granites.

Now, smaller crystals of this same feldspar in the rock are not so entirely decomposed; and as the case is instructive, and the decomposition so prettily seen in progress, I add a drawing of a section of one of the crystals, which is seen in Fig. 3 on Pl. 5. The outside of the crystal is entirely altered into an aggregate, while within the fresh material shows the bands characteristic of triclinic feldspars. On revolving this section between crossed Nicols, the feldspar within shows alternations of color and darkness, and its optical properties can be determined, while the oustide of the crystal is always colored, and no optical property can be recognized, save those of an aggregate of minute needles.

What the product of this decomposition is, is of minor interest. The change has resulted in the production of a substance of a higher specific gravity, the gravity of the specimen analyzed being 2.96, while that of anorthite is 2.75. It is the substance called saussurite. Hunt found this saussurite in some Swiss rocks to approach, in composition and gravity, to zoisite. It may be that this saussurite is one mineral or more, and it may vary in composition according to the degree of the change. A number of other names have been given to this product by different analysts. Saussurite is the best known term among lithologists, to whom the subject is of the most interest.

Anorthite is often associated with labradorite in our basic rocks. When this is the case, the anorthite is usually in large crystals or grains, while the labradorite crystals are very small. The reason is, that the anorthite is much less fusible, and hence in rocks cooled from igneous fusion, the anorthite would crystallize first, and would have an opportunity to form larger crystals in the still plastic mass.

58. LABRADORITE [$(Ca, Na^2)\ Al^2\ Si^3\ O^{10}$].

This is a feldspar of much importance in our state, for it is an ingredient of the larger part of our basic rocks. Its study is therefore one chiefly of lithological interest.

On Mill mountain in Stark, very large masses of an apparently pure labradorite occur. It is an aggregate of crystals, but the microscopic sections bring to light such an amount of biotite and hornblende as to show that the rock is allied to the diorites. This is the most pure labradorite that we find. The rock is like one which occurs at Edenville, N. Y., and is allied to some of Hunt's norites.

Labradorite is subject to polysynthetic twinning. In basal sections, as already explained, it can be distinguished from other species, since a plane of elasticity cuts the base, making an angle of from five to seven degrees with the twinning plane.

In the labradorite from Stark, the angle is five degrees to one side and six to the other, making eleven degrees between the point when one set of laminæ is dark, and when the other set becomes dark.

But triclinic feldspars, and labradorite in particular, are subject to another system of twinning. In this case the base is the common face, and the axis of revolution is a line lying in the base and at right angles to the edge between the brachy-pinnacoid and the base. The twinning is repeated, as in the first case. This produces striations on the brachy-pinnacoid, and bandings of color in sections cut parallel to that face, and which are parallel to the edge between that face and the base. If, now, a section be cut parallel to the macro-pinnacoid, between crossed Nicols, both these systems of twinning will be seen at once; and in the Stark labradorite this is often the case, as well as in all the labradorites that are to be spoken of. This double system of twinning is shown in Fig. 4 on Pl. 5. Wide bands are shown which represent the laminæ parallel to the brachy-pinnacoid, and in the laminæ *a* and *b* are seen cross bands that are parallel with the base, and which make nearly a right angle with the plane of the other bands (the inclination of the base on the brachy-pinnacoid being 93°), and hence in two consecutive bands these striæ make a very obtuse angle with one another (174°). In feldspars that are more finely striated this inclination of the laminæ to one another is not plain, and the same cross band seems to run through several laminæ, giving a netted appearance to the crystals.

The labradorite of the gabbros possesses peculiarities. It was first shown that the feldspar of the gabbros at Waterville and Mt. Washington river is labradorite by Mr. Dana and Mr. Hunt, who analyzed that which is found at Waterville, while that found on Mt. Washington was analyzed by Mr. B. T. Blanpied, of Hanover. These analyses are as follows:

	Waterville (Dana[*]).	Mt. Washington (Blanpied[†]).
Silica, ...	51.03	51.50
Alumina, ...	26.20	25.90
Iron sesquioxide, ...	4.96	5.00
Lime, ...	14.16	14.29
Soda, ...	3.44	2.95
Potash, ...	.58	.50
	100.37	100.14

This feldspar[‡] is dark in color, and is covered with fine striations.

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[*] *Am. J. Sci.*, iii, vol. iii, p. 49.

[†] *Hitchcook's Ann. Rep. Geology N. H.*, 1871, p. 27.

[‡] This same feldspar was also analyzed by Dr. Hunt, with a result essentially the same. I have selected Dana's analysis because it was first published. Hunt obtained SiO_2 50.30, Al^2O_3 25.10, Fe^2O_3 4.23, MgO 2.95,

The quantivalent ratio, in Mr. Dana's analysis of the protoxides, sesquioxides, and silica, is as 1 : 3 : 5.5, which indicates a trifle less silica than typical labradorite, the result being a little irregular, as remarked by Mr. Dana, on account of the presence of microscopic grains of a titanic magnetite, which with the greatest care could not be all separated. A glance at this labradorite in a thin section indicates the impossibility of obtaining pure material for analysis. The analysis of Mr. Blanpied agrees very closely with that of Mr. Dana, both showing a labradorite rich in lime, and containing the same impurities, as is confirmed by my microscopic sections.

The microscope indicates in this feldspar a system of twinning like the labradorite of our other rocks, but the regularity and parallelism of the bandings are markedly absent. The feldspar is fresh and undecomposed, and the bands receive the highest color in polarized light; but the individual striations are very narrow and often irregular, on account of the complex nature of the grain. The appearance of the feldspar is seen in Fig. 1 on Pl. 10. Among the microscopic impurities of this feldspar are olivine, biotite, and magnetite, but more interesting than these are the microscopic black needles that are represented in Fig. 5 on Pl. 5. The presence of these crystallites is very characteristic of the feldspars of gabbros; and they have been investigated by many observers, notably by Schrauf,* who studied the feldspar of gabbros from Labrador. He finds little plates, the nature of which he is unable to determine, inlaid in two planes parallel to the edge between the macro- and brachy-pinnacoids, but which are not planes occurring on labradorite crystals. The reflections from these plates produce the aventurine effect of labradorite. These plates are not present in our feldspar, and hence it is not aventurine; but the needles are sometimes present in multitudes, and most abundant in the centres of crystals. They are usually found inlaid parallel to the basal and prismatic cleavages; but in our gabbro, it appears as though their arrangement were quite complex. This section in polarized

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CaO 14.07, soda and potash, 2.65=99.30. (*Hitchcock's Ann. Rep.*, 1871, p. 27.) The quantivalent ratio of this analysis is as 1 : 2.2 : 4.6. This, which is a wide variation from labradorite, is explained by Dr. Hunt by the presence of biotite which he recognized, and it is true that the rock contains some biotite; but there is none of the rock which, under the microscope, is not seen to contain much chrysolite as an essential ingredient, and this, it seems to me from microscopic investigation, must be the main cause of the variation, since its presence would account for the variation very exactly, while the biotite is but sparingly present.

* *Wien. Akad.*, Ber., lx, 996.

light shows no bandings, and is consequently parallel to the brachy-pinnacoid, while a cleavage line indicates the direction of the base; hence we know the position of the crystal section. As is usual, it is plain from the figure that the most of these needles are parallel to the vertical axis, since they make an angle of 112° with the cleavage. Parallel to the base there are only a few, but those that lie in this direction are all notably very long. Both of these sets of needles are in the plane of the section or brachy-pinnacoid. There are, then, two more sets, making with one another a little more than a right angle, which is nearly bisected by the vertical. These needles are also numerous, but they do not lie in the plane of the section, but pass very obliquely through it, and hence lie in the plane of some octahedral faces, the angles of which cannot be ascertained on account of the obliquity. The needles are referred to augite by Schrauf. These structural directions indicate an interior development of these irregular grains, according to quite a complex crystalline form.

The labradorite is often crystallized in the diabases, giving to them a pretty porphyritic character. These crystals are often quite noticeable, both from their form and the beauty of their sections. The feldspar of a somewhat decomposed gabbro from Waterville was analyzed by Mr. E. S. Dana,[*] with the following result:

Silica,	52.25
Alumina,	27.51
Iron sesquioxide,	1.08
Lime,	13.22
Magnesia,	.99
Soda,	3.68
Potash,	2.18
	100.91

The accession of potash and all the other characteristics of change are here seen, but only in an incipient form. A point of interest is remarked by Mr. Dana, that the New Hampshire labradorites are remarkable for their high percentages of lime.

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[*] *Am. J. Sci.*, iii, vol. iii, p. 50.

59. Andesite $[(Ca, Na^2)\ Al^2\ Si^4\ O^{12}]$.

This is the feldspar intermediate in composition between labradorite and oligoclase. The necessity of its recognition as a species is questionable, since, chemically considered, the lines of its division from the two species mentioned are indistinct, and, optically, it cannot be distinguished from oligoclase.

A feldspar occurs in the Dixville Notch, which is very noticeable on account of its very clear, glassy lustre, and its perfectly undecomposed appearance. It is found in the diorite, which by its decay has formed a bed through which a stream runs, and forms the Twin cascade,—one of our most beautiful falls. It gives the rock a remarkable appearance, for it is found in rounded pieces as large as walnuts, and the rock, when broken open, exhibiting these large, round, glassy spots, and large, black hornblende crystals, is quite striking in appearance. It would make a beautiful stone, if polished. This feldspar has a cleavage in two directions, as usual, though it often shows conchoidal fractures like quartz, which are deceptive. The crystals are twinned, but the separate laminæ are broad, and there is, consequently, not such a fine striation as is common in these species. My analysis of this feldspar from Dixville is as follows:

Silica,	56.24
Alumina,	26.95
Iron sesquioxide,	tr.
Lime,	9.37
Soda,	4.93
Potash,	1.25
Water,	1.15
	99.89

This analysis gives as a quantivalent ratio, 1:3:7, which shows it to be one of those varieties intermediate in composition between labradorite and oligoclase, and may be called andesite. A basal cleavage piece shows that an elasticity axis makes an angle of four degrees with the edge of the brachy-pinnacoid, which is an angle to which oligoclase sometimes reaches. Its sections show that it is pierced with a few large apatite needles, not enough, however, to influence the analysis.

This mineral shows very well the greater power which a pure, glassy feldspar possesses to resist decomposition, for it shows not the slightest change either in pieces or under the microscope.

60. OLIGOCLASE [(Ca Na^2 K^2) Al^2 Si^5 O^{14}].

This, again, is an important and frequently occurring feldspar in our rocks. At Orange summit, specimens suitable for the cabinet are found, but its chief interest is lithological. The feldspars thus far considered are characteristic of basic rocks; but oligoclase being of a more acidic character, is often found with orthoclase in such rocks as granite, sienite, hornblende schist, and the like, and is more widely disseminated than was suspected before the microscope was brought to aid rock analysis. In thin sections of these rocks it is very easily distinguished from its associate orthoclase by its triclinic character, and its banded structure produced by twinning, which is so evident in polarized light. Sometimes this mixture of orthoclase and oligoclase is macroscopically apparent, when the rock is coarse-grained in texture; for in such cases the feldspars are often of different shades of color, and the oligoclase can be distinguished by its greater tendency to alteration, which causes cleavage surfaces, where exposed, to appear duller than do those of the orthoclase; and though cases exactly the reverse have been observed by Zirkel and Rosenbusch, it may be regarded as the general rule. It may also be distinguished by the striations, which are sometimes apparent, and which are superficially developed, sometimes by weathering, when they cannot be seen on fresh surfaces of rock. Their presence may be regarded as conclusive of the triclinic character of the feldspar, though their absence is not equally so.

In sections of the rock the bands of color produced by a twinning are often extremely narrow, and the absence of superficial striation on oligoclase is perhaps often due to the extreme fineness of the lines. In Fig. 6 on Pl. 7, a basal section of a grain of oligoclase from the Antrim granite is shown. The bands of color are very thin, there being here a thousand to an inch, and they are also of extreme regularity, as is quite usual in the oligoclase of granites. The section is so placed in the drawing as that one set of laminæ are dark, and the laminæ make an angle of 3° with the spider line in the ocular. It must be turned 6° in the other direction to make the other set dark. The yellow mineral to the right, without bands of color, is orthoclase.

61. ALBITE [$Na^2 Al^2 Si^6 O^{16}$].

This feldspar is found in the great granite veins such as exist in Grafton, Acworth, Alstead, etc.; and in mining for mica very large amounts of it are extracted and thrown away. It occurs in tabular, white crystals belonging to the variety called clevelandite. It is whiter than the orthoclase with which it is associated. It is often crystalline; and in places where the veins are cavernous, fine bright crystals of the ordinary form are found. The crystals are twinned according to the rule for triclinic feldspars. The optical properties of sections have already been given.

Our albite from Alstead* was analyzed by Prof. J. D. Whitney, with the following result:

Silica,	70.83
Alumina,	21.20
Soda and impurities,	7.97
	100.00

Albite is not an important mineral in our crystalline rocks. G. Rose stated that albite was never present as a constituent of rocks. This has been shown to be otherwise. It does exist in small amounts in some of our granites, where it is associated with orthoclase and characterized by an excessively fine striation.

62. ORTHOCLASE [$K^2 Al^2 Si^6 O^{16}$].

This, the most common feldspar, is monoclinic. Its basal and brachydiagonal cleavages make a right angle with one another, and basal sections are consequently black between crossed Nicol prisms when the sharp edge formed by these two cleavages is parallel or perpendicular to the plane of vibration of the light. It is subject to twinning; but one crystal is rarely composed of more than two parts,—hence in the rocks it is never confounded with any other species of feldspar.

The orthoclase of the most mineralogical interest is found in the mica quarries at Acworth, Grafton, etc., where very large crystals from eight

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* *Geology of New Hampshire*, Dr. C. T. Jackson, p. 178.

to ten inches in diameter are not uncommon. The forms of the crystals are simple. They are rarely perfect, but their great size makes them interesting. The feldspar of these quarries is not economized, though similar veins in Connecticut, where the mica is of a poor and unmarketable quality, are worked for the orthoclase alone. The feldspar is valuable for the manufacture of porcelain.

In our granitic rocks orthoclase forms crystals of considerable size, producing porphyritic rocks. In these cases the crystals are very commonly twins, recognizable macroscopically as such by the different reflections of light from the two sides of the crystal, the cleavage faces of which are differently inclined. Crystals of orthoclase, freely developed in cavities, are twinned according to one of four different methods; but ingrown crystals, with which we have mostly to deal, are almost always what are called Carlsbad twins. These twins are formed as if the crystal were divided in two by a plane parallel to the clino-pinnacoid, and then one half revolved 180° about an axis perpendicular to the ortho-pinnacoid, and the two parts united together again, or grown into one another. The clino-pinnacoid, by the large development of which ingrown crystals are commonly flattened, is therefore the composition face, but not the twinning plane. Examples of ingrown Baveno twins, though uncommon, are not unknown; and a crystal of this nature is represented in Fig. 4 on Pl. 10, and is described under the head of quartz porphyry.

Orthoclase in granites, sienites, porphyries, etc., is white, flesh-colored, or red. In our oldest gneisses, its crystals are flattened and rounded, and surrounded by black mica, which gives them the appearance of eyes, from which these gneisses have gained the name of augen gneiss. The appearance of the porphyries is much modified by the color and lustre of the feldspar. They are light in color when it is white and opaque; it sometimes makes them red, and when the feldspar is colorless and transparent they are nearly black. The latter is the character of some of the porphyries about Albany, and these rocks, when held in a proper position, exhibit a beautiful play of colors that proceeds from the feldspar. This play of colors is most characteristic of labradorite; but in our state there is no labradorite that exhibits such a beautiful opalescence as this orthoclase. This rock, if polished, would make a most beautiful ornamental stone. These colors in orthoclase have been shown by Reusch to be due to a cleavage of extreme delicacy parallel to the plane of the clino-diagonal, producing interference colors like those of thin films.

It is to be regretted that the various analyses that have been made on New Hampshire orthoclase have been unaccompanied by optical microscopic work, since triclinic feldspars are so often thus seen to be associated with it. Enough has been done to show, however, that our orthoclase usually has a part of its potash replaced by soda. Jackson found this so in the orthoclase from the granite veins, which may be assumed to be pure. As typical of many analyses of the orthoclase of our rocks, the following by C. A. Seely, of a specimen from Bartlett, is selected:

Silica,	66.06
Alumina,	20.04
Iron oxide,	trace.
Lime,	2.08
Soda,	7.28
Potash,	5.47
	100.93

Typical orthoclase contains silica, 64.6, alumina, 18.5, potash, 16.9. The analysis indicates the large replacement of the potash; and all the analyses that have been made show the same thing. Des Cloizeaux regards such analyses as indicating the existence of a soda feldspar isomorphous with orthoclase.

In thin sections, orthoclase is commonly seen as grains which show more or less of an effort at crystallization. It is a fact of lithological importance that the fusible feldspar formed its crystals in these common acidic rocks before the infusible quartz did. At times these crystals are quite perfectly developed, and then they have the quadratic, rhombic, and hexagonal forms that would be expected from common crystals of orthoclase. In old rocks like ours, orthoclase usually appears more or less impure on account of the minute particles of foreign substances, and pores, and cleavage planes that exist in it. It often contains mineral enclosures, such as little scales of mica, particles of hornblende, etc., but the rare occurrence of the cavities containing fluids, which are so uniformly present in the quartz, is very noticeable. Cavities often exist in it, but they are commonly empty, as is shown by their sharply defined outline. When examined with polarized light, twin crystals are most easily recognized, since the two parts are very differently colored, and stand sharply separated from one another.

The microscopic study of the granites reveals some peculiarities of interest, one of which may be noticed here. Often a grain of feldspar is found which consists of laminæ, or parts arranged at nearly right angles to one another. This subject has been discussed by many writers. Zirkel has shown that this effect is sometimes produced by the alternations of pure and impure orthoclase. Again: this is the characteristic structure of microcline which occurs interlaminated with orthoclase, as shown by Des Cloizeaux, and which will be considered beyond; moreover, it is a well known fact that orthoclase and albite are sometimes interlaminated in this way. It is to such an interlamination that I now refer. Occasionally in the Concord granite, crystals of orthoclase are found which are quite impure and ingrown with them. They are very pure white crystals, which are arranged in two directions at right angles to one another, as shown in Fig. 6 on Pl. 5, and which in polarized light show the finest striations and the characters of albite. These crystals are arranged parallel and perpendicular to the clino-diagonal, since the optical deportment indicates that this section is nearly basal. I introduce this pretty case so that such a kind of interpenetration may not be confounded with what follows. Rosenbusch has observed some effects of this kind.

Another kind of interlamination of orthoclase is not uncommon in our rocks, which is illustrated in Fig. 1 on Pl. 8. This figure represents a crystal of orthoclase as it is commonly seen in the sections of granite from Chocorua mountain, when polarized light is employed. Each crystal is composed of a great number of irregular laminæ, all having a common direction, and which are invisible in ordinary light. The reason of this is, that the elasticity axes have a different position in one set of laminæ than they do in the other, and the two sets, therefore, do not become dark between crossed Nicols at the same point; but between the position in which one set of laminæ becomes dark, and in which the other set becomes dark, there are a few degrees of difference. This causes the laminæ to assume different colors in any position between the Nicols. This variability of the axes in monoclinic crystals is not at all uncommon.

63. MICROCLINE $[K^2 \, Al \, Si^6 \, O^{16}]$.

Microcline is a feldspar of the same composition as orthoclase, but differs from it in being triclinic. Its position as a species has been fixed by Des Cloizeaux. The difference in the angle of its planes that determines it to be triclinic is very slight, for the angle between the base and the clinopinnacoid varies but 16′ from a right angle,—a result obtained as the mean of many measurements. This difference is of course imperceptible to an ordinary observer; but the optical distinctions are so marked that its determination becomes very easy. As already explained, a basal section of orthoclase is black between crossed Nicols when the edge of the clino-pinnacoid is parallel to the plane of vibration of the light. If, now, a section of microcline is placed in the same position, it will be brightly colored, and will not be dark until it is revolved 15° from this position. This indicates that a plane of elasticity normal to the plane of the lateral axes cuts the base, making an angle with an axis,—a property of triclinic crystals.

Microcline is most commonly green, forming what is called Amazon stone. At the Notch very pretty crystals of green orthoclase occur, and also a more massive variety. I have examined this feldspar, and, as might be anticipated, it proves to be microcline. As is the case with microcline in general, it possesses a complicated structure induced by twinning, which takes places in planes parallel and perpendicular to the clino-pinnacoid, and accompanied with this twinning there is also an interlamination of orthoclase in the same planes. Therefore a basal section of our Amazon stone, when examined in polarized light, appears as made up of innumerable laminæ running at right angles to one another. Its appearance between crossed Nicols is illustrated in Fig. 2 on Pl. 8, which is drawn from a section of this Notch microcline. It is placed in the figure in such a position that the edge of the brachy-pinnacoid is parallel to the plane of vibration of the light, as indicated by the lines. Now, in this position the orthoclase will be black like the field to the left, and it is plainly seen in bands of various lengths and breadths, while the larger part, being microcline, is highly colored, and one part of it becomes dark on turning 15° to the right, and the rest, on turning the same amount to the left.

Now in sections of our granites and gneisses, crystals with this structure are not uncommon, and it is often possible to prove them to be microcline mixed with orthoclase. It is probable that they are always partially microcline. The Roxbury and Troy granites furnish examples in which quite large grains exist, which can be demonstrated to be microcline. Des Cloizeaux shows that albite is also commonly interlaminated in smaller or greater amounts, recognizable by the small angle at which, in albite, the extinction of light takes place between crossed Nicols. The green color of these crystals has been supposed to be due to the presence of a trace of copper, of protoxide of iron, and of organic matter. Analysis detects no copper, but a little heat destroys the color, which supports the idea that it is due to a minute amount of some organic substance.

64. TOURMALINE $[(K,^2 Na,^2 H^2) (Mg, Fe)^2 (Al,^2 B^2)^3 Si^4 O^{20}]$.

Tourmaline is a very common mineral, and also offers some peculiarities in our state. It is hexagonal, and is found in three-sided prisms, which by the multiplication of prismatic faces, become sometimes nearly cylindrical. When well crystallized it is usually terminated by the three planes of the rhombohedron $-\frac{1}{2}R$, or by a combination of this with other rhombohedrons. It is generally black; but light brown crystals are also found, which are more highly prized on account of their rarity. The great granitic veins are the most noteworthy localities, though tourmalines are scattered through all the old schists, and are common in some granites.

At Springfield very large crystals are found, which are quite unique from the extraordinary development of the basal plane. Fig. 3 on Pl. 3 is drawn from one of them. The crystals, which are short and thick, and possess the planes represented in the figure, sometimes reach the great size of five inches in diameter, still maintaining their perfection and habit. They occur in the granitic veins.

The best brown tourmalines are found at Orford, where they have crystallized in a bed of steatite, and often are of a large size. Crystals six inches long and two in diameter have been found, but more often it occurs in radiating masses of imperfect form. Brown tourmaline, in a massive condition, is found at Warren.

Blue and green tourmaline, called indicolite, is found at Hinsdale, and also abundantly in a granite near Winchester.

As localities that are of note for black tourmaline, may be noted Grafton (small, stellated forms of great beauty, and single fine crystals; communicated by Mr. A. Brown), Sullivan, Unity, Newington, Barrington, Bedford, Moosilauke mountain, Hinsdale, Chichester, Goshen, Lyme, Moultonborough, Saddleback mountain, White Mountain Notch (very large), Monadnock mountain, Surry, and Mt. Kearsarge. Pretty specimens, formed by needles of black tourmaline piercing white quartz, have been found at Hanover, Gilmanton, and Haverhill. A mineral, thought to be the kind of hornblende called bentonite, which is found at Lebanon, has been shown by Pisani of Paris to be bladed tourmaline.

The finest tourmalines that are taken from the granitic veins, occur in quartz; but the mineral is also found associated with the feldspar and mica. When in the mica the crystals are usually flattened out into blades, and these blades are often so thin that they are translucent, and can be used as polarizers (see p. 85). I think that good specimens for the making of a polariscope could be obtained from Grafton.

The difference of color in tourmalines is much dependent on the percentage of iron they contain, which is quite variable. The black tourmalines contain much iron, and the brown tourmalines, little. The composition of our tourmalines is well illustrated by the two following analyses made by Rammelsberg.* The first one is of brown tourmaline from Orford, and the second is of the black tourmaline from Unity:

Silica,	38.33	36.29
Boric acid,	9.86	9.04
Alumina,	33.15	30.44
Iron protoxide,	2.88	13.23
Magnesia,	10.89	6.32
Lime,	.77	1.02
Soda and potash,	1.52	1.94
Water,	2.81	1.72
	100.21	100.00

These analyses agree with the formula given above; and the great difference in the amounts of iron contained in the brown and black varieties will be noticed. The blue and green varieties, like those at Hinsdale,

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* *Handbuch der Mineral Chemie*, 1875, p. 541.

usually contain some lithia, and are referred by Rammelsberg to a second division of the species. They contain no iron, and have a different general formula, the difference being mainly produced by a higher percentage of alumina.

Beside the localities mentioned, tourmalines are abundant in many of our rocks in such quantities as to excite interest, though cabinet specimens are not common. For example: all through the White Mountains little tourmalines are seen here and there scattered through the schists. Sometimes they are very abundant, and of considerable size, and sometimes they are very small and sparsely disseminated.

The power which tourmalines possess to polarize light depends simply on the circumstance that the light only passes through the crystal parallel to the vertical axis, the vibrations at right angles thereto being absorbed. This gives a most ready means for recognizing tourmalines in rock sections, since those sections which are cut parallel to the prism, when placed under the microscope with only the lower Nicol on the instrument, are light colored when the longer axis of the crystal is parallel to the plane of vibration of the light, and almost black when placed at right angles to it. Basal sections must therefore be nearly opaque, and do not change on being revolved. Biotite, hornblende, and other dichroic minerals possess perfect cleavages, while tourmaline has none. Microscopic tourmalines are often seen in our rocks.

65. ANDALUSITE [$Al^2 Si O^5$].

This silicate is very often found in our rocks. It crystallizes in square prisms of the orthorhombic system, which vary in size from microscopic bits to crystals an inch square. Their surfaces are never smooth, and their edges are usually rounded. At times, crystals or portions of crystals are pure, and possess a vitreous lustre; but, on the other hand, andalusite is more common, which presents itself as a mere hard, irregular spot in the rock, which becomes prominent on account of its greater ability to withstand the weather. Moreover, the centres and surfaces of the prisms often differ in their power of withstanding decay; and hence crystals are often found which have become hollow cylinders, a result of the rotting out of the centre. Again: both surface and centre resist while the rest gives way, and we then obtain a hollow cylinder with a core. The crystals are ordinarily gray in their color. The White Mountain Notch, Boar's Head (near Rye, in boulders), Charlestown, Troy, Rochester, Farmington, Mt. Kearsarge, Mt. Pequawket, Mt. Monadnock, and Andover, are a few localities where good crystals are found.

The variety of andalusite called chiastolite is abundant in our state, and many rocks are beautified by the very pretty figures with which this mineral dots them. Sections across the ends of these crystals show crosses, squares, etc., due to the regular arrangement of impurities, which produce the black figures on a white ground, with which all are familiar. The microscope shows that these black portions are made by little black scales enclosed in the pure material, and, as a little heating destroys them, they are supposed to be coaly, bituminous matters. Chiastolite abounds on some parts of Mt. Washington, in Walpole, Albany, Alstead, Langdon, and Rye, and poorer specimens are found in many other places. Chiastolite is always found in argillitic rocks.

If we obtain sections of crystals of andalusite we might suppose that they would exhibit the characters of an orthorhombic crystal, but this they rarely do. On revolving them between crossed Nicol prisms, no point of maximum darkness is found, but the field remains light all the time, and shows only the effects of aggregate polarization. This of course indicates an alteration of the crystal; and we have the material for observing its progress and result. Even the hardest and apparently most unaltered crystals under the microscope show alterations, as indicated by the multitudes of minute crystals which radiate from the cleavages. These cleavages are parallel to the faces of the primary prism, which has an angle of almost 90°. These secondary crystals are made visible by polarized light, and cause the section to assume a most beautiful appearance when thus examined. Fig. 1 on Pl. 6 represents a basal section of such a crystal, in which this incipient alteration is shown. It is of course impossible to indentify the mineral species into which the andalusite is here turning; but last summer Prof. Brush brought some andalusite crystals from New Preston, Conn., which he allowed me to cut. The inner structure of these crystals is illustrated in Fig. 2 on Pl. 6. Here it is evident that a complete alteration of the crystalline arrangement has taken place, for the section figured is a basal one. None of these crystals are dark between crossed Nicols when parallel with the plane of vibration of the light, which indicates that they are probably triclinic. The specific gravity of andalusite is 3.1, while the specific gravity of these altered crystals is 3.56, as proved by several determinations by Prof. Brush. My analysis of these crystals was as follows: Silica, 37.90, alumina, 62.12, water, .90 = 100.92. Now all these characters belong to cyanite, and demonstrate that a tendency exists in andalusite to alter the arrangement of its particles from the form of andalusite into the triclinic cyanite, which has a higher specific gravity, but the same chemical composition. The natural outer angles of these crystals are often much distorted by this change, and on examining a number of crystals wide variations were found in those angles that should be uniform. A still further process of alteration converts andalusite into mica, kaolin, etc., making it opaque and lustreless. Therefore the microscopic study of andalusite becomes a study of aggregates of other minerals.

66. FIBROLITE [Al^2 Si O^5].

This mineral is the same in composition as andalusite, and differs from it only in the greater angle of its prism and the smaller angle of its optic axes, neither of which is a consideration with which we can deal, since it is only found in fibres in the schistose rocks. That it really has some specific difference is evident from the circumstance that it does not decompose as does andalusite, but, although in small crystals, is usually clear and fresh.

Fibrolite exists in some of the schists of the White Mountains in such amounts as to give a character to the rock. In thin sections it is recognized as orthorhombic, by noting that the fibres all become black when they are parallel to the plane of vibration of either one of the crossed Nicols. The interference colors that are obtained when it is in any other position are very bright. In Fig. 3 on Pl. 8 a section of fibrolite schist from the Notch is represented. The fibrolite pierces the biotite and the quartz in such a way that it is plain it was the mineral first formed in this schist, with the exception of the little magnetite grains, a few of which are included in the fibrolite. Winchester is another locality where fibrolite abounds.

67. CYANITE [$Al_2 Si O_5$].

The ordinary blue, bladed crystals of this mineral abound in many localities in our state. They are conspicuous, and easily recognized. These blades are made by the meeting of prismatic planes, which make an angle with one another of 106°, and which are also the cleavage planes; hence, in thin sections of the rocks, cyanite, when cut parallel to the base, appears as composed of many little rhombs. In thin sections it can easily be recognized as triclinic, since none of its sections are dark when the prism is parallel with the plane of a Nicol. This can also be tried with cleavage bits, that are so easily obtained; but it is to be noted, that unless they are very thin, no result is obtained, since the large crystals are so often composed of little crystals in twinned positions that the splinters, if not very thin, are always colored when revolved between the Nicol prisms. Bellows Falls, Lyme (in the north-west part), Jaffrey (Mt. Monadnock), Orford, Warren, Hanover, and Norwich, Vt., are places where good specimens of cyanite can be obtained.

68. TITANITE (SPHENE) [$Ca Ti Si O^5$].

This is not of much mineralogical interest, save as a rock constituent, in which condition it is widely distributed, though rarely visible except with the microscope. It commonly presents itself in rounded grains, but sometimes the rhombic and six- or eight-sided forms, which are obtained by cutting its common crystals, are seen. The sections are usually greenish-yellow and dichroic, but, owing to the faintness of its color in thin sections, it is not always possible to observe this. In color and dichroism it looks like epidote, from which it is easily distinguished, because, between crossed Nicols it gives scarcely any colors, while epidote gives very brilliant interference colors.

In our rocks titanite appears usually to be a product resulting from the decomposition of titanic iron. For example: it has been explained that the titanic iron in our greenstones is often subjected to a peculiar kind of decomposition. Now, where the skeletons of titanic iron are most abundant, there the sphene is found in the largest amounts. As was stated, the iron of titanic iron being removed, the product remaining has been shown by Prof. Lasaulx to be titanate of lime, but, if silica takes part in the reaction, sphene is formed. The diorites and amphibolites about Littleton are rocks in which sphene is common.

Again: on the road from the Glen house to the top of Mt. Washington, some large dykes of diabase occur. They are full of titanic iron. Now, on the junction of these dykes with the surrounding rock, a thick layer of a very ferruginous chlorite occurs, which is a product of the decomposition of the trap. This chlorite is filled with crystals of sphene. This association of minerals is common, and perhaps may often be explained in this way.

69. STAUROLITE [$H^2 (Mg, Fe)^3 Al^{12} Si^6 O^{34}$].

Staurolite is very common in our slaty rocks. Here as elsewhere it is found in the twin crystals, from which it derives its name. The crystals cross one another at right angles when the twinning plane is the prismatic one, and at 120° when the plane is octahedral. The crystals vary in color from light to dark brown, and, though sometimes nearly transparent, are often well-nigh opaque from the presence of impurities. Staurolite is abundant in the mica slates about Lisbon, and at Mink pond in that neighborhood they are found loose in the soil, having been washed out of the decomposing rock. Large brown crystals occur at Franconia, and very large crystals at Charlestown. Mt. Washington, Grantham, Bellows Falls, Walpole, Enfield, and West river, Vt., are localities that are notable for staurolite, though they are found all along the Connecticut valley. It is very often associated with garnet.

Though the chemical composition of some varieties of staurolite corresponds to the formula given, it varies greatly, as is shown by the two following analyses of staurolite from our state by Rammelsberg.* The first is of a brown crystal from Franconia, and the second of one of the clear deep brown crystals from Lisbon.

	Sp. Gr. 3.76 Franconia.	Sp. Gr. 3.41 Lisbon.
Silica, ...	35.36	49.10
Alumina, ...	48.67	37.70
Iron sesquioxide, ...	2.27	....
Iron protoxide, ...	13.05	10.69

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* *Mineral Chemie*, p. 590.

Magnesia,	2.19	1.64
Ignition,	.27	.68
	101.81	99.81

This very great difference in the two analyses is explained by the circumstance that the staurolite with a high percentage of silica is rendered impure by the enclosure of quartz, as has been proved by a number of investigators; and these irregular varieties, when purified from the quartz by treatment with hydrofluoric acid, as was done by Rammelsberg, give, on analysis, a composition which corresponds also with the formula. This admixture of quartz is apparent in the specific gravity which sinks from 3.76 in the purer variety from Franconia to 3.41 in the impure variety from Lisbon. Sections of the Lisbon staurolite show the quartz, which is present as large clear grains scattered through the interior of the crystal.

Staurolite forms macles, or tessellated crystals like andalusite; but this is a rare occurrence, and I am not aware of such having been observed save those noticed by Jackson at Charlestown, in our state. These macles of staurolite are made in the same manner as the andalusite macles by the symmetrical arrangement of pure and impure material. Fig. 8 on Pl. 2 represents the base of one of these crystals. They are found in the mica slate, which Jackson states gradually passes into an argillite, and with it the character of the crystals changes till they become andalusite macles in the argillite.

This staurolite is not in twin crystals; a rare occurrence, since staurolites which are apparently simple usually prove to be compound when cut and examined. These peculiar macles have been examined by Peters and Rosenbusch, and by Jackson. Fig. 8 is taken from Jackson's article. Fig. 8 *a* is from Rosenbusch's *Mikroscopische Physiographie*, by which it is shown that the macle is not produced by twinning, since the cleavage lines are undisturbed, but that the case is one where a core is surrounded by another crystal, giving to the whole a laminated structure, and the macle results from the regular arrangement of impurities and cavities, which are most abundant between the outer and the inner crystal.

The microscopic characters of minute crystals are usually the same as those of the large ones. In them more or less quartz is found, and apparently simple crystals, with polarized light, are seen to be twins;

but when staurolite sinks to microscopic proportions in the slate rocks of the Connecticut valley, it shows what is rarely seen,—really simple crystals. The color of this microscopic staurolite is deep brown. It is highly dichroic, and if its sections are revolved over one Nicol, when the long axis of a crystal is parallel to its plane, the crystals are deep brown, and when at right angles thereto, they are nearly white. The crystals are extremely impure. They possess no terminations; but the direction of the prism is indicated by their fibrous character, and they are recognized as orthorhombic, since between crossed Nicols the maximum extinction of the light in all sections takes place when this striation is parallel to the plane of one Nicol. Basal sections do not show the striations, but are still dichroic (distinction from biotite), and show some very rude attempts at the formation of a six-sided figure, which is more often nearly round. None of these microscopic crystals are twins. They might at first be mistaken for biotite, but not after a moment's examination. The appearance of this common staurolite is given in Fig. 4 on Pl. 8. It is drawn as it appears when the lower Nicol is on the instrument, and the plane of the light is indicated by the arrow. The excessive impurity of the staurolite will be noted; but this character is much more evident when both Nicols are upon the instrument. This figure is introduced as explanatory of the analysis with the high percentage of silica, and also as showing a deceptive, simple form into which staurolite sinks in our rocks.

Hydrous Silicates.

New Hampshire, which, as is well known, is mostly occupied by granite hills and old crystalline rocks, is mostly composed of anhydrous silicates, and, as might be expected, is poor in the hydrous species, for there has not been the opportunity here for their formation. The great trap dykes of the Mesozoic, which have proved to be so rich in these species, come only to our boundaries; and, though trap dykes are abundant in our state, they are not large, are rarely amygdaloidal, and do not offer conditions favorable to the formation of minerals from their decomposition: hence our list of hydrous silicates is small in comparison with the number of species described. Those which occur in any abundance belong to the foliated micaceous margarophyllites.

70. PREHNITE [$H^2 Ca^2 Al^2 Si^3 O^{12}$].

This mineral is found at Bellows Falls, and also at Franconia. It is a green mineral, orthorhombic in form, which results from the alteration and decomposition of other minerals, especially of the basic minerals of trap rocks. It is inconspicuous in our state. It is found only in thin crusts, which appear almost amorphous, being aggregates of so many small crystals.

71. ANALCITE [$Na^2 Al^2 Si^4 O^{12} + 2H^2 O$].

I am aware of only one occurrence of this mineral, and that a microscopic one, which presents the usual optical peculiarities of this species. Some of the augite porphyry at Campton falls is filled with little microscopic cavities. These cavities are represented in Fig. 3 on Pl. 6. The walls of all these cavities were first coated with a yellow, formless, drusy mineral called sphærosiderite, a carbonate of lime and iron. Then there was a growth of hexagonal calcite crystals, terminated in some cases by the planes of an obtuse rhombohedron, and sometimes extending entirely across the cavity; and, lastly, the remaining room in the cavities was entirely filled with analcite. This analcite shows a quite fine cubic cleavage, a thing not often macroscopically seen in such perfection. Analcite is isometric. Isometric crystals are black between crossed Nicols, and act like amorphous bodies, but this analcite does not so behave. Some few of its sections are black; but the larger part are dark only in certain positions, and on revolving them they assume a bluish-black color, become sensibly lighter in shade, and become black again when they have been revolved 90°, and thus, though faintly, they show all the peculiarities of prismatic crystals. This deportment has caused serious doubts to be thrown upon the isometric character of analcite; and leucite, which crystallizes like analcite, and shows the same peculiarities in a somewhat more marked degree, is quite satisfactorily proved to be tetragonal. The anomalies of analcite were first noticed by Brewster; and Des Cloizeaux subsequently determined that sections cut parallel to any of the cubic faces act in parallel polarized light like isometric crystals,—that is, light passing parallel to any axis is not modified. Analcite, which like this entirely fills cavities, has been noticed in several basaltic rocks, chiefly Italian.

72. TALC [$H^2 Mg^3 Si^4 O^{12}$].

Talc, as it occurs in New Hampshire, is chiefly of the variety called steatite, or soapstone, of which we have large beds that have been extensively worked. At Francestown there is a large quarry where talc of exceptional purity has been mined since 1802. At Orford there are five beds, but the mineral is of a slaty character, and not so easily worked. At Richmond the beds are still more impure, and the mineral contains anthophyllite and pyrites, which interfere with the sawing of it into blocks. Keene, Weare, Warner, Canterbury, and Lancaster are other localities where steatite has been found. The impure varieties are of economic value, though they may not be transported to markets at a distance. At Haverhill a large bed of steatite was long ago found, and very large boulders of soapstone are found at Pelham, which have been transported from some unknown locality. At Norwich Vt., the pretty green foliated variety of talc has been found.

Talc is not found with well formed crystal faces, but it is considered orthorhombic, and its microscopic characters correspond to those of such crystals. The steatite in thin sections appears to be a fibrous mass, and where the fibres do not overlie one another so as to interfere with one another, the fibres are dark when parallel to the plane of vibration of the light. If we take one of the foliæ of the nice green talc from Norwich, and put it under the microscope, take out the ocular and cross the Nicols, we shall see a black cross which opens out into two hyperbolas as the section is revolved, and which shows the biaxial character of the crystal, and that the optic axial angle is not large (17°–19° in the air). These characters agree with those belonging to talc, in which the cleavage is basal, the bisectrix normal to the base, and the optic axes in the plane of the macrodiagonal.

Talc is a constituent of some of our rocks. In thin sections of them it is usually in radiated masses. It is distinguished from chlorite in that it shows neither dichroism nor absorption of light, and is usually fresh and undecomposed.

Talc enters into some granitic rocks, forming protogene, and with some accessories forms the stratified talc schist. Much of the so-called talcoid schist of Vermont and New Hampshire was shown by Prof. G. F.

Barker to be argillitic mica schist, since on analysis the specimens yielded no magnesia. They were supposed to be talcoid because they had a soft-soapy feel, and an appearance of talc. These schists are widely distributed, while the talc schists are much more local occurrences.

73. SERPENTINE [$Mg^3 Si^2 O^7 + 2 H^2 O$]

Serpentine is not a common mineral in our state. It is found in small amounts in some chloritic rocks of the Connecticut valley, and Mr. Huntington has observed it at Pittsburg. It is found in light green granular layers or aggregations, which are either interstratified in the rocks, or scattered irregularly through them. Again : in some of the trap rocks, serpentine is a microscopic product which results from the alteration of olivine. As serpentine, wherever found, has the microscopic appearance of being a product of alteration, so, in thin sections, it has not the properties of an original crystal, but its optical behavior is that of an aggregate. It gives bright colors when revolved between crossed Nicols, but shows no other crystalline characters. Its microscopic appearances are various, and depend much on the mineral from which it is derived; but no extensive material for its study is offered in our state.

74. KAOLIN AND CLAY [$Al^2 Si^2 O^7 + 2H^2 O$].

Products going under these names abound all over the state. Kaolin is the mineral species to which they must be referred, although in a pure state it is not common. Kaolin is formed in all granitic regions by the decomposition of feldspar. In the Southern States, below the limit of glacial action, where the resultant products have often remained in place, there exist immense beds of soft rock composed essentially of quartz and kaolin; but in our section, where the glaciers broke down and removed all such decomposed materials, the kaolin is found in the lowlands mixed with pulverized quartz, forming the clay beds. Under the microscope, the composite nature of clay becomes very evident, yet the kaolin is often seen to be in minute crystalline scales. This crystalline character of the kaolin of clays was first pointed out by S. W. Johnson and Blake. Kaolin is orthorhombic. That the particles are crystalline is easiest seen by noting that they are double-refracting, and give colors between crossed Nicols. Besides quartz, our clays contain ferruginous materials, which cause the bricks made from them to burn red. At times they contain much lime, when they are called marl.

Kaolin, when pure, is white, and often flaky. When clay is consolidated, it forms beds of argillite, and this is the first stage in metamorphism. The beginning of the change is marked by the production of an imperfect schistose structure, a loss of a part of the water and of the soapy feel.

Clays are not merely variable on account of their composite nature; but a large number of apparently pure and homogeneous products have been analyzed, and a number of species established as the result. Amorphous clay-like products, very different in appearance and physical properties, are found. They are, as a rule, kaolin in different states of consolidation, but one most peculiar product, called mountain cork, is found at Franconia. It is extremely light, though apparently firm and compact. It is made of the finest microscopic fibres, so interlaced as to make the mass very tough and hard to tear, though it cuts with a knife like cork. It floats lightly on water, but it rapidly absorbs water, and then sinks. Its weight is about equal to that of cork, and its whole appearance immediately suggests the name by which it goes. Similar products to this, and which are called by the same name, are composed of hornblende; but this substance, which I have analyzed, and which was furnished to Prof. Brush by Mr. Pierce, of Providence, who obtained it from our state, gave as the result of analysis,—

Silica,	58.15
Alumina,	13.20
Magnesia,	9.75
Water,	18.68
	99.78

The same product was analyzed by Mr. Calder, of Providence, and his results were not widely different from mine; but every new analysis that he made gave him new results. Hence, as no two analyses can be made to agree, it is plain that the substance is not homogeneous, and that it is merely a hydrated and altered asbestus (hornblende). It fuses without difficulty before the blow-pipe, and its composition is such as to make this conclusion tolerably certain. This product has excited considerable interest. What the mineral is now cannot be said with certainty, since it is not homogeneous. It has at least got quite near in composition to some of the kinds of clays. It occurs chiefly in cavities of the slaty rocks.

75. Pinite.

Under the head of pinite, a number of amorphous products are classed together by Prof. Dana, which are essentially hydrous silicates of alumina and potash, and which have resulted from the decomposition of alkaline silicates. A green substance, which has been referred to pinite, occurs in the granites of Bellows Falls, and in the protogene rocks at Littleton and other places in the neighborhood. These substances, when examined in thin sections under the microscope, resemble serpentine, a mineral to which, in its mode of origin, pinite is closely related.

76. Margarodite—Sericite.

Muscovite, as is well known, is exceedingly subject to hydration, and while yet maintaining its physical and optical properties, gives, on analysis, considerable water. This change is evinced in an increase of pearly lustre and opacity, but in other characters it is still like muscovite. A large amount of the mica in our rocks is more or less hydrous, and may be called margarodite, if one so choose; but in the study of lithology there is a stage beyond this, where a hydrous mineral, nearly related to these in composition, has none of the characters of muscovite, and is a fibrous mineral resembling talc, from which it is distinguished by its composition. This mineral was called sericite by List, on account of its silky lustre; and the rocks containing it have been called sericite schist, gneiss, etc. Rosenbusch believes that sericite is a well established species, thoroughly distinguished from micas by its fibrous structure, while Lasaulx regards this subject as needing investigation, and thinks that various micaceous minerals are included under the name sericite. Prof. Dana calls these rocks, which contain this soapy, talc-like mineral, hydromica schist; and although, while the question stands as to-day, this is the best name, yet it may be stated that we have in our rocks, first, a hydrous mica with a micaceous structure, and with the optical properties of muscovite. It is usually yellow in thin sections, and shows the cleavage very distinctly. Again: we have in other rocks a fibrous mineral which bears no resemblance to mica, which, however, is certainly related to it in composition, which looks in the microscope like talc, and gives its character to the rocks, and is what has been called sericite. Such rocks occur at Northumberland, and at various points on the Connecticut. Lasaulx shows this mineral to be a product of the decomposition of feldspar in some cases.

In regard to margarodite, it may be noted that a visit to our mica mines shows how quickly muscovite is turned to margarodite, after a little exposure. The mica that is rejected, and thrown into piles on one side, very quickly becomes hydrous, loses its transparency, and becomes silvery. A piece exposed less than a year gave me 4.2 per cent. of water; and hence we might expect that the mica, wherever exposed, would be hydrous.

A hydrous mica is found at Enfield, associated with quartz, which forms rounded mammillary forms, composed of excessively minute scales. The whole appearance of the mica resembles prehnite, but it is nearly infusible, and close examination reveals its micaceous structure. I have examined this mica, and have found it to be a soda-potash mica, intermediate between margarodite and paragonite. It resembles one analyzed by Smith and Brush, from Litchfield, Conn.* The specimens examined were furnished by Mr. Downs. These intermediate species between the hydrous, potash, and soda micas, indicate that the dividing lines between them are indefinite.

CHLORITE.

Under this head it is proposed to describe those minerals which, though having essential chemical differences, yet have those well known properties in common that cause them to be all usually called chlorite. The chlorites are hydrous silicates of magnesia, iron protoxide, and alumina; their hardness varies between that of talc and gypsum; they are foliated like mica, but their foliæ are not elastic as are those of mica; and they are of various shades of green, according to the amount of iron which they contain. The three most common species of chlorite are the monoclinic ripidolite, the rhombohedral penninite, and the hexagonal prochlorite. The first is biaxial, the second and third uniaxial, though

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* See "Margarodite," *Dana's Mineralogy.*

the latter species has often a slight angle between its two optic axes. Chlorite forms large aggregations which might be termed rocks, and besides its occurrence in what would be termed mineral specimens, it is an essential constituent of chlorite schist, diabase, &c. The particular species of a chlorite which exists in a chlorite schist is often hard to determine, and the more so because more than one species are liable to be present together. For example: in some schists there are basal sections of chlorite which remain dark between crossed Nicol prisms during a whole revolution (hexagonal), while others, in position likewise parallel to the cleavage or base, do not remain dark, and are therefore biaxial. The name viridite is reserved for those green chloritic products which can be referred to no species, which cannot be isolated for examination, and in reference to which it only is known that their appearance and association indicate them to be chlorites. The chlorites are usually dichroic, with the exception of the viridite which acts at times like an amorphous substance.

Besides its occurrence in the rocks, chlorite is found often in radiated and foliated aggregations, in cavities and clefts. The process of hydration and alteration of basic rocks usually gives rise to the formation of more or less chlorite. The following species have been determined in our state.

77. RIPIDOLITE (MONOCLINIC) [$Mg^5 Al^2 Si^3 O^{14} + 4H^2O$].

This is probably the chlorite that is most abundant in the chlorite schists. It is also found in the beds of talc and talc schist, and it occurs in well formed crystals at Orford. It is bright green in its color, but strongly dichroic, being green in the direction of the vertical axis, while it is brown or yellow in a transverse direction. This is best observed in thin sections under the microscope. In these sections, as a rule, no crystalline form can be noted, but all the sections are double-refracting. This chlorite occurs in rocks that do not contain large percentages of iron, and do contain considerable magnesia. It may be an original product, and it may be the result of the alteration of other minerals. Between crossed Nicols it gives brilliant interference colors, and is usually more or less impure from the presence of magnetite.

78. PENNINITE.

To penninite are referred those little hexagonal plates of chlorite that are sometimes found in the chlorite schists, and which have the optical properties of an uniaxial crystal. No chlorite of this form and composition has been found in condition for analysis, and it is hence only to be borne in mind as being a probable constituent of our chlorite rocks.

Quite different, now, are those chlorites that are so abundant in basic rocks, being usually products of the decomposition of ferruginous minerals. One of the best determined of these minerals is,—

79. PROCHLORITE [H^{22} $(Fe, Mg)^{10}$ Al^6 Si^6 O^{42}].

This is a chlorite of an uncertain crystalline form, though often found in hexagonal plates. It is not strictly uniaxial, however, and its optical properties do not appear to be those of an hexagonal mineral. It is a magnesia iron chlorite, which, according to Rammelsberg, has an atomic ratio between the protoxide elements, the alumina (Al_2) and silica of 3.3 : 1 : 2 as the mean of many analyses.

On the road from the Glen house to the top of Mt. Washington there are some large trap dykes; and between these dykes and the surrounding rocks is a layer, six inches or more in thickness, of a pure crystallized chlorite, which forms a selvage. It gave me, on analysis,—

Silica,	25.32
Alumina,	20.94
Iron sesquioxide,	1.94
Iron protoxide,	26.71
Manganese protoxide,	.20
Magnesia,	14.05
Water,	9.90
	99.06

It is remarkable how very closely this analysis approaches to the atomic ratio adduced for prochlorite, which proves conclusively that it is that mineral.

This chlorite is very deep green, and in thin sections is dichroic, though not so strongly so as some other chlorites. Under the microscope it appears unusually pure, its only inclusion being crystals of sphene. In microscopic sections it is seen to possess a concentric radial structure. This structure is wholly microscopic, for, although chlorite is noted for assuming fan shapes, no arrangement of the kind is macroscopically visible. This chlorite was evidently formed from the products of the decomposition of the rock.

80. VIRIDITE, DELESSITE, DIABANTITE.

When now we come to consider what is the chlorite that is formed in the basic rocks themselves, the investigations are quite conflicting. It is known that in almost all the old basic eruptive rocks, much chlorite has been formed at the expense of the augitic and hornblendic constituents, and the nature of this chlorite has been studied by many mineralogists. It is well known that these are chlorites which contain much iron, and are liable to give the most variable formulæ on account of the ready oxidation of this iron. Delessite is probably the name by which they are best known, but Kengott would refer them all to the species last described (the ripidolite of G. Rose). The formula of delessite could never be fixed because the analyses were so various. Liebe came very near it, and from the mean of several analyses deduced a formula, and named the mineral diabantachronyn, because it was the coloring mineral of diabase. I obtained this chlorite in a very pure state from the diabase near New Haven, and got an analysis which seemed to me must be pretty near the original composition of this chlorite, since the iron was essentially all protoxide. The analysis confirmed Liebe's results, and so I took the name he had given it, only shortening it to diabantite. The analysis was as follows: SiO 33.68, Al_2O_3 10.84, Fe_2O 2.86, FeO 24.33, CaO .73, MgO 16.32, water 10.02.* The quantivalent ratio of its bases and silica are as 1 : 1, while in the prochlorite, the analysis of which is given, they are as 3 : 2, and the formula of diabantite, as drawn from the analysis, is $(Fe, Mg)^{12} (Al^2, Fe^2)^2 Si^9 H^{18} O^{45}$. The exact equivalence of the elements, its undecomposed appearance, and all its characteristics, indicate that this is very likely the chlorite of diabases, and that delessite is likely the same thing in an impure condition. It may at least answer the purpose of this study to assume that we know the approximate composition of the chlorite of diabase, and that it is certainly near that indi-

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* *American Journal of Science*, iii, vol. ix, p. 455.

cated by the analysis given above. As observed in thin sections, this chlorite, which is formed by the decomposition of basaltic, ferruginous minerals, often refracts the light so as to give the brightest colors between crossed Nicols, and often it is seen as an aggregate of fine scales; and, again, a green, ferruginous chloritic substance is often found in such rocks, which acts on the light like a perfectly amorphous body. It is black in every position between crossed Nicols, as is a glassy substance. This at first deceived observers, but it is now known that this substance is chloritic in its nature. For such products as this last, and for other products of this nature, the compositions of which are only approximately understood, and which can be with justice referred to no mineral species, the name viridite is applied.

In our diabase rocks, chlorite sometimes takes very pretty microscopic forms when its surroundings allow it to crystallize freely. For example: in Pl. 8, Fig. 5, is a representation of a section of diabase in which is seen a kind of cavity filled with calcite, and in the calcite are numerous little spherical concretions of chlorite. They are light green in color, and their radiated structure is not very evident. If, now, we put them between crossed Nicols, all their structure is developed, and they appear as radial discs traversed by a black cross, and look very pretty. This is what is illustrated in the figure, which will be readily understood. If the concretions are made of needles or plates of an hexagonal mineral, all those crystals which coincide with the plane of either Nicol prism will be black, while all others will be colored. As, now, in these concretions, crystals radiate out in all directions, each concretion must be crossed by two bars coinciding with the planes of the Nicols. The planes of the Nicols are indicated in the figure by the spider lines. This figure is drawn from a section of the diabase of Dixville. The centres of some of the concretions are filled with calcite. The other minerals in the section are a triclinic feldspar, recognized by its striations; augite, colored blue and yellow by interference of the rays; brown biotite; and the light calcite, with its characteristic cleavage.

81. COLUMBITE [$Fe\,(Cb, Ta)^2\,O^6$].

This comparatively rare mineral has been found in the granitic veins of Acworth. The crystals there found possess an individual character from the large development of very acute octahedral planes, which produce long, pryamidal summits on the crystals. These crystals were first described by Prof. C. U. Shepard, who made an excursion to Acworth for minerals in 1830.

Columbite is a very heavy mineral, but there are wide variations in the gravities that have been taken upon specimens from various localities. This variation has been shown by Marignac to be due to the varying amount of tantalic acid, which increases the specific gravity in proportion as it is present in greater amounts. Pure columbate of iron has a gravity of 5.4, and pure tantalate of iron has a gravity of 8. Most of the columbites that have been analyzed are isomorphous mixtures of these two compounds, and have intermediate gravities. Marignac,* who investigated this subject, examined the columbite from Acworth, and he found that it had a specific gravity of 5.65, and, in accordance with the rule deduced, it contained 15.8 per cent. of tantalic acid. Columbite is also found associated with beryls at Plymouth.

82. APATITE. $[Ca^5\,P^3\,O^1{}_2\,(Cl, Fl)]$.

This mineral is found abundantly in the vein of feldspar and quartz at Westmoreland, which has been previously referred to as a locality for molybdenite. The hexagonal crystals of apatite are there found abundantly, and are often large. Blue and green apatite in very pretty crystals is found at Grafton. Fine crystals occur in a bed of white limestone at Piermont. Apatite is also found in Jackson.

Besides its occurrence in these fine crystalline varieties, it is almost universally spread about as a microscopic accessory constituent of the rocks. Though not constant, there is no variety of rock in which it is not sometimes found. When the crystals are not too minute it is easily recognized in thin sections, because it is always well crystallized, and consequently its sections are either hexagons or parallelograms. These needles and prisms of apatite pierce through all the other minerals that are common in rocks, and thus indicate that apatite was the first formed. The crystals are usually quite long in proportion to their size, a character that distinguishes them from nephelinite, which is almost the only mineral with which they might be confounded, but which is not found in our rocks. The sections of apatite are usually colorless, but when

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* *Archiv des Sci. Physiques et Nat. Nouvelles*, xxv, p. 24.

revolved on the stage of the microscope, while only the lower Nicol is on the instrument, sections not parallel to the base show a greater absoption of light in one direction than they do in the other.

In our eruptive rocks apatite is very abundant. It is usually microscopic, and only visible in thin sections. It is apt to be aggregated in some parts, while other parts of a section show none. Fig. 4 on Pl. 6 represents apatite as it appears in the diabase at Bemis rook. It will be noticed that the needles, though small, pierce through all the other minerals. Such little apatite needles as these are apt to be seen in almost all our rocks.

But apatite, as a rock constituent, reaches much larger proportions without becoming macroscopic. For example: the augite sienite of Jackson is filled with very perfect crystals which are large enough for optical examination. Their basal sections remain black when revolved between crossed Nicols, while the prismatic sections are black when the long axis is parallel with the plane of vibration of the light. Again: the gabbros at Waterville and Mt. Washington contain apatite in fine crystals of some size, but which first become evident in thin sections, and which offer some interesting peculiarities. Fig. 6 on Pl. 8 is a representation of the apatite as seen in this rock. It will be noticed that the crystals have taken form and position without reference to any other constituent. They pierce the infusible olivine and magnetite as readily as the pyroxene and feldspar. It is the only substance that has crystalline outlines. Some of these crystals are crowded full of minute cavities. These cavities are heaped more abundantly in the centre of the crystals. Such crystals have been observed by Zirkel, Rosenbusch, and others. Again: some of the crystals appear to have other crystals running through them. Sometimes there is but one large one, and again there are several. The sides of the interior crystals are parallel with those of the large one; but perhaps of more interest is the odd outline of many crystals, which in part are bounded by straight crystalline edges, while the remainder of the crystal is jagged and rounded, and bears all the appearance of having been eaten into by some reagent. Sometimes the whole half of a crystal looks as if thus dissolved, and sometimes merely a piece of the margin is destroyed. Effects of this kind have been observed in augite and hematite crystals in basaltic rocks, and they are explained by the supposition that during the cooling of the rock, when it had reached the temperature at which some minerals could crystallize, from some reason an elevation of temperature took place, and the crystals were again partially dissolved. To such a cause the odd outlines of these apatite crystals may be referred.

From such microscopic proportions, apatite increases in size till it can sometimes be seen in the rock with the unaided eye. For example: a porphyritic diorite at Dixville notch is very black in color; but through it run fine white needles, which, with the lens, appear clear and glassy, and which it requires no microscope to recognize, nor to see how they pierce through all the other minerals which are porphyritically developed. As phosphoric acid is one of the essential constituents of plant food, the wide and universal distribution of apatite may be regarded as fortunate.

If it is wished to make certain that a little hexagonal crystal in a rock section is apatite, one may use the reaction which Streng* applied to distinguish apatite from nepheline.

Upon a crystal in a section with an uncovered surface, place a drop of a concentrated nitric acid solution of molybdate of ammonia, and watch the reaction with the microscope. The nitric acid will gradually decompose the apatite crystal, and in the drop there will presently appear a precipitate of the ammonium-phospho-molybdate, which has a bright yellow color, and is composed of little crystals which are either octahedral or dodecahedral. This reaction cannot fail to be recognized, since this precipitate contains only 3.6 per cent. of phosphoric acid, and is correspondingly bulky; moreover, it is soluble in an excess of phosphoric acid, and hence directly over the exposed crystal no precipitate will be seen, but the precipitate will surround this spot with a crystalline wreath. Again: if a crystal be treated in like manner with a little drop of nitric acid, and, after it is well decomposed, a tiny bit of sulphuric acid be added, a precipitate of sulphate of lime will form; or, if the crystal be treated directly with sulphuric acid, its exposed surface will be quickly covered with a white coat of the same, which will prevent all further action.

83. TRIPHYLITE $[(Fe, Mn, Li^2)^3 P^2 O^8]$.

At Grafton in our state this rare species is found more abundantly,

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* A. Streng, *Tschermak's Mineralogische Mittheilungen*, 1876: Heft iii, p. 166.

perhaps, than elsewhere in the United States. It occurs in the great granite vein; and in blasting for mica, large pieces of it, some of which weigh more than fifty pounds, have been thrown out. Mr. M. A. Brown reports that he obtained blocks of the pure mineral as large as water-pails. It is light blue in color, possesses a resinous lustre, and cleaves very well parallel to the base of its orthorhombic crystals, though the form of its crystallization cannot be determined from any faces that the mineral presents. The exterior of the masses and the cleavage surfaces are often blackened by the decomposition, which might be expected in a mineral so rich in protoxides of manganese and iron. A careful analysis of this triphylite from Grafton has been made by Mr. S. L. Penfield,* of the Sheffield laboratory, which is as follows:

	I.	II.
Phosphoric anhydride,	44.18	43.88
Iron protoxide,	26.09	26.38
Manganese protoxide,	18.17	18.24
Lime,	.89	.99
Magnesia,	.56	.61
Lithia,	8.77	8.81
Potash,	.32	.32
Soda,	.16	.09
Water,	1.47	1.47
	100.61	100.79

From this analysis, which is the first that has been made on an American triphylite, Mr. Penfield calculates that the right formula is $R^3\ P\ O^1 + \dot{R}^3\ P\ O^8$ (R standing for univalent elements, and $\dot{R}$ for the bivalent), a formula suspected by Rammelsberg to be the correct one, but to which no previous analysis has so closely approximated. Mr. Penfield points to the circumstance that our mineral is richer in manganese and lithia than the Bavarian mineral, which has been the chief subject of previous investigation.

SCORODITE—WAVELLITE.

Scorodite, the hydrous arsenate of iron, has been reported as found at the Jackson tin mines. Its occurrence is doubtful. Wavellite is put in some lists of mineral localities as occurring at Bellows Falls. Mr. Downs, of Lebanon, says that it is not to be

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* *Am. Jour. Science*, iii, vol. xiii, p. 425.

found there, and he thinks that the prehnite which occurs there had deceived the finder.

84. AUTUNITE [$Ca U^2 P^2 O^{12} + 10H^2 O$].

This rare mineral has been found in little scales in the mica quarries at Acworth. The scales are little tabular crystals of the orthorhombic system. Its colors are light green and straw yellow. They are planted on the feldspar.

85. WOLFRAMITE [$(Fe, Mn) W O^4$].

This heavy black mineral, which is everywhere a common associate of tin ores, has been identified as occurring in small amounts in the veins at Jackson with the cassiterite.

86. BARITE [$Ba S O^4$].

This mineral has been found at Piermont. It occurs in bunches, and nests in the specular iron ore on Cross hill. It is white. There is little probability that it can be found in any such quantity as to make it an economic mineral.

87. MELANTERITE (GREEN VITRIOL) [$Fe S O^4 + 7H^2 O$].

In several parts of the state this salt is found as a result of the alteration and oxidation of iron pyrites. It occurs as a pulverulent kind of efflorescence, with a sweetish, astringent taste, and of a greenish-white color. It is soluble in water, and hence, when it forms upon the surface, it is quickly removed; but in enclosed spaces under ground it is preserved in larger masses. It is noticeable as occurring in the beds of iron ore at Brentwood, Gilmanton, Rindge, Hopkinton, and Plymouth. It is liable, also, to be found in insignificant amounts in general in the pyritiferous rocks where the pyrites is exposed to air and moisture.

This salt is easily recognized by its taste. By exposure, it is further oxidized to the sulphate of the sesquioxide of iron.

88. KALINITE (ALUM) [$K^2 Al^2 S^4 O^{16} + 24H^2 O$].

This mineral occurs as an efflorescence upon schists and shales, and is made by the action of sulphuric acid upon decomposing feldspar. It has been found at Bath, Bedford, and Walpole, in small, grayish-white efflorescences. It is easily recognized by its astringent taste. It is isometric in crystallization, but is usually found in mealy crusts.

89. CALCITE [Ca CO^3].

Calcite, although abundant enough in New Hampshire, is generally found in the massive condition, forming limestones, or, mixed with other minerals, forming calcareous rocks: hence its consideration belongs chiefly to lithology. Good rhombohedral crystals of calcite are, however, found at Amherst, Surry, Warren, and the Notch. The variety of calcite called argentine is found at the iron mines in Lisbon. It is called argentine on account of its silvery lustre.

In its more ordinary forms, calcite is widely distributed. It occupies veins in other rocks, as at Portsmouth, where it usually shows large cleavage surfaces, indicating coarse crystallization. It also forms thick beds interstratified with the surrounding rocks, as at Orford, Haverhill, Meredith, and Littleton. At the latter place it is filled with fossils; and the accumulation of beds of limestone is supposed to be largely due to the various organisms, whose calcareous shells are so often found in them. When the last remnants of this organic life have been destroyed, the limestones are white, while otherwise they are blue or gray.

Calcite is constantly met with in thin sections of some classes of our rocks, sometimes as an original component, and sometimes as a secondary product. As a constituent of the basic eruptive rocks, it has plainly resulted from their decomposition, since it is usually found in little cavities, though it is also scattered all through the rock, as can be proved by moistening them with hydrochloric acid, and watching for an effervescence. Such minerals as pyroxene, by slow acting agencies, give up a part of their lime, and are converted into chlorite, while the basic feldspars quite easily part with theirs, as was shown in the discussion of anorthite. Thus results the calcite which so commonly fills all the pores of such rocks, and by such processes the lime has been separated from the original basic rocks to form beds by itself.

The microscopic characters of calcite, as seen in thin sections, are very characteristic. It is strongly double refracting, and the light which passes through a crystal with its vibrations in a plane parallel to the vertical axis of the crystal (extraordinary ray), are not so much refracted, and pass through with more ease than do those at right angles thereto. Hence sections of calcite exhibit absorption, and when viewed with the microscope with only the lower Nicol on the instrument, they are brighter and clearer in certain positions (that is, when the plane of the Nicol and the plane of the extraordinary ray coincide) than they are in others. With crossed Nicols, calcite gives no very brilliant colors, but when revolved on the stage of the instrument there are alternations of great brightness with the darkness. A peculiar silvery color is ordinarily obtained, which is very characteristic. Of course, basal sections are always dark between crossed Nicols; and in such sections, if the ocular is taken out of the instrument and the Nicol replaced, the black cross and colored rings can be seen. In quite thin sections, in order to see this, the higher powers must be employed. The perfect rhombohedral cleavage of calcite is always very evident in thin sections.

Most especially in our marbles, and in the calcite that is found in the crystalline rocks as an apparently original product, an appearance is seen that resembles in a degree the polysynthetic twinning of feldspar. The calcite in such rocks possesses a laminated structure which is usually only brought into view when a thin section is brought between crossed Nicol prisms, and then it is very evident. The plane of the laminæ does not correspond with the cleavage, but is parallel to planes of the obtuser rhombohedron $-\frac{1}{2}$ R. Quite often two sets of these laminæ are seen crossing one another, and as there are three like rhombohedral planes, so it is evident that there might be at the same time a twinning parallel to all at once, and that if the crystal were cut in the proper direction all three sets of these laminæ might be at once visible. The appearance of crystals exhibiting these laminæ between crossed Nicol prisms is seen in Fig. 5 on Pl. 6. In some of the grains two systems of laminæ are seen at once. The different shades of the calcite depend, of course, upon the varying relations of the axes in the different grains to the plane of the light. This figure is drawn from calcite in the micaceous diorite at Stewartstown. It represents very well what is to be seen in sections of any of our limestones, and in the calcite enclosed in many of our rocks. Stelzner was the first to suggest that the entire irregularity of the grains of calcite in limestones, and these twin lamellæ, are very probably due to the effects of the pressure which was exercised upon the rocks during their metamorphism, because Reusch had already shown that these lamellæ could be induced in simple calcite crystals by slicing off two of the opposite edges of a cleavage rhombohedron, and exerting a gradually increasing pressure upon the little faces thus made. When calcite is formed in cavities and cracks of the rock, where the rocks had plainly taken their last form before the calcite was produced by their decomposition, this twinning (if it is a twinning) is not often found;—a fact which might be expected if the above mentioned theory is correct.

In the amygdaloidal cavities calcite sometimes assumes pretty, microscopic forms. For example: in Fig. 3 on Pl. 6 are represented the amygdaloids which abound in the olivine diabase at Campton falls, and which are filled with analcite. Before the analcite was formed, there was, however, a growth of hexagonal prisms of calcite, which were terminated with the planes of an obtuse rhombohedron. In some of the cavities these prisms had grown from side to side, thus forming a bar across the little chamber.

Some of our limestones, as, for example, those at Littleton, when examined in thin sections, exhibit peculiarities in the cleavage. The lines are no longer straight, but traverse the grains in curves. This is probably another result of pressure which at some time acted upon the stone.

In some limestones the organic matters, which were originally present in the shells, etc., have not been entirely destroyed, but are left in a bituminous condition; and these rocks, when struck, give forth a foul odor, from which the stone is called fetid limestone or stinkstone. Such a limestone occurs at Orford.

Numerous analyses of New Hampshire limestones have been made by Dr. Jackson and others.* It would be profitless to introduce them here, since their bearings are merely economic. They show all grades of impurity, from the pure white limestone of Haverhill, which contains 99.3 per cent. of calcium carbonate, to a gray, Cornish limestone, which contains 63.4 per cent. of impurities. Thus, by the gradual introduction of other minerals, limestones grade into other rocks. Besides this kind of

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* *Geology of New Hampshire*, Dr. C. T. Jackson, pp. 173-175.

impurity, in some of our limestones the analyses show a greater or less replacement of the calcium by magnesium. By this replacement, calcite approaches dolomite.

90. DOLOMITE [(Ca, Mg) CO^3].

Pure dolomite is not very common in our state, though the limestones very often contain more or less magnesia. It exists in considerable quantities at Lyman, and also at Plainfield. It is readily distinguished, because it does not effervesce in cold, diluted hydrochloric acid. Our dolomites are gray, and quite impure. Dr. Jackson's analysis of the Plainfield dolomite indicates the presence of about thirty per cent. of impurities, which are of mica, quartz, and other silicates. In thin sections, it does not show the twin laminations in polarized light that are shown by calcite.

91. ANKERITE [(Ca, Mg, Fe, Mn) CO^3].

This mineral, in which the magnesia of a dolomite is more or less completely replaced by iron and manganese, is commonly present in the quartz veins that have been shown to be auriferous, and is, indeed, characteristic of them. It is found in good rhombohedral crystals of a honey-yellow color, and on heating them in the reducing flame of the blow-pipe they become magnetic. Littleton, Lisbon, and Lyman are localities where they are abundantly found. In some veins the quartz, though containing no ankerite, is filled with rhombohedral cavities, showing that there once were crystals that have been dissolved away.

92. SIDERITE AND SPHAEROSIDERITE [Fe CO^3].

The carbonate of iron, as has been before noted, is common in the deposits of bog-iron ore, but not as a mineral of interest, since its presence is only shown by the effervescence that takes places when they are treated with acid. Near us, at Plymouth, Vt., there are deposits of siderite.

Sphaerosiderite is a concretionary variety of siderite that is found in globular or mammillary forms. This mineral is quite often found as a constituent of our rocks, as a lining of cavities; but it is chiefly microscopic. For example: in the olivine diabase of Campton falls, the little cavities which were represented in Fig. 3 on Pl. 6 to show the analcite, were all first coated with sphaerosiderite, which often assumed in them the most fantastic forms. In the thin sections it is deep yellow in color, appears often agate-like in structure, but in polarized light appears to be an aggregate of very fine fibres or scales. It is not uncommon to find some of this substance in sections of our basic rocks.

93. RHODOCHROSITE [$Mn\ CO^3$].

This mineral is found at Winchester. When pure, it has a light rose color ; but our mineral is usually blackened by decomposition. It is not common, and does not show its crystalline form, which is rhombohedral.

94. MALACHITE [$Cu^2\ CO^4 + H^2O$].

This bright green carbonate of copper, though not found in well crystallized forms, occurs at Littleton in the slaty rocks, in stellated groups of needle-like crystals. In the condition of a green crust it has been found in the rocks at Franconia, Hanover, Dalton, and Orford. It is associated with sulphurets of copper, and generally results from their decomposition.

95. AZURITE [$Cu^3\ C^2\ O^7 + H^2O$].

The blue carbonate of copper is associated with the green at Franconia. Like the malachite, it is in the condition of a non-crystalline earthy crust.

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In concluding this chapter, what has been said with reference to the localities of minerals may be very conveniently summed up in a catalogue of the towns, and the minerals that, to the knowledge of the survey, have been there identified. This catalogue not only embraces those mineral occurrences that have been referred to in the preceding pages, but also includes many others which in those connections it would have been tedious to enumerate, and mention of which is more serviceable when placed here. Though many of these minerals have been known to exist for a century, still to the field laborers on this survey, with Prof. Hitchcock at their head, the people are indebted for a knowledge of a large number of these occurrences.

CATALOGUE OF MINERAL LOCALITIES IN NEW HAMPSHIRE.

ACWORTH. *Beryl*, *tourmaline*, *mica crystals*, *orthoclase*, *albite*, *columbite*, *rose quartz*, autunite.

ALEXANDRIA. Mica crystals.

ALSTEAD. *Mica*, *black tourmaline*, *albite*, *molybdenite*, andalusite, staurolite.

ALTON. Arsenopyrite, galenite.

AMHERST. *Idocrase*, *yellow and cinnamon garnet*, amethyst, calcite, magnetite, pyroxene, limpid quartz.

ANDOVER. Andalusite, graphite, milky quartz, rose quartz.

BARTLETT. *Hematite*, *magnetite*, *limonite*, danalite, quartz crystals, smoky quartz.

BARRINGTON. Graphite, tourmaline, bog-iron ore.

BATH. Galenite, chalcopyrite, alum.

BEDFORD. Alum, tremolite, epidote, graphite, black, green, and yellow mica, limpid quartz, tourmaline.

BELLOWS FALLS. Cyanite, staurolite, prehnite.

BENTON. Quartz crystals, magnetite, *epidote*, beryl.

BERLIN. Magnetite, amethyst, pyrite, *chalcopyrite*, hornblende.

BRENTWOOD. Pyrites, sulphur, melanterite.

BRISTOL. *Graphite*, galenite.

CAMPTON. *Beryl.*

CANAAN. Gold in pyrite, *garnet.*

CANTERBURY. Soapstone.

CHARLESTOWN. *Staurolite*, chiastolite, bog-iron ore, cyanite, prehnite.

CHATHAM. Beryl.

CHESTER. Graphite, tremolite, sulphur.

CHESTERFIELD. Limonite.

CHICHESTER. Black tourmaline.

CLARKSVILLE. Galenite.

CONCORD. Fibrolite.

CONNECTICUT LAKE. Chalcopyrite, galenite.

CORNISH. *Staurolite*, smoky quartz, rutile in quartz, stibnite, tetrahedrite.

CROYDON. Iolite, chalcopyrite, *pyrrhotite*, *pyrite*, blende.

DALTON. Chalcopyrite, bornite, galenite, garnet, malachite.

DORCHESTER. Garnet.

DUNBARTON. Arsenopyrite.

EASTON. Magnetite.

EFFINGHAM. Molybdenite.

ELLSWORTH. Galenite.

ENFIELD. Galenite, gold, green quartz, ripidolite, brown and gray cymatolite, staurolite, margarodite, paragonite.

Epsom. Black tourmaline, arsenopyrite.

Errol. Garnet.

Exeter. *Epidote*, hornblende.

Farmington. Andalusite, galenite.

Francestown. *Soapstone*, arsenopyrite, red and yellow quartz crystals.

Franconia. Arsenopyrite, chalcopyrite.

Gardner Mountain. *Chalcopyrite*, *pyrite*, *galenite.*

Gilford. Magnetite, native lodestone.

Gilmanton. Red and yellow quartz crystals, tremolite, epidote, muscovite, tourmaline, limonite, jasper, hornstone.

Gorham. Quartz crystals.

Goshen. *Graphite*, micaceous hematite, black tourmaline.

Grafton. *Mica*, *albite*, *beryl*, *tourmaline*, *garnet*, *apatite* (blue, green, purple, and white), *fluorite*, *triphylite*, arsenopyrite, cleavelandite, columbite, quartz crystals, rose quartz, molybdenite, rhodonite.

Grantham. Gray and brown staurolite.

Groton. Arsenopyrite, *blue*, green and yellow *beryl*, *muscovite crystals*, large feldspar crystals, columbite, quartz crystals.

Hanover. *Garnet*, *black tourmaline*, *quartz*, hornblende, cyanite, *anorthite*, epidote, pyrrhotite, red and yellow quartz, zoisite, malachite, gold.

Haverhill. *Garnet*, *arsenopyrite*, *arsenic*, galenite, blende, pyrite, chalcopyrite, pyrrhotite, marcasite, tourmaline, bog-iron ore, steatite.

Hebron. *Beryl*, andalusite, graphite.

Hillsborough. Graphite.

Hinsdale. Molybdenite, indicolite, black tourmaline, rhodonite.

Jackson. *Cassiterite*, *arsenopyrite*, arsenic, drusy quartz, fluorite, apatite, *magnetite*, *molybdenite*, wolfram, chalcopyrite, copper.

Jaffrey. Cyanite, limonite.

Mt. Kearsarge. Andalusite, tourmaline, rose quartz.

Keene. Graphite, milky quartz, rose quartz, fibrolite, soapstone.

Kingston. Limonite.

Lancaster. Bog-iron ore, steatite.

Landaff. Gold, *molybdenite*, pyrrhotite, magnetite.

Langdon. Chiastolite.

Lebanon. Arsenopyrite, galenite, magnetite, pyrite, bog-iron ore, hornblende, massive tourmaline, gold, epidote, chlorite, saponite, kaolinite, graphite.

Lempster. Beryl, andalusite.

Livermore. Zinc blende (head of Swift river).

Loudon. Galenite.

Lisbon. *Staurolite*, *black and red garnets*, magnetite, hornblende, epidote, zoisite, hematite, arsenopyrite, galenite, gold, ankerite. At Franconia Iron Mine—*Hornblende*, *epidote*, *zoisite*, *hematite*, *magnetite*, titanic iron, *black and red garnets*, *arsenopyrite*, danaite, chalcopyrite, molybdenite, prehnite, green quartz, malachite, azurite, cyanite.

LITTLETON. Ankerite, gold, bornite, pyrite, chalcopyrite, malachite, menaccanite, chlorite, sericite.

LYMAN. *Gold*, *ankerite*, *arsenopyrite*, dolomite, galenite, pyrite, copper, pyrrhotite.

LYME. *Cyanite*, *black tourmaline*, rutile, pyrite, chalcopyrite, stibnite, staurolite, *molybdenite*, cassiterite.

MADISON. *Galenite*, *blende*, chalcopyrite, limonite.

MANCHESTER. Biotite crystals, drusy quartz.

MARLBOROUGH. Beryl, mica, fibrolite, rose quartz, crystals of feldspar.

MARLOW. Beryl, andalusite.

MEREDITH. Galenite.

MERRIMACK. Rutile.

MIDDLETON. *Rutile*, arsenopyrite.

MILAN. *Chalcopyrite*, *galenite*, blende.

MILLSFIELD. *Beryl*, garnets.

MONADNOCK MOUNTAIN. Andalusite, fibrous hornblende, garnet, graphite, orthoclase, tourmaline, beryl, fibrolite.

MONROE. Blende, chalcopyrite, pyrite.

MOOSE MOUNTAIN (Hanover). *Quartz crystals*, quartz with rutile, *quartz with acicular tourmaline*.

MOOSILAUKE MOUNTAIN. *Tourmaline*.

MOULTONBOROUGH. *Hornblende*, tourmaline, bog-iron ore, pyrite.

NELSON. Graphite.

NEWBURY. Fluorite.

NEWINGTON. Garnet, tourmaline.

NEW IPSWICH. Beryl, kaolinite.

NEW LONDON. *Beryl*, *molybdenite*, muscovite crystals.

NEWPORT. *Molybdenite crystals*, staurolite.

NORTHWOOD. Graphite, pyrite.

NOTTINGHAM. Limonite.

ORANGE. Blue beryl, chrysoberyl (at Orange summit), Amazon stone, *mica*, *albite*, tourmaline, apatite, galenite, limonite.

ORFORD. *Brown tourmaline*, *steatite*, *rutile*, cyanite, limonite, chalcopyrite, chalcocite, melaconite, malachite, galenite, garnet, graphite, titanic iron, molybdenite, pyrrhotite, *ripidolite*.

PELHAM. Steatite, in boulders.

PEMBROKE. Limonite.

MT. PEQUAWKET. Andalusite, damourite.

PIERMONT. *Micaceous hematite*, ordinary hematite, barite, green, white, and brown mica, apatite, titanic iron.

PITTSBURG. Gold, hematite.

PITTSFIELD. Galenite.

PLAINFIELD. Chalcopyrite, limonite, magnetite, gray and brown staurolite, dolomite.

PLYMOUTH. Columbite, beryl.

PORTSMOUTH. Epidote.

RAYMOND. Rose quartz, quartz crystals.

RICHMOND. Iolite, rutile, steatite, pyrite, anthophyllite, talc, pinite.

ROCHESTER. Andalusite.

RUMNEY. Beryl, galenite, blende, graphite.

RYE. Chiastolite.

SADDLEBACK MOUNTAIN. Black tourmaline, garnet, spinel.

SALISBURY. Limonite.

SHELBURNE. *Galenite, black blende, chalcopyrite, pyrite*, pyrolusite.

SPRINGFIELD. *Beryl, manganesian garnets*, massive garnet, *albite, mica, tourmaline*, rose quartz.

STARK. Labradorite.

SUCCESS. Quartz crystals.

SULLIVAN. *Black tourmaline*, beryl.

SURRY. Amethyst, calcite, galenite, hematite, limonite, pyrrhotite, plumose cyanite, tourmaline.

SUTTON. *Beryl, graphite.*

SWANZEY. Magnetite, graphite, potstone.

TAMWORTH. Galenite.

THORNTON. Graphite.

TROY. Andalusite, graphite.

UNITY. *Chalcopyrite, pyrite*, magnetite, *iolite, chlorophyllite*, green mica, actinolite, garnet, titanic iron, tourmaline.

WAKEFIELD. Epidote, molybdenite.

WALPOLE. Chiastolite, alum, graphite, rose- and straw-colored mica, staurolite, prehnite (Drewsville), fibrolite.

WARNER. Talc, soapstone.

WARREN. *Chalcopyrite, blende, epidote*, quartz, *pyrite, tremolite, galenite, rutile, talc*, molybdenite, *cinnamon garnet, pyroxene, hornblende, beryl*, calcite, cyanite, cymatolite, tourmaline (massive).

WASHINGTON. Graphite.

WATERVILLE. Labradorite.

WEARE. Arsenopyrite, soapstone, asbestus.

WENTWORTH. Graphite, galenite.

WESTMORELAND. *Molybdenite, fluorite*, chalcopyrite, *apatite, blue feldspar*, bog manganese, quartz, amethyst.

WHITE MOUNTAINS. At Notch—*Green octahedral fluor spar*, quartz crystals, galenite, pyrrhotite, ankerite, *black tourmaline*, garnet, chiastolite, albite, beryl, chlorite, calcite, amethyst, jasper, smoky quartz, gieseckite. On Mt. Washington—Rose quartz (on Glen House road), prochlorite.

WHITEFIELD. *Molybdenite*, massive garnet.

WILMOT. Beryl.

WILTON. Menaccanite.

WINCHESTER. Pyrolusite, rhodonite, rhodochrosite, psilomelane, magnetite, granular quartz, spodumene.

WINDHAM. Garnet.

WINNIPISEOGEE LAKE. Hornblende (on Red hill), beryl (on islands).

WOODSTOCK. Galenite.

NOTE. The names of minerals are italicised when the specimens obtained are better than ordinary.

MOAT MOUNTAINS AND NORTH CONWAY.

CHAPTER II.

LITHOLOGY.

HAVING now briefly considered the mineral species that have been found in our state, it is intended in this chapter to describe the rocks that are composed of aggregates of them. Lithology is a geological science, and therefore it does not deal with small and rare deposits, which, although of interest to the mineralogist, are of little importance in the structure of a world; but whenever a mass of material of such extent as to constitute a feature of the earth's crust is found, this mass is called a rock, and it is considered in the science of lithology. New Hampshire is a favorite field for the pursuit of this study. The surfaces of many states of our country are covered by rocks and soils which present little diversity;—but we live in a region which has been the scene of disturbances which have uplifted grand mountains and upturned the crust of the earth, presenting to us for our study many most deeply buried strata; and through rifts in these strata the underlying molten matters, which form a very diversified system of eruptive masses, have reached the surface. On our rocks the modifying influences of long ages have left their marks; and therefore the fundamental question of lithology,—Of what is the earth composed, and how did its constituent rocks reach their present condition?—becomes one of some complexity, but also one of much interest.

The age and distribution of our rocks are topics which have been discussed in other parts of this report. It is the object of this chapter to supplement the work in the field with the results obtained in the laboratory. It aims clearly to explain the composition of *specimens* of rocks which have been selected as typical, and to discover as much as possible of the origin, mode of formation, and history of the masses, by the study of samples. Microscopic study has of late been far the most fruitful in the growth of the science, and therefore this method has been chiefly employed. The value of work of this kind in connection with geological surveys has been sufficiently well demonstrated by the labors of others; and if this work is uninteresting it is the fault of the writer, for our rocks furnish a most beautiful series of objects for microscopic investigation.

The field is also comparatively new. Dr. F. Zirkel, of Leipzig, one of the most eminent authorities upon microscopic lithology, has written a very valuable and most beautifully illustrated treatise on the rocks collected by the United States Fortieth Parallel Survey (C. King, in charge). But those rocks belong largely to the newer formations; and with the exception of isolated specimens which have fallen into the hands of lithologists, the microscopic study of our old crystalline rocks has been but little prosecuted, and hence a systematic investigation of their microscopic structures and the properties of their constituent minerals, opens a field which cannot be barren of interest.

But the results which in the past have been achieved by other laborers in other ways must not be lightly passed. The laborious chemical researches of Dr. T. Sterry Hunt, and the deductions which he has drawn from them, are familiar to all, and lose no value to us because performed on allied rocks in other regions. Incidental to his geological investigations, most valuable lithological conclusions have been obtained by Prof. J. D. Dana; and besides these gentlemen, a large number of able geologists have studied, with greatest care, either parts of our formations, or others closely allied to them. If, now, in approaching this subject from a somewhat different standpoint, in many cases the same conclusions are reached, the author would wish to add them to the credit of those gentlemen. He would also recognize the labors of the European lithologists who have most carefully studied allied rocks by the same methods here employed, and whose results constitute the larger part of lithological literature. Every new region, however, furnishes new variations on old facts, and thus helps to strengthen, and sometimes to build up.

Before proceeding to the description of particular species of rocks, a few remarks of a general character, applicable to the rocks of our region, may make more simple the method of arrangement adopted in this treatise.

A hundred minerals have been described as occurring in our state; of these, more than half are now classed out as of no importance to lithology, and the diversity in our rocks is produced by the various combinations of the remainder. At times we have a simple aggregate of one mineral, and, again, a most complex mixture. Yet it is not like the formation of words, without number, by combinations of the letters of the alphabet. The subject obtains interest from the fact that rocks resultant from the combinations of minerals are limited in number and in kind by certain chemical considerations. Now, the mere determination of the mineral ingredients of a rock has little besides an economic importance. The subject, as a science, has its chief interest in the study of the conditions under which our earth has become thus covered with such very diverse accumulations of material; how the particular minerals became combined in such ways; and how they obtained their present form and condition. Bound thus to a central idea, the study of the mineral composition becomes interesting; and this central idea should give the basis for classification and arrangement of the material for study.

The following is the general mode of origin of diversity in rocks: The earth was once in a condition of igneous fluidity, and while in this condition, with the particles of matter freely movable, the various materials that composed the earth's outer zone would enter into their most stable combinations, and would form one immense, homogeneous mass; and thus the first crust of the earth may be supposed to have been quite uniform in character and composition, with only the variations induced by gravity, which would draw heavier materials to a lower level. But the conditions of chemical stability, in a state of igneous fusion, are quite different from those in the cold. Not merely are certain elements, with strong affinities for one another, but which in the heat are separated from one another by different degrees of volatility, brought to act upon one another again, but in the cold many stable compounds are formed in the presence of one another which are impossible in the heat, while at the same time entirely different mechanical agencies are brought to bear upon matter. The original crust is now so deeply buried as to be inaccessible to the student; but it is plain that the nearest spot to which it can be approached is the starting-point of lithology, and the study of the various changes and modifications which this matter has passed through will indicate the reason for the physical and chemical diversities which are now so prominent.

What rocks are most nearly like the earth's original crust is not hard to decide. Chemistry points to a basic, siliceous rock, from theoretical considerations; and geologists find such rocks cutting through the oldest formations, indicating that they came from a lower level. These rocks, of which diabase and basalt are typical, are found with tolerably uniform composition all over the world. Whether the rocks mentioned, or any allied to them, are really composed of matter erupted from an unsolidified zone of the earth's original substance, matters not here. These rocks fulfil the conditions that must have existed, and at least represent most nearly the first rocks from which all others have been derived. With the study of the basic, eruptive rocks, our lithology therefore begins.

But it has been deduced, as a result of the labors of this survey, that all our rocks are very old. A little area of Helderberg limestones represents the youngest of our stratified rocks, while the larger area is covered by archæan deposits,—and so all our rocks have been subjected to the influence of ages of time. At the risk of being wearisome, in the mineralogical chapter it was necessary to describe how almost every mineral, when microscopically examined, was found to be subject to some mode of decomposition peculiar to itself;—therefore sections cut from the various rocks of our state are continually presenting to us the processes of decay and change by which old rocks are changed into new ones; and, by illustrating as clearly as possible these processes, it is hoped to simplify our lithology.

It must be borne in mind that rock species, which are made of mixtures of minerals which vary in their relative amounts, can have no such definite boundaries as do minerals which are definite chemical compounds;

but, on the contrary, by the gradual introduction of new minerals, and the elimination of others, they so gradually approach and grade into one another as to make it a matter of personal judgment where the dividing line must be drawn. Hence, the science of lithology is unsatisfactory and puzzling to those who pursue it with the idea of the classification and nomenclature of their specimens in the foreground, while the indefinite limits of species, and the gradations that occur between different rocks, are aids to those who study the subject with the idea of discovering the nature and origin of rock types.

The study of a rock begins in the field; and though in the laboratory the student with his microscope can surmise many facts that are properly ascertained where the rocks are in place, the necessity of field work is not at all diminished. The first point to be noted in the field is the relationship of the given rock to those about it, and on this relationship the chief division of rocks is founded. Fragmental rocks are masses of loose or merely cemented sedimentary materials. The crystalline schists are masses of sediments, the materials of which have been reärranged in crystalline form. These two kinds of rocks show plain evidences of stratification. Intrusive rocks are those that bear no relationship to those about them, save that they form dykes or veins in them, and cannot be said to belong to the formations in which they occur. Between these groups of rocks, the members of which are either plainly stratified or plainly intruded, there is a group of rocks which are subject to discussion. At times they appear to be stratified, at times they are plainly intrusive; but more often they show plain evidence of neither one nor the other. In New Hampshire all these groups are very fully represented. Intrusive rocks are constantly met with, stratified rocks are everywhere, while there are members enough of the intermediate group, the relationship of which it is the duty of a treatise of this kind to discuss. It will thus be seen, that, as the boundary lines between species are indistinct, so, too, are those that divide the great classes from one another. This will make still more plain the force of what has been said on the subject of classification, while it may again be said that this indefinite division is a help towards the understanding of rocks in general; for it is easier to travel a smooth road than to spring from stone to stone. As an adjunct to geology, the difficulties with which lithology is beset partially disappear, for classification becomes its least interesting feature.

METHODS OF STUDY.

In reference to the application of the microscope to this subject, sufficient has already been said in the introduction to the first chapter, while the optical properties of all of the minerals that are found as constituents of our rocks have been indicated in describing them. In this chapter, therefore, it will be assumed that no explanation of the optical effects that are reproduced in the figures is necessary. Some of the figures represent rocks as they appear with ordinary light, and hence need no explanation. When crystals are represented as they appear in polarized light, it is to be understood that the position of the Nicols is a determinate one only in those cases where the planes of vibration of the light in the Nicols are represented by cross lines on the figure; for, as a rule, where nothing is to be gained by indicating the position of the axes of elasticity in crystals, the Nicols have been so placed as to obtain colors which would not complicate the lithography. I refer those again, who wish systematic instruction on this subject, to the works of Zirkel and Rosenbusch.*

If, as has been shown, the microscope with ease and certainty determines minerals where chemical analysis fails, discovers ingredients in rocks the presence of which was not before suspected, and brings to the foreground many little circumstances which prove to be exceedingly weighty, there are, too, cases where it fails. For example: in accurately prepared sections from crystals of the triclinic feldspars, one can easily determine the species; but when the crystals lie scattered at haphazard, though one can easily recognize them as being of triclinic feldspar, one cannot often determine the species, and in some such cases chemical analysis is advantageously employed. Not long since the science was largely dependent upon chemistry for its determinations, and cumbersome methods for the separation and determination of ingredients

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* The work of A. von Lasaulx, "*Elemente der Petrographie*," is a condensed presentation of general lithology, embracing the latest discoveries. The two volumes by Rosenbusch, on Mikroskopische Physiographie, are very systematic and very valuable. The first volume treats of the minerals of importance in lithology, and the second volume treats of the massive rocks.

were instituted, which now are only employed in most special cases. To-day, chemical analysis, with such ends in view, is only undertaken when the necessity is indicated by the microscopic examination.

But there is a value beyond the determination of mineral constituents, which is attached to chemical analyses. Knowing the mineral constituents, it may be desired to determine their proportion; or, the ultimate composition of a rock, without reference to its mineral constituents, may be desired. On the data furnished by such analyses much reasoning has been based, and many valuable conclusions arrived at, concerning the chemical relationship of rocks formed at different times and in different ways. The tabular works of J. Roth contain most of the analyses which have been made.

In the preparation of this work, some hundreds of thin sections of our rocks have been prepared and examined, and chemical analyses have been made, where an end seemed likely to be gained. It is hoped that the specimens chosen as typical have been so carefully selected, that persons can recognize, in the descriptions, the rocks from other localities in the state which are not discussed, so that these pages may be found to contain a tolerably complete presentation of the lithology of New Hampshire.

The following are the species of rocks that are considered in this report, and the order in which they are described: *

Basic Eruptive Rocks.

Diabase.
Diorite.
Gabbro.

Acidic Unstratified Rocks.

Felsitic.

Felsite.
Porphyritic Felsite. (Porphyries.)

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* In this classification only the most general divisions of the rocks are given, and the varieties and sub-varieties are not enumerated. In the report, the extensive introduction of adjective terms in the nomenclature of varieties and sub-varieties will be noticed. Many of these rocks have received special names; but convenience and simplicity are both promoted by making specific names dependent only upon the most fundamental distinctions. The introduction of special names for rocks which possess particular local characteristics, or peculiar accessories, is not favorable to a science the characters of whose species are so very inconstant as are those of lithology.

Granitic.

Granite.
Sienite.

Crystalline Schists.

Gneiss.
Mica Schist.
Argillitic Mica Schist.
Quartz Schist.

Greenstones.

Metamorphic Diorite.*
Amphibolite.
Chlorite Schist.

Half Crystalline Rocks.

Clay Slate.
Quartz Schist.

Minerals as rocks have been treated of in the preceding chapter. Fragmental rocks have been discussed in the part upon Surface Geology, and are hence very briefly treated here.

BASIC ERUPTIVE ROCKS.

The investigations which thus far have been made upon our basic eruptive rocks leave much to be desired in detailed knowledge of their nature and composition. The dark-colored rocks which intrude themselves, here abundantly, there sparingly, through our crystalline strata, have in some cases been correctly identified from their coarse-grained and porphyritic varieties; but, when examined with the microscope, rocks which are apparently alike are found to be so different,—so many unsuspected ingredients are found to be present, so many suggestive structural effects are seen,—that it becomes plain that such study is necessary

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Moreover, in the present confusion (especially among writers in the English language), while every writer uses his own nomenclature, and impresses on each name his own signification, the adopted method will most certainly convey the idea that is intended.

No new names have been introduced, though I am certain that, according to precedent, material is at hand. This feature of my report I hope will be commended.

* This rock is mostly massive. I think it will be found satisfactorily explained, however, why it is considered in this connection.

for their elucidation. Before proceeding to special descriptions, we will consider their position among rocks of this class, and what they have in common which isolates them as a well defined group.

The first great division of eruptive masses is into basic and acidic rocks. The first are characterized by a content of silica lower than sixty per cent., and basaltic rocks are typical of them. The acidic rocks are lighter in gravity, contain more silica, and trachyte and quartz porphyry are typical examples. These two great classes were instituted by Bunsen, and were by him supposed to represent two great zones or layers of fused matter, which originally underlaid the crust of the earth, separated from one another by their specific gravities. He supposed that at different periods of the earth's history matter was erupted from different layers of this mass beneath, and thus we have basic and acidic eruptive rocks, and also intermediate varieties, which represent the intermediate zone of the molten matter. By further study, this once so plausible theory has been mostly done away with. It is now considered that the shifting of sediments, and vast movements in the earth's crust, may render fluid, or plastic, beds of previously solid matter; and thus, at different times and at different places, the crust of the earth may be underlaid by beds of molten material, which may be composed of the unstratified, original matter of the earth's exterior, or of sediments of variable composition; and through rifts in the superficial beds we may hence obtain most diverse eruptive rocks. The two great divisions of rocks are, however, maintained, and we have in our state numerous representatives of both classes. It is the basic division that we are now to consider.

Besides this great chemical distinction, there are certain geological conditions which sub-divide eruptive rocks. It is found that those rocks which have been erupted in the later periods of the earth's history possess certain characteristics that distinguish them from others. They show in general the effect of more rapid cooling, and are either composed largely of glassy matters, or enclose more or less glassy material in their masses. They often possess certain types of microscopic structure indicative of free movements in the plastic mass. Of this class the basalts are typical among the basic rocks. The older rocks, on the contrary, are completely crystalline, and in their microscopic structure are entirely granitic. These observations have led the German lithologists to sub-divide their rocks into older and newer, and sharply to separate them in their nomenclature into two classes, according to their geological age, the tertiary being the turning point. This separation has been strongly opposed by some American and English geologists, and the objection has been made good by proving that the distinctive characters are sometimes wanting where they should be found. Although the result of the discussion may be to eliminate the element of age from nomenclature, still the characters that distinguish old eruptive rocks from the newer ones are so very fundamental and so very general, that the value of these distinctions is recognized by every one. If, with this distinction in mind, one examines sections of our basic eruptive rocks, all the characters that are assigned to very old rocks are immediately recognized. They possess a crystalline structure that throws them into contrast with younger rocks, and in their compositions and transformations they show all the effects of age. They do not come within the boundaries of the discussion before named, because geology and microscopy both would assign them to old formations.

Of the basic eruptive rocks of this country, those that cut the Mesozoic sandstone have been best studied. One vast series of dykes extends up the Connecticut valley from the sound to the border of our state, and though they do not come within our boundaries, and hence are not within the limits of our descriptions, it is instructive to compare our rocks with a well defined American formation. We are indebted to Prof. J. D. Dana for most of our knowledge of these rocks, and Mr. E. S. Dana has examined them with the microscope. These rocks are essentially uniform in general appearance and in mineral composition wherever found, from Nova Scotia to Carolina. Some analyses made by myself indicate that their chemical composition is also almost invariable. Diabase is the typical rock of the whole formation, varying only in the amount of hydration and alteration. Sometimes it is clear and undecomposed, with scarcely a trace of hydrous minerals, and sometimes its constituents are all hydrated and decomposed, but in all cases it bears evidence of having been the same in original composition. These rocks were erupted after the accumulation of the Mesozoic red sandstones. Turning now from this grand uniform system to our old trap dykes, all this symmetry disappears. Not only do we find that there are varieties representing all the stages of alteration and decay, but that the original rocks were most diverse, both in their mineral constituents and in their structure. Rocks which to the eye appear substantially the same, are, after microscopic examination, found to be widely separated from one another. Closely adjoining dykes, which at first glance would be assumed to be identical, prove to be very different; and this makes it plain that we deal with a complicated question. We find that these rocks cannot be regarded as forming any defined system, but that they are probably eruptions that took place at intervals during those long past ages when our rocks were accumulated and elevated, and owe their great diversity to variations in the underlying melted matters, in the conditions of eruption that obtained place at different periods, and to alterations produced in them by subsequent ages. Any effort now to subdivide them, and to refer different classes to different times, and to make geological systems of them analagous to the Mesozoic system, would be nearly impossible ;—therefore we must take them as a whole, as an old mass of basic eruptive rocks, and treat them all together.

Not merely in physical and chemical properties do these rocks differ from the later eruptions. The Mesozoic trap rocks form, as a rule, large and conspicuous dykes. The scenery of the lower Connecticut owes much of its beauty to their high, overhanging cliffs, for trap rocks usually make impressive scenery. So it is with the European basalts. They commonly stand in conspicuous masses above the surrounding region; and many often visited places are dependent upon basaltic rocks for their celebrity. But in New Hampshire all this is reversed. The trap rocks cut through old crystalline rocks, which, being very hard, are not more rapidly denuded than are the trap rocks, and hence the latter are not brought into prominence. In fact, more often the trap rocks, on account of their basic composition, are more easily decomposed and disintegrated, and hence, when they are brought into prominence, it is commonly in an inverse way; for, by yielding more readily to wear and decay, their removal from their position in the crystalline rocks forms gorges or flumes, many of which are celebrated for their beauty. Our trap dykes are, moreover, very often of such small size that in no case would they make striking features in the landscape.

The first person who directed his attention to the trap rocks of New

Hampshire was Prof. O. P. Hubbard, of Dartmouth college, who in 1837 made a geological excursion through various parts of the state, and who made special observations on the eruptive dykes.* This gentleman recognized clearly the great differences in these rocks, and noted the variations in their appearance, even when situated side by side. But the means for careful discrimination being at that time beyond the reach of our science, all these rocks were classed together as trap. I hope that gentleman will not be displeased to know that some of his specimens, collected so long ago, have fallen into my hands, and that we now have the means for classifying them.

Besides researches made on the rocks actually within our borders, more extended studies have been prosecuted on allied rocks in adjoining regions. The most prominent of the investigations are those prosecuted by Dr. T. Sterry Hunt, when connected with the Canadian survey.† The rocks which he studied and classified are nearly allied to ours, and in many cases identical. In reference to this work it may be said, that although microscopic study in many cases would, I think, cause a nomenclature essentially different to be adopted, yet any new results which might by that means be attained would in no degree lessen the weight of Dr. Hunt's reasoning in reference to the origin of this class of rocks, or any of his theoretical and geological conclusions, which must be what he chiefly values. The more essential features of Dr. Hunt's work have been by him embodied in his *Chemical and Geological Essays,* a volume easily accessible to all, while the geological report is not.

All our basic eruptive rocks are essentially compounds of triclinic feldspar, with either hornblende or pyroxene, and, according to which of these latter minerals is present, they are divided into two classes. For the determination the microscope is often necessary, with the aid of which a number of accessory minerals are found, which are either essential and constant, like magnetite and apatite, or accidental and variable, like chlorite, biotite, calcite, etc. The pyroxene or hornblende has at times been removed by process of alteration and decay; but still its original presence, and its influence in producing the structure observed, are so plain as to make no difference in the classification of the rock. The

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* *Am. Jour. Science,* i, vol. xxxiv, p. 105.

† *Geology of Canada,* 1863.

hornblendic varieties are therefore all *Diorite*, and the pyroxenic are all *Diabase*.

When the feldspathic constituent is considered, subdivision is again necessary. Often any determination beyond the triclinic character of the feldspar is impossible on account of the decomposition, which has so nearly destroyed the crystals that only such little particles are left intact as suffice for the simplest optical examination; but, on the other hand, crystals are often found in such well preserved condition as to allow their species to be determined, and to prove that different species exist in different rocks. In diabase, labradorite appears to be most common and most constant; but rocks are found in which anorthite becomes prominent and easy to determine. In diorite the feldspar is commonly plagioclase (either labradorite, andesite, or oligoclase), but cases where anorthite is present are not wanting.

Besides these general sub-divisions, varieties are produced by the prominent presence of accessory or variable constituents; and, aside from all mineralogical distinctions, there are very marked structural differences which sub-divide each species into compact and porphyritic varieties. There are, moreover, many varieties formed by degrees of alteration; but these are not recognized in classification, and the description of these rocks must consist, very essentially, of a history of change, reorganization, and decay. It must be borne in mind that such rocks are peculiarly subject to change, for their mineral compounds are not very stable, and their bases are in part readily oxidizable. Expose such rocks therefore to the influences of ages,—to the mechanical movements, change of temperature and condition that must have found place in the folded and contorted strata of our state,—and this diversity in present condition becomes an interesting feature which might be expected to present itself.

Besides the rocks mentioned, there is another basic eruptive rock, which in its structure and habit is so distinct, that, although composed of the same ingredients, and scarcely more than a variety of diabase, it may most advantageously be described by itself. This is *Gabbro*, which is considered last.

DIABASE.

Diabase is a crystalline granular mixture of augite with a triclinic feldspar, which is usually labradorite. An oxide of iron, in the form of magnetite or titanic iron, is always present, and usually, also, some green chlorite which has resulted from the decomposition of the other minerals. Numerous accessories are constantly or accidentally present. The rocks are gray, black, or green, according to the relative amount of the ingredients, and their condition as regards decomposition. Many of them are massive, but with us the larger part are more or less porphyritic. Although varieties abound in which large and prominent crystals are developed in a ground mass that is apparently very compact, still in no sense is this ground mass to be confounded with an amorphous or non-crystalline body, for when magnified it is found to be entirely composed of crystals, and hence these structural differences are not of the nature to separate the porphyritic rocks from the others. Fundamental distinctions are formed by the introduction of anorthite in some cases, and of olivine in others. On these characters the group is sub-divided.

Diabase (massive). Common massive diabase, as found in New Hampshire, is composed of a mixture of labradorite, augite, and magnetite or titanic iron. It is nearly black when its ferruginous constituents predominate, light gray when the feldspar predominates, and green when much chlorite is present. It varies in its texture somewhat, but is usually so fine that no ingredient can with certainty be recognized by the unaided eye. Its dykes occur in all parts of the state, but most abundantly in the mountainous regions. When its thin sections are examined with the microscope, decomposition of one kind or another is found to have made extended progress, but the modes in which this decomposition has progressed are very diverse, and have created quite distinct types of rock.

Chlorite is the most prominent result of one common method of decomposition. In thin sections of these rocks a green chlorite is seen surrounding remnants of augite. The structure and general appearance of a section of this kind of diabase is represented in Fig. 1 on Pl. 9. It is made from a green-colored rock taken from a dyke in East Hanover, and may be considered as a typical specimen of this variety. The augite crystals, at the expense of which the chlorite has been formed, were originally quite large, but now only little rounded grains are seen. In polarized light some of them are found to be twin crystals; in ordinary light their color is brownish red. The feldspar shows its characteristic bandings in polarized light, but is usually troubled and clouded by decomposition. The bandings are sometimes almost obliterated on account of alteration, and then the crystals do not become dark in any position between crossed Nicols, but show only the effects of an aggregate of secondary products. Crystals or grains resembling magnetite are found intact; but often a black rounded kernel or skeleton is found in a grayish mass, which is recognized as characteristic of the decomposition of titanic iron. Very minute needles of apatite, which pierce through the other minerals, and which are often grouped together in large numbers, are invariably present. Other products have also resulted from decomposition, a characteristic one of which is epidote. This is often macroscopically seen filling amygdaloidal cavities, but is more often seen with the microscope, especially in sections that show a much altered feldspar. It appears as a very light yellow, slightly dichroic product, often in very minute particles which in polarized light assume the most brilliant colors. Calcite is rarely absent. It fills the cavities and pores, and, when not visible with the microscope, a specimen of the rock when moistened with acid will effervesce, and indicate its pressure. Biotite is not rare, but whether as an original or a secondary product is not certain. Quartz is not uncommon, but it is plainly a secondary product. These are the most general characteristics of the first well marked variety, which may be called the chloritic type.

There are some large dykes of this rock on the road from the Glen house to the summit of Mt. Washington. In sections of specimens the double system of twinning, which so often characterizes labradorite, is conspicuous. A section of a specimen from Stark indicates that the augite is almost entirely gone, and chlorite takes its place, fills cavities in the rock, and forms little concretions in spots. A rock near the Sagamore house resembles the last, but in it much more epidote has been formed and less chlorite, and, as is usual in such cases, the feldspar has suffered more and the augite less. This rock also contains pyrites. A rock that forms a dyke which cuts the gabbro on Mt. Washington river is remarkable for its large content of pyrite and magnetite. The augite is in small grains, and has been altered in part into chlorite, and in part into hornblende. The decomposition of a light-colored diabase has formed Hitchcock's flume in the Notch. In this rock the feldspar is much altered; the augite is entirely decomposed into chlorite and calcite, and the magnetite is in crystals. At Rye, a diabase occurs that combines almost all the peculiarities of decomposition that have been mentioned. It contains labradorite, augite, magnetite, and apatite as original constituents, and chlorite, hornblende, biotite, epidote, and calcite as secondary. It also contains pyrite, which is mixed with the magnetite. And thus we might go on, for every rock presents some variations peculiar to itself. The variations are, however, those of different proportion in the original constituents, and in the relative amount of decomposition products of the various kinds mentioned, and description becomes, therefore, the endless repetition of the same idea.

The next most prominent variety of massive diabase which occurs in New Hampshire may be called *mica diabase*. The difference between this and the last variety was not originally great, but the mode of alteration has widened the gap between them. In this rock, the decomposing agencies have produced no chlorite of consequence, and hence the rocks are not green, but of a light gray color. In appearance they are as fresh as if crystallized yesterday. On being moistened with dilute acid they do not effervesce, and in looks and behavior quite surprise one who is looking for old weather-beaten rocks. But the microscope indicates as much alteration here as in the first case, for, on applying polarized light, what was originally augite is seen to be no longer a homogeneous mineral, but an aggregate of minute crystals that resemble calcite. On treating the rock with dilute acid it does not effervesce; but if the acid is heated it effervesces long and powerfully, and in the solution lime, iron, and magnesia are abundantly found. This indicates the formation of dolomitic and ferruginous carbonates by decomposition, and makes it plain why the rock looks so fresh. The rock is quite feldspathic, and the feldspar is undecomposed, and its bands of color are clear and distinct. This fact, united to the circumstance that the augite is converted into carbonates, accounts for the light color and fresh appearance of the rock. The appearance of a section of a specimen from Bemis brook, in ordinary light, is represented in Fig. 4 on Pl. 6. Biotite is a characteristic mineral in this variety of diabase, and is very conspicuous in thin sections. It exists in little scales, which, when lying in the plane of the section, are often seen to be hexagonal. Here and there in the mixture of carbonates a kernel of augite is found; apatite needles are very abundant; also, crystals of magnetite. Here and there a well formed crystal of hornblende is seen, and also a bit of pyrite. The chlorite that is very sparingly present can be called nothing better than viridite, for it is in minute, formless bits, which in polarized light behave like an amorphous substance.

As the feldspar is quite fresh and predominant in amount, an analysis of this rock may have some value as indicating its original nature. It is indeed interesting to note that with the complete destruction of the augite, the feldspar has so well maintained its identity. This rock from Bemis brook gave Mr. Pease, of the Sheffield Labratory,—

Silica,	47 64
Alumina,	18.35
Iron sesquioxide,	4.20
Iron protoxide,	6.52
Manganese protoxide,	.16
Lime,	7.08
Magnesia,	4.36
Soda,	3.31
Potash,	1.96
Water,	2.33
Carbonic acid,	5.01
	100.92

The calculations on analyses of such heterogeneous mixtures are not very satisfactory, and if we allow at the highest twenty per cent. for carbonates, iron oxide, &c., the silica is increased to sixty per cent., but as we know that silica that is liberated by decomposition is often present in such rocks in unrecognizable form, the probability that these are labradorite rocks is indicated.

The variations in this variety of diabase are not wide. A specimen from Tripyramid mountain contains much more unaltered augite, but is otherwise the same. The Flume at Lincoln is made by the disintegration of a diabase identical with that from Bemis brook, save that it contains more iron oxide and pyrites, which aid its decomposition. A dyke at Dixville is the same, but more green chlorite has been formed, and which has gathered into little radial concretions in cavities, which are otherwise filled with calcite (see p. 120). Some of the augite in this rock is quite fresh, and some is entirely decomposed.

Diabase (Porphyritic). All the remaining varieties of diabase that have been found in New Hampshire are porphyritic; and though many are massive, the development of large crystals in a ground mass of fine crystals is much more characteristic of the basic eruptive rocks of the state. Sometimes but one ingredient is porphyritically developed; and sometimes nearly all the constituents are in part large crystals. The ground mass is in no sense an amorphous or half crystalline substance, but is a fine-grained diabase; and therefore the difference between the massive and porphyritic varieties is merely a structural one, which is dependent on certain conditions which I shall endeavor to point out.

The most common variety of porphyritic diabase is the one in which large crystals of labradorite are developed in a fine-grained ground mass. The rock is ordinarily called *labradorite porphyry.* With its large white crystals so conspicuous in their black surroundings, it is very beautiful. This feldspar is often perfectly fresh and undecomposed, and thin cleavage pieces can be obtained, the optical properties of which prove the crystals to be labradorite. The angle between a plane of elasticity and the twinning plane, as measured in basal cleavage scales obtained from specimens from Ossipee and Center Harbor, is about seven degrees. The specimen from Ossipee will be described as typical. In thin sections, the augite in the ground mass is seen to be altered into an aggregate of chlorite, calcite, etc., while the large and small crystals of labradorite are still intact. Two systems of twinning are often seen in the large crystals, which show very clear and distinct bands of color in polarized light. The other constituents and peculiarities of the rocks are those of common diabase, and which need not be repeated. Specimens from Center Harbor, and Concord, Vt., have been examined, and offer no further peculiarities. A specimen from Bartlett contains some quartz. In all the specimens the large crystals are flat and tabular, and hence on surfaces of fractures they appear long and narrow. This is because the lateral planes of the crystals are developed, but none others. The terminations of the crystals, as seen in the rocks, are consequently irregular.

Some sections of the labradorite porphyry from Ossipee present a most interesting phenomenon. Many of the large crystals of labradorite are seen to have been all broken up after they had been formed, and then cemented together again. Fig. 2 on Pl. 9 represents one of these crystals. In this crystal, the bandings of color that are induced by polarized light are dislocated and out of joint, while below are pieces which have evidently been broken off. Other crystals in this section have been all broken up into a complete mass of fragments, and then all cemented together again. It appears in this case that the large crystal had grown to its full size before the mass had solidified, and at some given time a movement or commotion took place which broke into fragments many of the crystals that had been formed, and induced at the same time some change in condition, which caused quicker cooling and the solidification of the residue of the matter in little crystals. A sudden change of condition is, then, one cause which results in the production of porphyries.

Anorthite Diabase. The diabase of New Hampshire, in which anorthite has been proved to enter as an essential, is also porphyritic. The reasons why it should be so are of a different nature from those just referred to for the explanation of the structure of labradorite porphyry. The essential ingredients of common diabase do not widely differ from one another in fusibility; but anorthite fuses with difficulty, and hence, if it is to be formed in a mass cooling from a state of fusion, its crystals will have the first opportunity to grow; and where it is found in such rocks in our state its crystals are quite large and well formed. When sections are examined with polarized light, these crystals are found to be more or less completely altered into an aggregate of fibres, but a well defined centre is often left intact. The ground mass is usually coarser than that of the labradorite porphyries. A good example of this rock is found at East Hanover, in a series of small dykes that intersect the slaty rocks. The anorthite is in crystals as large as hickory nuts, possessing quite a variety of planes (see p. 90), although these planes are quite rough, as might be expected in such surroundings. The crystals are commonly altered into a translucent, waxy substance, which, as already stated, is a mere aggregate of fine needles, and is called saussurite; but often crystals with clear and undecomposed centres are found. The appearance of a thin section of one of these crystals is represented on

Pl. 5 in Fig. 3. The rock contains augite of a light pink color, much green chlorite, and a little biotite. The iron oxide is titanic iron, and its solid centres are usually surrounded by a gray, translucent rim. Apatite is abundant.

The massive portion of this rock has been analyzed by Mr. Pease, of the Sheffield laboratory, with the following result:

Silica,	47.38
Alumina,	19.08
Iron sesquioxide,	2.66
Iron protoxide,	8.81
Lime,	8.37
Magnesia,	6.07
Soda,	3.54
Potash,	1.31
Water,	3.39
Carbonic acid,	.79
	101.40

Specific gravity, 2.90.

An analysis of the anorthite from this rock has been given on page 91, which indicated the composition of the aggregate into which the large crystals have been converted. But the feldspar in the compact part of the rock is not so altered as are the large anorthite crystals; and the analysis points towards a soda lime feldspar like labradorite, and makes it probable that two kinds of triclinic feldspars are present, as has often been proved to be the case elsewhere.

A specimen from Moose Mountain, and another from Stark, offer no further peculiarities, save the presence in them of much pyrites. A specimen from Concord, Vt., contains much calcite, and the anorthite is almost entirely altered into an aggregate.

Besides the occurrences of diabase porphyries that have been mentioned, there are a great many others in which the feldspar has reached such a state of decomposition that neither analysis nor the microscope can determine its species. In regard to all these, it may be said, that whether originally labradorite or anorthite is now of little consequence, since time has reduced one and the other to the same thing, and for such rocks porphyritic diabase is a name sufficiently satisfactory. It may be said of those specimens which have been determined, that the anorthite varieties have crystals that are short, thick, and well defined in outline, while the crystals of labradorite are long and irregularly terminated. If this should be regarded as characteristic, both varieties are present among these more decomposed rocks.

Olivine Diabase. Ever since Prof. O. P. Hubbard found the remarkable boulders of this rock at Thetford hill, those interested in them have been hoping to find the rock in place. The employment of the microscope brings these interesting rocks to light, and the specimens, though not so remarkable when examined with the unaided eye, are, when cut into sections and magnified, found to be very interesting and beautiful.

The boulders found at Thetford hill are composed of large round masses of olivine sometimes two inches in diameter, large rough greenish plagioclase crystals, and large black augite crystals, all embedded in a small amount of a ground mass. Dr. Hunt has described a rock exactly like this, which is in place at Montarville, in the neighborhood of Montreal. From whence these boulders came is not known.

Olivine bearing diabase is not a common rock, though it seems quite plain, as Mr. Rosenbusch remarks, that microscopic studies will much increase the number of its representatives. As found in dykes at Campton falls, it is a black porphyritic rock. The macroscopic crystals are jet black, and with the unaided eye it would be hard to say whether they were of augite or hornblende, as they are not large, and show no distinct cleavage. They have, however, very well defined outlines, indicating a good crystallization. The olivine is not distinguishable as such, and the reason becomes very plain when the sections are studied: it is because they are no longer olivine. In the thin sections, we see that in a compact and very fine mixture of crystals of a triclinic feldspar, augite, biotite, hornblende, chlorite, and magnetite, are larger and well formed crystals of a triclinic feldspar, augite, and olivine. The olivine is very well crystallized, and a section through two of its crystals is represented in Fig. 4 on Pl. 7. This olivine is all much altered. The centres of the crystals are in some places intact, but most of them are entirely changed into a greenish-fibrous serpentine-like mineral—a kind of alteration to which olivine is peculiarly liable. The augite is quite abundant, and its large crystals are perfect in outline, but the fine augite scattered through the ground mass is without crystalline form. The rock contains many microscopic cavities, which are filled with a quite complex mixture of decomposition products. The outer walls of the cavities were first lined with sphaerosiderite, then there was a growth of hexagonal calcite crystals, and finally the cavities were filled with analcite, the peculiarities of which have been described in the mineralogical chapter.

Another specimen of this rock, also from Campton falls, offers some other interesting microscopic peculiarities. The external appearance of the rock is the same, but decomposition has produced substances of different aspect. The chlorite in the ground mass is replaced by a dull white translucent substance, which is probably carbonate of lime, and the cavities filled with minerals are absent. The large crystals are concentrically banded, the different zones resulting from some differing conditions at stages of their growth, and from subsequent alteration. The plagioclase crystals have impurities heaped in their centres, while on the outside the crystals are clear. The augite is in zones, which differ but slightly in their color, but which are brought into stronger contrast when polarized light is employed ; for when the Nicols are crossed and the section is revolved on the stage of the microscope, the different bands do not become black at the same time, which shows that the planes of elasticity in the different parts of the crystal take slightly different directions, and therefore, whatever be the position of the Nicol prisms, the crystal sections are banded with different colors. These augite crystals are represented in Fig. 3 on Pl. 9. The crystals of olivine are also quite peculiar in their mode of decomposition. They are affected to their centres, yet the cores have still, in polarized light, the optical behavior of crystals, though the clear color usual to olivine is mottled by decomposition products. Next to the centres are radiated fibrous masses of serpentine which give beautiful green colors between the Nicol prisms, but the outsides of the crystals have been apparently entirely removed, and the spaces filled with a mixture of calcite, quartz, and pyrite. The pyrite is in cubes, and some of the crystals have dodecahedral planes. One of these crystals of olivine is shown in Fig. 4 on Pl. 9. This is simply another form of the alteration which constitutes so large a part of the study of our basic eruptive rocks.

I call attention here to the fact that the gabbros, which are described later, are very nearly related to diabase, and, indeed, may well be classed as varieties of it. They have, however, such distinctive characters that I do not like to introduce them here between rocks which are more in need of classification.

DIORITE (PORPHYRITE).

Diorite is a crystalline, granular mixture of a triclinic feldspar, hornblende, and an oxide of iron, which is either magnetite or titanic iron. There are in New Hampshire two well defined and very distinct kinds of diorite. One contains a green, more or less fibrous, hornblende, and also often contains quartz, which at times is present in such amounts as to relate the rocks to the amphibolites in composition. The rocks are light green in color, and though massive their beds are arranged conformably with the surrounding strata. Such rocks in Canada have been shown by Dr. Hunt to be sedimentary beds metamorphosed into diorites. The conformity of rocks of this nature at New Haven with the surrounding strata has been clearly shown by Prof. Dana; and others have followed in their studies upon rocks of various regions. The diorites of the other class are in New Hampshire black rocks. The hornblende that they contain is in compact grains, or in crystals with defined outlines. It is not green, but is black, and in thin sections it is deep brown or dark yellow, and is strongly dichroic. The rocks of this nature occur in well defined dykes cutting through the strata, and are plainly eruptive. It is understood that, in this place, we are treating only of the latter class; the former are described among the greenstones of the Connecticut valley.

These rocks sometimes resemble diabase, and though in those that contain large crystals the hornblende can be recognized by its cleavage, in the more compact varieties this is not possible. A glance with the microscope is, however, sufficient for their determination; and the necessity for careful discrimination by such a method becomes very evident when it is found that dykes of diorite and diabase are situated side by side, specimens from which could with difficulty be distinguished from one another. Being so associated, little room is left for generalization upon their relationship to one another as regards position. The microscope reveals the frequent presence of the same accessory ingredients, such as biotite, apatite, chlorite, pyrite, and calcite.

The study of these rocks leads us through the same channels as before. We have to consider wide differences in the composition of the original rocks, and wide differences that have resulted from the decay which long ages have induced. It may be stated, however, that the differences in the original compositions of our diorites are greater than of our diabases, while the more stable nature of hornblende has preserved the diorites from such universal alteration as characterizes our diabase.

Diorites may originate from an alteration of the augite of diabase into hornblende, or from the original crystallization of hornblende. Mr. Alport states, that the first process of formation is quite general in the English rocks at Landsend, and that all stages of the process of change are easily found. I have spoken of incipient change of this kind in describing certain kinds of diabase; but our eruptive diorites usually contain microscopic or macroscopic hornblende crystals, which are quite well crystallized in the form characteristic of the species,—and hence we are dealing in this respect with primary formations.

Our diorites, being mostly porphyritic, belong to the class of rocks which, by some Germans, are called *porphyrite.* I think no one will object to the simple inversion of their terms which I employ. Porphyritic diorite means the same as diorite porphyrite. The ground mass of these porphyritic diorites is wholly crystalline, and though large crystals are developed in it, it is diorite still.

There seem to be two quite distinct types of this rock in New Hampshire, one of which is very basic in composition, and only hornblende is porphyritically developed in it, while the latter contains more silica; and both hornblende and plagioclase are conspicuously developed in the black compact ground mass. The first variety contains a triclinic feldspar, which cannot be identified with any certainty, and we will call the rock merely basic diorite. The second variety contains andesite or oligoclase, and we will speak of it as plagioclase diorite.

Basic Diorite. (Porphyritic Diorite.) This is a rock which has for a ground mass an aggregate of crystals of triclinic feldspar, hornblende, biotite, and magnetite or titanic iron, with usually some chlorite and apatite. In it well formed crystals of hornblende are developed, and at times quite large crystals of titanic iron. Under the microscope, with polarized light, feldspar crystals of some size are seen, but they are so impure that they can scarcely be distinguished from the ground mass without polarized light. In some specimens, however, they are pure enough to see all their bandings; and in appearance and mode of decomposition they much resemble the anorthite of the diabase, and are entirely unlike the feldspar of the diorites next to be described. At Campton falls there are several dykes which furnish handsome specimens for those who admire dark, porphyritic rocks. The black crystals of hornblende are not large enough to determine with the unaided eye, but they are very brilliant and numerous. The following analysis made by Mr. Pease, indicates the general composition of this rock:

Silica,	43.39
Alumina,	15.85
Iron sesquioxide,	6.56
Iron protoxide,	9.51
Lime,	9.47
Magnesia,	5.01
Soda,	5.15
Potash,	.19
Carbonic acid,	2.47
Water,	3.29
	100.89

This analysis is interesting as showing the very basic nature of these rocks, but beyond that, little can be deduced from it, though it may be suspected that the feldspar is basic too; but the predominance of hornblende, the presence of much magnetite or titanic iron, and the complicated nature of the rock, leave any conclusion that may be drawn only probable.

When examined under the microscope, beyond the general characteristics of the rock already mentioned, some interesting details are brought to view. The hornblende crystals are deep brown when the light passes through them in one direction, and bright yellow when it passes at right angles thereto. They are often twins, the twinning plane being parallel to the orthodiagonal. Moreover, some of these crystals are hollow, and the cavities that they contain have a contour like the exterior, and are filled with the same aggregate of minute crystals as that which forms the ground mass. This enclosure of material is usually indicative of rapid growth. A section of a crystal of this nature is shown in Fig. 5 on Pl. 9. It is drawn as it appears in ordinary light, and even there the twinned sides of the crystal can be distinguished from one another by a slight difference in their shade. To the left of the large crystal is a hexagonal crystal, probably of titanic iron, though such a section could be cut from a dodecahedron of magnetite. Mr. Zirkel, when he found crystals exactly like these in the basalt of the Lacher See, supposed them to be of titanic iron. Inside the hornblende crystal, a crystal of this iron oxide of some size has developed among the other finer ingredients of the rock. With the aid of polarized light, the clear spots in the base are found to be feldspar crystals, the outlines of which are hidden in the ground mass. Some clear spots are cavities filled with calcite, and which evidently were formed by the rotting away of some mineral.

In another specimen from Campton falls the feldspar becomes more prominent, and the rock consequently lighter in color; the mica decreases in quantity, and fine crystals of hornblende take its place in the ground mass. This ground mass is so coarse as almost to destroy the porphyritic character of the rock. Apatite needles are abundant, and the iron oxide appears to be crystallized magnetite.

A specimen of diorite, from boulders in North Lisbon thought to have been derived from dykes cutting porphyritic gneiss, shows the interesting feature of the well defined outlines of hornblende and augite crystals associated together. They were plainly simultaneous and original formations. This rock contains more feldspar, and the ground mass is consequently quite light in color, but the feldspar is so decomposed that in thin sections it is only translucent, and its optical properties are obscure. Embedded in this coarse ground mass, black hornblende crystals are prominent, and in thin sections they appear to be perfectly fresh and undecomposed, and in part very well formed. The augite which first becomes visible when the microscope is employed was originally very perfectly crystallized, but now it is nearly all decomposed, and its place is filled with an aggregate of epidote, calcite, chlorite, &c., but still some of its original structural lines are preserved in the new products, and some crystals still possess an augite core. One section that I have examined is particularly interesting. A crystal of augite and one of hornblende lie united together, with their prisms parallel to one another, and the section is so cut as to intersect the prisms in a plane parallel to their bases. This section is represented in Fig. 6 on Pl. 9. Though the outlines of both the crystals are very perfect, they are united together by an irregular line. The hornblende crystal is entirely fresh, but the augite is decomposed and dissolved away, and its place is now filled with decomposition products. But among the chlorite, epidote, and calcite are some fragments of hornblende which are indeterminately situated, and perfectly angular and fresh. They must have dropped into the cavity made by the decay of the augite crystal, from the irregular edge of the hornblende crystal, at a time when the space was partially empty, and have been subsequently enclosed in the new products. No other space originally filled with augite contains any hornblende, with the exception of this one where the crystals lie together, and the irregularity of the edge of the hornblende would make it easy to derive such fragments from it. This section furnishes a very pretty illustration of the stability of hornblende as compared with augite, and was one of the cases which was in mind in the discussion of the chemical differences between these species when associated.

But in this kind of diorite the hornblende does sometimes entirely decompose. We will next consider a case of this kind. Near the Profile house there is a dyke of black rock, which, on being examined with the microscope, proves to be a diorite which originally had well defined crystals of hornblende; but now the spaces bounded by the crystalline outlines of hornblende are filled in most cases with a heterogeneous mixture of biotite, magnetite, and calcite, while occasionally a centre of dirty-green hornblende is still preserved. At other times, only magnetite and calcite are seen; and in the aggregate the cleavage directions of the original mineral are indicated by clearer spaces through the turbid mass. The rest of the rock is composed of an aggregate of crystals of hornblende, biotite, chlorite, plagioclase, calcite, and magnetite. A section through one of the hornblende crystals is shown in Fig. 3 on Pl. 7, and another in Fig. 3 on Pl. 2. Externally, this rock has lost the porphyritic appearance that characterizes most of our diorites, and the reason is self-evident.

Plagioclase Diorite. (Porphyritic Diorite.) There is another kind of diorite, which has been found in boulders scattered all over New Hampshire, and which is in place in the Dixville Notch and at other points in the northern part of the state. This diorite is characterized by the porphyritic development of all its ingredients; but large grains, which are sometimes an inch and a half in diameter, of a clear white, glassy feldspar, are particularly conspicuous. This feldspar is in condition for accurate determination, and proves to be a variety of plagioclase; and hence this diorite can be more definitely classified than the others thus far described. The feldspar is very striking in appearance. At the first glance it looks like quartz, for, in some directions, its fracture is vitreous, but on examining further, in other directions, bright cleavage faces are identified. In composition, it is near andesite, and its analysis has been given under that head (see p. 96). In polarized light few bands are found, for its separate laminæ are quite broad. Its optical properties are those of oligoclase, and, according to Des Cloizeaux, andesite is identical with oligoclase. I call the diorite, plagioclase diorite, because a variation no greater than what is very liable to occur would make this feldspar labradorite or oligoclase; and the members of the class of plagioclase diorites are subject to variations which embrace this sub-species. The hornblende of this rock was also analyzed. It was found to be quite aluminous. The magnetite is also porphyritically developed; and even the apatite is macroscopically visible in long, slender, clear needles, which pierce indiscriminately through all the other ingredients. The ground mass of this rock is an aggregate of the same constituent. The strong contrasts between the bright black and clear white crystals, and the dark, compact ground mass, make this one of the most striking rocks that occur in our state.

When microscopically examined, this andesite is found to be fresh and clear, and in polarized light shows no effect of decomposition. In this respect it is almost isolated among our basic feldspars, and furnishes a good illustration of the greater power of a glassy mineral to resist decay; but in a specimen of this rock from Dorchester, in which the crystals are very large, all the minerals are much altered, and epidote becomes a prominent ingredient of the rock.

Another diorite at Dixville is worthy of mention. This rock cuts the slates, and on fresh fractures it is red. This color results from the separation of iron oxide. The rock is porphyritic; but many crystals have rotted away, and the stone is now full of cavities containing calcite.

Mica Diorite. A diorite in which biotite replaces hornblende occurs at Stewartstown. This is not a porphyritic rock, and, in addition to its triclinic feldspar, which is probably anorthite, and its biotite, it contains much calcite, and also some magnetite, pyrite, apatite, and chlorite. Some such calcareous rocks were called hemithrene by Brongniart, but the term is now obsolete; and the rocks so called are referred to diabase and diorite, to which their nature and composition most closely relate them. This specimen of diorite is rather different from all others collected in the state, and whether it is an original product, or a result of decomposition, is questionable.

GABBRO.

This rock in its mineral constituents is closely related to diabase, from which our varieties are distinguished not only by the circumstance that the pyroxene is of the foliated kind which is called diallage, but also by their coarse granular structure, which in its details is much more like that of granite than that of the diabase that has been described.

Gabbro is found in immense masses in Waterville, and in the vicinity of Mt. Washington. The relationships of its masses to the surrounding strata are not so easily determined as are those of the little dykes of diabase and diorite, the walls of which are usually plainly seen; but at some points the rock possesses all the structure of an eruptive mass, and when in other places this is not found, the evidence furnished by more favorable localities, as well as that furnished by allied rocks in other lands where they have been more thoroughly investigated, must at present be decisive.

Our gabbros are coarse granular mixtures of labradorite, foliated augite or diallage, olivine, and magnetic or titanic iron. Apatite and biotite are the constant accessories. Hypersthene is sometimes prominent, and sphene, chlorite, and pyrites are often present. The first four ingredients are macroscopically conspicuous, and the rest are identified in thin sections. The prevailing color of the rock is dark gray, but it varies with the proportion of the ingredients from light gray to black. Future search will certainly bring to light many more varieties of this rock than I have to describe, for the regions in which these rocks are found are strown with boulders which are composed of varieties of gabbro, which it would be a pleasure to investigate if their source were accessible.

In Silesia, and in some other regions, mountains and cliffs composed of gabbro are conspicuous in the landscape. Owing to their smaller bulk, and the condition of the surrounding strata, this is not the case in New Hampshire; but as lithological specimens, they are no less interesting. There are some general differences between the specimens from our two localities where this rock is found in place. We will first speak of the gabbro from Waterville.

As here found, the rock is very coarse in texture, and nearly black. The feldspar is dark in color, and possesses bright cleavage surfaces on which fine striations are very conspicuous. In regard to the chemical and microscopic properties of its individual minerals, considerable has already been said. Analyses of the feldspar and olivine, by Mr. E. S. Dana, have been given on pp. 93 and 70. These analyses show that the feldspar is labradorite rich in lime, and that the olivine is a variety very rich in iron. The diallage, though apparently black, is in thin sections, of a pinkish color. This mineral, in many typical gabbros, when cut and examined with polarized light, presents a very fine fibrous structure. This is not seen in the diallage of our rocks, and neither is it at all an essential feature, since the ready separability of the augite into laminæ is the characteristic of diallage, and the fibrous nature of the mineral in thin sections is only characteristic of occurrences from certain localities. The augite of our rocks is like that of the variety that has been called palatinite. This name was given by Laspeyres to a gabbro of carboniferous age, which is abundant about the Pfalz on the Rhine, though varieties from other regions have since been embraced in the name. This gabbro, however, is not entirely crystalline, but contains more or less of glassy matters which are not found in our rocks. The unessential nature of the distinction between diallage and augite, and the identification of all the intermediate structural varieties between the most typical specimens of the two minerals, makes more forcible what was previously said in regard to this rock,—that when strict rules are applied it can only be classified as a variety of diabase. This is the opinion of Mr. Rosenbusch, and other eminent lithologists.

Fig. 1 on Pl. 10 represents a magnified section of this rock as it appears in polarized light. The diallage possesses peculiar outlines, owing to the influence of the feldspar upon it. These crystals crowd upon it, often pierce through its margin, and sometimes a rectangular feldspar crystal is wholly enclosed in the diallage. Hypersthene is recognized by its orthorhombic behavior in polarized light, and by its peculiar interpositions, which are arranged in three definite planes (see p. 54). The olivine is yellowish-green, and in thin sections it is light yellow, and being fresh and undecomposed it gives very brilliant interference colors when examined with polarized light. As usual, it is traversed by irregular rifts, which are made very prominent by the black stains caused by beginning decomposition. It is often impure on account of the enclosed magnetite. The black grains of iron oxide are very abundant in this rock. It is not crystallized, and in part at least is very magnetic; and as it has been shown by Mr. Dana that it is quite titanic, it is a titanic magnetite. In some grains of this magnetite I once found some little specks of metallic iron. Dr. J. Lawrence Smith, to whom I gave some of the rock, also found some; but it is not easy to find it when one seeks for it, and it may have resulted from the accidental reduction by some carbonaceous material that came in contact with the oxide when it was hot, and may be very local, and not widely distributed through the rock. If this is so, it has no special lithological significance.

The labradorite is very white and clear in thin sections, although it is filled with impurities. It contains numerous grains of augite and magnetite, scales of biotite, and crystals of apatite, and sometimes innumerable minute needles run in several well defined directions through it. These needles are common in the labradorite of gabbros. They were described on page 94, and Fig. 5 on Pl. 5 represents them. The labradorite in polarized light is banded with the most brilliant colors; but, as indicated in the figure, the exact parallelism of the bands does not extend over any great width of the grains.

The apatite is microscopic, but some of its crystals are quite large. They exhibit most interesting peculiarities. Sometimes little crystals, or crystalline forms of darker color, are arranged in their interiors, with their axes and sides parallel to the crystal that encloses them. Some crystals are filled with cavities which are apparently empty; and the sides of many of the crystals are eaten through as if by some reagent. Sometimes only the margin is attacked, and sometimes three quarters of the crystal is eaten away. Some of these crystals are represented in Fig. 6 on Pl. 8. The apatite was the first mineral to crystallize in the rocks, since its position was apparently taken independently of the other minerals. These etched crystals are explained on the supposition that after the apatite had crystallized from the cooling mass there was a return to former conditions, whereby the apatite was again partially destroyed. The perfect crystals may have formed subsequently.

Of accessory constituents, biotite is the most common. It is very dark in color, and very dichroic. A grain of sphene is occasionally met with. Serpentine and chlorite are sometimes present as decomposition products in superficial specimens.

One very peculiar rock forms a bed of some magnitude in the neighborhood of the Waterville gabbro. It is a coarse-grained rock, light in color, and resembles diorite. Its feldspar was analyzed by Mr. Dana, and shown to be labradorite, but all the minerals that form the rock are much altered. When thin sections are cut from this rock, all the ingredients of the gabbro are found as cores of the decomposition products, with the exception of the olivine, which is more easily altered, and which is completely changed into green serpentine. The unaltered remnants are identical with the minerals of the rock just described; and the very peculiar and striking appearance of this rock is due to the strong contrast into which the minerals are brought by decay. The originally black labradorite has become opaque white; the black diallage is light brown, or green; but the magnetite maintains its old form and lustre, and the apatite is also intact. The presence in the apatite of its very marked peculiarities, which render it so interesting, points conclusively to the circumstance that this is only a form of gabbro which has resulted from decomposition.

The masses of gabbro that occur on the Mt. Washington river present only minor variations. The rock occurs in immense masses that are best exposed on the borders of the river-bed. It is lighter in color than the Waterville rock, because it contains more labradorite and less magnetite.

Its feldspar is also labradorite, as shown by an analysis by Prof. Blanpied, of Hanover (see p. 93). I have not found any hypersthene in it, and all the constituents are in smaller crystals or grains.

In going up the Mt. Washington river to observe this formation, one is obliged to progress in the bed of the stream by springing from rock to rock, since the woods are so thickly undergrown that they can with difficulty be traversed. If one stops to look at the rocks on which he steps, I think he will be struck with the variety of interesting specimens of gabbro which have been brought down by the stream, and lie scattered along its course. The stream in the spring time is a rushing torrent, and rolls along large boulders. The region up this stream has not yet been explored by a lithologist; and I think that a careful search of it would enable one to collect a series of specimens of gabbro that would equal in interest those from any one of the celebrated European localities. Many water-courses and boulder-covered fields in New Hampshire present a most diversified cabinet of lithological specimens, but which lose their present value because their origin and surroundings are unknown. Many may have travelled long distances, and many may be in place near by; but the observation of these boulders is of interest to the student as indicating the possibilities of our future lithology.

There are two or three kinds of boulders which ought not to be entirely passed by, because they have attracted much attention and are widely known, and they may naturally be mentioned here. In and about Gilford are many boulders of a beautiful variety of gabbro, in which the large, foliated grains of diallage are round in form, and spot the rock in such a way as to make it very beautiful. Thin sections under the microscope show that this diallage is partially altered to hornblende. A chemical examination indicates that the feldspar is anorthite. Our country, which has furnished thus far few gabbros, certainly possesses a most interesting and beautiful one, which this represents.

The labradorite boulders in Stark are very well known, and many people have taken specimens from them. Though found in no other place, they are there so abundant that some have thought they must be in place near by. I have some thin sections cut from these rocks. They are essentially composed of labradorite. The interspaces between the crystals of this mineral in most of the rocks are filled with hornblende, biotite, magnetite, pyrite, and sphene. The rocks are therefore allied to diorites. The interspaces in another section are filled with an entirely different substance, which probably is a very impure pyroxenic mineral, too opaque, even in the thinnest sections, for determination. Dr. Hunt told me that these rocks were about identical with his norites; and, as the microscopic examination presents no objection to this, it cannot be said that these rocks were not brought from the great Norian formations in Canada described by Dr. Hunt.

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Remarks concerning basic eruptive rocks. Looking backward now at the general nature of our basic eruptive rocks, there are a few conclusions to be drawn which are not only instructive in reference to them, but are also helpful in our study upon the classes of rocks which are hereafter to be considered.

It is to be noted that there are wide differences in them, which are of three kinds. The first results from a difference in the composition of the original mass; the second is a difference in structure; and the third is a difference due to alteration and decay. We will briefly consider these differences and their causes.

First: in regard to difference in original composition. Eruptive rocks are derived from those layers of fused and liquid rock materials which underlie the earth's cold crust. It was long supposed that the whole earth was molten and fluid, with the exception of the crust, and that rifts in this crust gave passage to the molten materials that were beneath it, and which had never been solidified. The demonstration by Hopkins, that solidification induced by pressure began at the centre, and that the unsolidified zone of the earth is one which lies between the core solidified by pressure and the crust solidified by cooling, introduced some new features, since, as shown by Scrope, portions of the earth once solidified might become again fluid on account of movements in the earth's crust and the transportal of sediments, resulting in the derangement of the balance between the two elements which determine the position of the fluid zone. Scrope, Scheerer, Elie De Beaumont, and others have held it to be a fundamental circumstance, that water, when present in small amount in the materials of rocks which are subjected to heat and pressure, causes them to become plastic at a temperature far below the point at which their materials are fusible. These views indicate that not only can eruptive rocks be derived from the unsolidified molten materials that are beneath the earth's crust, but that matters once solidified may be re-fused, and that sedimentary deposits impregnated with water, though lying far removed from the seat of pure, igneous fusion, may be melted, and be erupted if circumstances favor.

Dr. Hunt, who has advocated these views in this country, has been led by his studies to believe that the crust of the earth is so thick, and the agencies for liquefying once consolidated matter so efficient, that it is not to be expected that any erupted matter comes from such depths as that occupied by material which has never been consolidated, and that we are to look among the sediments for the equivalents of all erupted rocks. This view has been opposed by Prof. Dana, who points to the almost perfect uniformity in the composition of the Mesozoic traps, from Nova Scotia along the whole of the eastern border of our continent; and which could not be expected in masses of fused sediments. It is not my place to discuss these theories. I only wish to make it plain, that if some clefts do descend to the matter which represents the original crust of the earth, it is admitted by all that sedimentary deposits may become fused or plastic; and in this circumstance we have an explanation of the fact that many of our eruptive rocks are very basic, many others are less so, and many more, which we are going on to consider, are highly acidic. Now, the Mesozoic diabase rocks which Prof. Dana shows to be so uniform in composition, form immense ridges, and occupy large fissures which were made by a wide-spread general subsidence, which would very likely produce profound fractures. In New Hampshire, no such uniformity of condition can be pointed to. Here and there, all over the state, are big and little cracks, often so small that they could scarce be expected to be very profound, and they are filled with basic rocks, the diversities of which indicate eruption at different times; and if, as will be shown, dykes of the same form and appearance are filled with acidic rocks, then diversity in the original composition of the basic eruptive rocks is certainly to be expected.

A number of causes seem to have operated to produce structural differences. Rocks erupted in the later geological periods usually show a variety of effects which the laws of cooling bodies explain. For example: the diabase of the Connecticut valley, when in large dykes, usually possesses a more coarsely crystalline structure than when in little ones, and the sides of the dykes which are in contact with the country rock are finer in texture than the centres. These differences in texture are produced by the influence of the surrounding rocks on the rapidity of cooling. Again: columnar structure, which, both in shape, size, and direction of the columns, is dependent upon certain well understood laws of cooling, is everywhere apparent. Our old trap rocks show but little of all this. The smallest dykes are often coarsest in texture, and hence we must conclude that either these rocks were erupted into cracks in hot rocks, that they did not reach the surface, and hence solidified under pressure, or that they have, with the strata in which they occur, been subjected to metamorphic action subsequent to their eruption. As any or all of these causes may have acted to produce structural differences, we can understand why our basic eruptive rocks are so diversified; why diabase, diorite, and gabbro were formed out of nearly the same material; and why coarse or fine, compact or porphyritic rocks were made in fissures of the same form. Moreover, it has already been pointed out that movements took place in the half-made rock, breaking up crystals already formed, and apparently introducing new conditions for finishing the solidification. In the gabbros, the well formed crystals of apatite, which after being perfectly formed were again partially dissolved, point also to variations in condition. The consideration of this element of variable conditions during the solidification of the rocks accounts for many differences in texture, and may especially be applied in the consideration of the porphyritic varieties.

In reference to alteration and decay, it might appear that enough had been said, since the description of the rocks has consisted largely in details of the modes of decomposition. The natural conclusion of the process remains, however, to be considered. In New Hampshire one often finds dykes of compact white or light yellow material. This is usually one of two kinds of rock. Either it is a felsite, or it is a diabase, which by decomposition has lost all resemblance to its original self. Often this material can be found in connection with less modified portions, and the stages of decay can be noticed. I have sections cut from white decomposed diabase from Bemis brook and the Lincoln flume.

They show all the structures and the outlines of the original crystals that characterize diabase, but every crystal is altered, and converted into an aggregate. A determination of the silica in the specimen from the Lincoln flume gave 40.04 per cent. Allowing for the carbonic acid and water present, this indicates no material increase in the amount of silica and the consequent presence of most of its original constituents, for the undecomposed rock at the Lincoln flume, the analysis of which is given on p. 153, is just like the one from Bemis brook. This decomposition product, however, contains a large proportion of carbonates of lime, iron, and magnesia. The size of the flume shows how much of this dyke has been removed; and when this decomposition product is broken down and carried away, these materials will be separated,—the lime and magnesia will be carried to one place, the iron to another, and the siliceous residue to another; and this rock will be broken up into portions, which will be in part more basic, and in part less basic than the original rock.* The details of these processes of decomposition are as various as are the minerals and the circumstances that act upon them; but the general result is always the same, and hence this case may be taken as typical of the processes which have operated on the original basic crust of the earth to break it up and assort its materials into more and less basic portions.

ACIDIC UNSTRATIFIED ROCKS.

In approaching this great family of rocks, which with the crystalline schists forms our mountains and hills, some of the considerations drawn from the study of the basic eruptive rocks are of value. It was stated that of such basic material the original crust of the earth was probably formed, and that by the ordinary processes of decay the bases of such rocks are in part removed, are accumulated in the sea and in beds of limestone and iron ore, while a siliceous residue is left behind, or is washed away and accumulated in sedimentary beds. Beneath these secondary products the original crust of the earth is now so deeply buried that basic eruptive rocks are the only possible representatives of it. In some regions the limestone derivatives cover the whole surface; but

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* See, also, in this connection, the analysis of anorthite, on page 91, and the remarks in connection with it.

in New Hampshire the siliceous residues are the ones with which we chiefly have to deal. It has been stated that such sedimentary beds can become deeply buried, and that they may become plastic and enter into a condition that is termed igneo-aqueous fusion under the combined influence of the weight of the sediments above them; the lateral pressures, the force of which is evinced in the elevation of our mountains; the interior heat of the earth, and the water imprisoned in their mass, which in such circumstances becomes a most powerful reagent. This theory, which has been developed by the labors of several eminent geologists, has been strengthened by microscopic examinations, first and most prominent among which are those of Mr. Sorby, and it may be almost considered to be demonstrated. The features in these rocks that render the theory so probable, will be pointed out in the proper places.

Let us now suppose beds of great extent, such as may be derived from basic rocks by one or by repeated disintegrations, to be subjected to the influence of the agencies indicated. We may suppose, first, a wide variation in the composition of the sedimentary beds, resulting from differences in the agencies that had operated to decompose and re-deposit. From this cause, much diversity in the derivative rocks would appear. We may suppose a variability in the factors of heat and pressure, which would modify the completeness of the recrystallization or metamorphism; hence some beds under powerful agencies would be entirely recrystallized, while others more gently acted on would be only partially altered, and would possess some of the original ingredients or features which would indicate their relationship to the stratified deposits. We may suppose, if no movements took place to disturb the beds while in this plastic condition, that, though recrystallized into massive rocks, they would maintain their position, and when solidified would still be conformable with the surrounding strata. On the other hand, if great movements took place, such as must have accompanied the elevation of our White Mountains, fissures might be produced, into which the plastic rock might be forced, and the same identical rock might now present itself as an eruptive mass. Under other circumstances, the overlying strata might be crushed and mixed into the plastic mass; and many odd features in the arrangement and form of the masses might result from circumstances. All those who are familiar with our acidic rocks know how commonly all these things are to be seen; and with this short explanation, intended to show unity where much diversity is apparent, we will proceed to the description of the more marked varieties of these rocks.

Felsites, porphyritic felsites, granites, and sienites are the rocks that are considered in this general division.

FELSITE.

Felsite is a very fine-grained, compact rock, the composition of which is not at all evident to the eye on account of the minuteness of the crystals of its constituent minerals. In New Hampshire this rock is usually found in small dykes, and it usually has a white or gray color. It was long ago noticed that fragments were fusible before the blow-pipe, from which circumstance the nature of these dykes was suspected before it was known. In thin sections under the microscope it is seen to consist of an intimate mixture of quartz and orthoclase feldspar. It is the same substance as that which forms the ground mass of the porphyries, and hence its study forms a fitting introduction to that of those rocks.

Felsitic substances are divided into two classes, according to certain microscopic properties which were first pointed out by Zirkel. The first class embraces those compact mixtures of quartz and feldspar, which, even under the microscope in thin sections, cannot be resolved into its constituent minerals, and would be called noncrystalline, except that between crossed Nicols it does not become entirely dark, but shows faintly the optical properties of an aggregate. Glassy matters are, moreover, often present in such rocks. These rocks are called micro-felsitic. The rocks of the other class are to the eye homogeneous; but when thin sections are magnified they are seen to consist of well individualized though minute grains of the constituent minerals. These rocks are called macro-felsitic; and to this class all our felsites belong, for, although some of them are extremely fine in texture, they can all be resolved into granular mixtures when sufficiently magnified. The rocks that occur about Mt. Washington may be described as typical.

In going up the Mt. Washington river towards the gabbro rocks, several dykes of felsite are met with. They are white in color, and when freshly broken usually show some bright green spots, which at one time were cavities, but which are now filled by an aggregate of quartz and calcite, which is colored by a little of some chloritic substance. The mass of the rock is composed of very minute particles; and the quartz can be distinguished from the orthoclase by shutting off the light from beneath, when the feldspar, being partially decomposed, appears white and opaque, and the quartz, being still fresh, appears dark and clear. The feldspar forms the larger part of the rock. It is rather striking to notice that, just beside one of these felsite dykes, separated from it by merely a partition wall of the crystalline schists, there is a dyke of a black rock which a thin section shows to be a very fine-grained and considerably altered diabase.

A specimen from a felsite dyke at Bemis brook is brownish yellow in color, and so very compact that it resembles jasper, but under the microscope, though it is seen to be very fine, its felsitic character is observed. Here and there, in the specimens of this felsite, a crystal of quartz or orthoclase is seen, and their sparing presence introduces one stage of the easy transition from felsite to porphyry. A large dyke in Bartlett is composed of a felsite which, when microscopically examined, is found to be porphyritic in its character.

Some rocks in New Hampshire have been called felsites, which differ essentially from them. In Albany there are some light red rocks, very fine in texture, and spotted with minute little black dots. When sections are cut from these rocks, they are found to consist of orthoclase crystals quite well formed, and of some size, and the black specks are found to be of hornblende. The rocks are only fine-grained sienites.

Some very compact fine-grained rocks which resemble felsites are interstratified with the schists of the Connecticut valley. They are distinguished from quartzite by the circumstance that they fuse, and they have therefore been called felsites. Under the microscope these rocks show the constituents of argillitic mica schists, to which they are related, and from which they differ in the less amount of the micaceous ingredient, which accounts for the more massive condition.

The eruptive felsites often appear schistose; but this is a peculiarity which is often noticed, and is merely a secondary structure which has been induced in them.

PORPHYRITIC FELSITE (PORPHYRIES).

The porphyritic felsites, or porphyries, constitute a large family of rocks in New Hampshire, and the great variety in their structure and mode of occurrence makes the study of them very interesting. At times, like the felsites, they fill small dykes, but often they form mountain masses. Before proceeding to their description, it will be well to call attention to studies that have been made elsewhere in our region.

The porphyries are usually massive eruptive rocks. They form immense dykes; and in Silesia the columnar structure, and all other peculiarities of ordinary igneous rocks, are often seen. Dr. Hunt describes the porphyries of Canada as forming dykes, and in New Hampshire most of our porphyries are plainly enough eruptive. But in Massachusetts, in the neighborhood of Boston, there is a grand display of porphyries, felsites, etc.; and Mr. T. T. Bouvé* has shown that every shade of variation between most compact porphyry and conglomerate is to be there seen. This observation, which has been confirmed by other observers in other places, led Mr. Bouvé to assert the origin of porphyries from sedimentary deposits. Mr. J. C. Ward has also pointed out the passage by insensible gradations of certain fragmentary rocks into quartz porphyries in England.† If, now, the views in regard to the re-fusion of sediments, which have already been explained, are true, then the observations made by Mr. Bouvé are what would be expected, as a result either of a variation in the efficiency of the causes producing the fusion, or in the condition of the sediments submitted to their action. The same circumstance will explain the existence of many porphyries in New Hampshire, as, for example, a variety at Newcastle, and others elsewhere, which resemble sandstones while they have the features of porphyries, and which, even when microscopically examined, are hard to name. It is not our intention to describe in detail these peculiar or doubtful varieties, but, recognizing their existence, and the light which they throw on the general subject, we propose to devote the space to the description of the interesting features presented by those immense masses of typical porphyry which are so important to our lithology.

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* *Proceedings Boston Society of Natural History*, 1862, p. 57; 1876, p. 217.

† *Quarterly Journal Geol. Soc.*, No. 125, p. 25.

Porphyritic felsites are sub-divided into three species. *Quartz porphyry* consists of a felsitic mass of quartz and orthoclase, in which macroscopic crystals or grains of both these ingredients are developed. *Orthoclase porphyry* consists of the same ground mass in which orthoclase alone is porphyritically developed. *Quartz-free-orthoclase porphyry* contains quartz neither porphyritically developed, nor in the ground mass. The last division, though represented, is of no practical importance in New Hampshire.

Quartz Porphyry. Almost all the porphyries which occur in the state belong to this division. The ground mass is a felsite in which the proportion between the quartz and feldspar is variable, and in which magnetite, augite, hornblende, biotite, chlorite, hematite, apatite, and some other minerals may be present as accessories. Of the porphyritic minerals, the feldspar has usually a crystalline outline, and sometimes the quartz also. The greatest diversity in the appearance of the rocks presents itself. Some are black, some are gray, and some are red, and they may have a ground mass of any one of these three colors, and porphyritic crystals developed in it of any other of the colors; and so the variations become very numerous. This rock forms small dykes; and, on the other hand, immense mountains like Mt. Kearsarge are largely composed of it. Our porphyries are commonly massive rocks with no signs of structure, except in those cases where they possess a schistose nature that has been induced in them by external agencies. Their geological relationships, though sometimes evident, are more often obscure.

In the north-east part of Waterville a beautiful *black* porphyry is abundant, which, on account of the fine opalescence of its clear grains of feldspar, has been supposed to be a dolerite or labradorite rock, but the thin sections show that only orthoclase feldspar is present. The ground mass is very feldspathic, and contains some augite, chlorite, magnetite, apatite, and scales of hematite. The feldspar is clear, but is filled with minute fissures and microlites, reflections from which cause the irridescence. The rock is a beautiful one, and it would be much admired if cut and polished. It was analyzed by Mr. Pease, in the Sheffield laboratory, with the following result:

Silica, ...	63.63
Alumina, ...	17.42

Iron sesquioxide,	.15
Iron protoxide,	5.76
Manganese protoxide,	.22
Lime,	2.86
Soda,	4.52
Potash,	5.54
Ignition,	.15
	100.25

This analysis confirms the examination of the section, showing that the rock is mainly feldspar; and, indeed, this analysis does not vary widely from that of orthoclase. Only here and there among the porphyritic crystals is there a black glassy grain of quartz, and it is as sparingly present in the ground mass. A porphyry of the same nature occurs at Lincoln. In thin sections of this rock the hornblende is conspicuous in crystals of some size. Augite was originally present, but is now mostly changed into chlorite and epidote. The rock also contains magnetite and pyrite.

The black color of these quartz porphyries depends upon the circumstance that the orthoclase is clear. When this character is absent, and the feldspar is no longer transparent, the rock, which is otherwise the same, is gray in color. Such a gray quartz porphyry from Mt. Lyon has some interesting microscopic features. Although many crystals of orthoclase are porphyritically developed, they are not at all conspicuous in specimens. This is because they are so impure that they are scarcely individualized from the rest of the rock. Through the felsitic ground mass are distributed numerous rounded and angular grains of augite, biotite, chlorite, and magnetite; and through portions of the orthoclase crystals these grains are as thickly distributed as they are through the ground mass. The appearance of a section of this rock, as it looks in ordinary light, is represented in Fig. 2 on Pl. 10. If, now, polarized light be employed, the form of a large crystal of orthoclase is brought to view where nothing was visible before. The appearance of the same section in polarized light is represented in Fig. 3 on the same plate. This shows us that a pure, clear feldspar crystal began to grow in the rocks, but, for some reason, a change took place in the conditions at a certain period of its growth, whereby in its further increase it was obliged to include particles of the other minerals, which had formed or were forming in the rock. At first the particles were small, and were included in large numbers, but afterwards they were larger and more sparingly distributed. That this line between the pure and impure parts of the crystal is indicative of some important change, is shown by the circumstance that this line also separates two parts of the crystal in which the optical constants are differently orientated. For this reason the outer and inner zones appear differently colored in polarized light; and the difference is more plainly marked by revolving the section till one part is dark, when it will be seen that the section must be turned a certain number of degrees from this point in order to induce the maximum of darkness in the other part. This indicates that the directions in which the planes of elasticity cut this section make an angle at the point which separates the pure and impure portions of the crystal. These directions are indicated in the figure; and in the case of the crystal represented, the difference between them is five degrees. All the porphyritic crystals of orthoclase in this rock possess these noticeable peculiarities, which are interesting as giving evidence of the existence of stages of development. Indeed, the development of porphyries must depend more or less on the existence of stages, else the crystallization of large grains would have continued till the end.

The presence of augite in large and small grains is noticeable in this porphyry. It is not so very abundant as it is in the augitic porphyries about Leipzig, where it exists in such quantity as to relate the rocks which also contain plagioclase to diabase. But it is in this case, and in some others, a very characteristic feature of the rock.

Sections of a gray—almost black—quartz porphyry from Groveton offer other microscopic peculiarities. The porphyritic crystals are mostly of orthoclase, some of which are subjected to exceptional methods of twinning. Compound crystals of orthoclase, when ingrown in the rocks, are usually Carlsbad twins, those of other kinds being very rare. In this Groveton porphyry most of the crystals are Carlsbad twins; but some of the crystals are also twinned according to a different system, the composition plane being the clino-dome, and the twins consequently Baveno twins. The crystal which is most favorably cut to show this is represented in Fig. 4 on Pl. 10. It lies on the edge of a section, and so half of it has been broken away. It is, however, as fine a specimen as could be desired, to show a combination of two systems of twinning. When revolved between crossed Nicol prisms, this section reaches its maximum of darkness when a side is parallel to the plane of vibration of the light. The ortho-diagonal therefore lies in the section; and if the section is prismatic, then one composition plane is parallel to the clino-diagonal, and the other composition plane is the clino-dome, and we have a double twinning, which is not uncommonly found in crystals which have developed in cavities, but which is very rare in ingrown crystals. The contrasts of color in the section are not very great, for, in a prismatic section cut approximately parallel to the ortho-diagonal, neither kind of revolution throws the axes of elasticity far away from one another. Baveno twins have been found—first, by E. Weiss—in the sanidin of trachytes and modern eruptive rocks, but I am not aware of their having been observed in quartz porphyries, though they have been frequently observed, first by Rose, in granite.*

This porphyry contains odd little concretionary masses of hornblende and chlorite, which fill spaces that were perhaps originally empty. The mineral grains on the outside are stained yellow by decomposition, and thus the bright green minerals within are surrounded by a yellow wreath. Crystals of orthoclase, which are pure within and impure without, are also found here. The porphyries of this place are stated by Prof. Hitchcock to be plainly eruptive.

A gray quartz porphyry from New Zealand contains so many large crystals of quartz and feldspar, that the porphyritic character is almost obliterated; and from this rock to granite is not a wide step.

A gray quartz porphyry from Waterville possesses a very fine felsitic base; and the sections of many of the quartz grains are polygons, which indicate the presence of dehexahedrons of quartz that can often be macroscopically seen. As is usual in such porphyries, these crystals have rounded edges.

This porphyry is a favorable one in which to observe the innumerable little cavities which are characteristically present in the quartz of all porphyries. When highly magnified, in these cavities a fluid and a bubble are almost always seen, and, moreover, a little colorless cube is often

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* *Rosenbusch Physiographie der massigin Gesteene*, p. 12.

found in the larger cavities. The cube is supposed to be of chloride of sodium, of which the fluid in the cavity is a super-saturated solution. These cavities are mostly entirely irregular in form, but sometimes one is found with hexagonal outlines, which correspond to those of the crystal which encloses it, and the cavity is really an inverted crystal. In Fig. 6 on Pl. 6 some of the largest of these cavities, as they appear when very highly magnified, are represented. Such cavities are found in the quartz grains of nearly all the siliceous rocks; and hence what is here said will apply to most of those rocks which remain to be described.

The bubbles which float in the fluids that these cavities contain can usually be made to disappear by heating the section to such a point that the expansion of the fluid is sufficient to fill the space. Some cavities contain a bubble, which disappears when the temperature of the section reaches about 30° C. In such cases the determination of the coëfficient of expansion, and the optical and other properties of the enclosed fluid, prove that it is liquid carbonic acid. Such cavities are very abundantly found in certain specimens of sienite from our state; but the bubble in the cavities of all the porphyries and granites that I have examined is little affected by heat, and would only disappear at a high temperature,—and the fluid is therefore water.

Sorby [*] was the first to point out the geological significance to be attached to the presence of these cavities in the minerals of rocks, and he concluded that the mode of origin of a rock might be indicated from the circumstance whether it contained no cavities, or whether the cavities in it were empty, or filled with glassy material, or filled with fluid. The uniform presence of cavities filled with fluid in the quartz of granites he considered to be evidence confirming the views of Scrope and others, that water played an important part in the formation of these rocks. He moreover suggested that the relative volume of the fluid and the bubble might give some data for the calculation of the temperatures and pressures under which they were formed, since at a certain temperature the bubbles, which are spaces filled only with vapor of the fluid, disappear, and the fluid expands and fills the space as it must originally have done.

But a determination of the temperature at which a cavity containing a vacuity in a fluid becomes full, gives only the temperature at which the

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[*] *Phil. Mag.* [4] xv, p. 152. *Quarterly Journal Geol. Soc.*, vol. xiv, p. 453.

fluid expands under the simple pressure of its own vapor to the volume of the cavity, while it is certain that the rock at the time it was made must have been under a heavy pressure. Hence the relative volume of bubble and cavity is dependent on two factors, one of which is the temperature, and the other is the pressure at the time the rock was solidified; and if the coëfficient of expansion of the fluid is known, together with either one of these factors, the other can be calculated. Such calculations were made by Mr. Sorby, and after him by Mr. J. Clifton Ward,* according to the formula deduced by Mr. Sorby. Such calculations are rendered of doubtful value by the large number of inconstants that are introduced. The accuracy of the measurements on such minute and irregular cavities is always doubtful, and neither one of the two factors is known. Still, the observations possess weight when the results are accepted as approximations, for, taking as one factor the lowest temperature which would suffice to render these materials plastic with the aid of imprisoned water, the other factor is found to be very great; and hence these rocks must have been formed and solidified deep down in the bowels of the earth. This much can with certainty be assumed as the teaching of these minute cavities. Great variations in relative size of fluid and space, and in the expansibility of the fluid, caused by variable amounts of carbonic acid, which is either free or held in solution, are often observed in different cavities in the same crystal. This clearly indicates that changes of condition took place even in the growth of a single crystal. This variation in condition is also indicated by certain other microscopic properties of crystals in our porphyries, which I have already pointed out.

The little cube which is so commonly seen in these cavities is probably of chloride of sodium or potassium. On heightening the temperature, this cube will dissolve. Its existence depends on the same causes as does that of the bubble. Water, when heated and under pressure, possesses a very great solvent power. Hence, when the temperature is diminished and the pressure removed, the fluid, which has dissolved alkaline salts from the feldspathic materials, becomes supersaturated. (See further remarks in reference to this subject under Granite.)

The bubbles in the very minute cavities, when highly magnified, are

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* *Quarterly Jour. Geol. Society*, No. 124, p. 568.

found to be in perpetual motion. They dance about, and move most irregularly from side to side of the cavity, as though acted upon by some very erratic power. These movements are referred to the same cause as the so-called Brownian movements of fine suspended matter, and have been explained in various ways. They are by some supposed to be caused by the constant molecular movements that are believed to take place in all fluids; by others, they are supposed to be caused by a vibration or jar, which, though inappreciable to our senses, thus evinces itself to be ever active; by others, they are referred to the action of light, or are to be explained in the same way as are the movements of Crooke's radiometer. The motions referred to, which can be seen in any of our porphyries and granites, are certainly curious and interesting; but the phenomenon is a physical one, and has no geological significance. The lack of a satisfactory explanation will not therefore be felt. Zirkel remarks, that whatever may be the cause, it is an interesting thought that these bubbles, in number approaching infinity, have been dancing about during all the ages since the rocks were made. Unless it shall be shown that they are influenced by light, and that their movements therefore date from the time that the sections were made, it certainly is a strange thought to think of so much motion in a lifeless mass.

The region of Mt. Pequawket is a very interesting one in which to study the quartz porphyries, owing to their singular relationships to the surrounding rocks. At this point there are accumulations of clay slates; but at some places on the mountain they are all broken up, and again consolidated, so that they form an immense great breccia most striking in aspect. At some points which are characterized by this destruction of strata, the breccia is wholly of angular fragments of slate; at others, felsite and quartz porphyry form the cement which binds the fragments together; at other points, fragments of slate are sparingly distributed through the massive quartz porphyry. The region is, I think, considered a remarkable one by all those geologists who have visited it. It seems to be plainly indicated that here was the seat of some grand disturbance that resulted in the destruction of the strata of slate, and the eruption of quartz porphyries into the fissures made. Now, when the cavities in the minerals of plainly eruptive masses of porphyry or granite are examined, they show the same identical features as do others which appear to be resting quietly in their original beds. If the eruptions reached the surface of the earth the pressures would be relieved; and as the cavities point as before to very heavy pressures, we are led to suppose that such disturbances are the result of movements which took place in the earth's depths rather than upon its surface. The circumstance of the elevation of our mountains is sufficient to make plain the possibilities of such subterranean movements. This is an interesting spot, for such a mixture of stratified and unstratified material is not often seen.

Quite a variety of quartz porphyries are found in this region. Some are colored red by the oxide of iron that seems to have separated from the decomposing minerals; in some, but few crystals are porphyritically developed, and some others are nearly granitic in their texture. On the lower half of the mountain a gray porphyry is prominent, which possesses a very fine, compact, rather earthy-appearing ground mass, in which not only feldspar crystals are developed, but also numerous dihexahedrons of quartz. Such porphyries as this were once called clay-stone porphyries, on account of the appearance of the ground mass. Another specimen of this rock has a basis still more earthy in appearance, which results from the abundant presence in it of chlorite, biotite, and iron oxide, which are only microscopically identified. Moat mountain, and some other mountains surrounding Pequawket, are largely composed of porphyries.

A porphyry just like this, save that in it very much larger crystals of orthoclase and quartz are developed, occurs in the Notch in the White Mountains. This porphyry is considered by Prof. Dana to form a bed, the position of which is conformable with the strata of slates and schists, and thus it presents a case of a porphyry which was not disturbed from the place where its metamorphism took place.

A most diversified collection of porphyries can be obtained at Waterville. They are of various colors, owing to combinations of differently colored ground mass and crystals, but the prevailing color is red. This color is seen in thin sections to be due to oxide of iron, which is abundant in the ground mass, and is often spread through the minute fissures in the orthoclase crystals. Sometimes a black grain of iron oxide in a strong light will appear blood-red, and it is thus recognized as hematite. These porphyries also vary widely in composition. In some, quartz is abundant, both in the ground mass and among the porphyritic crystals; in others, it is nearly absent from both. In one variety, feldspar crystals, with the basket-work structure characteristic of microcline, are found.

In Albany there is a red quartz porphyry, in which some of the feldspar crystals are penetrated through and through by apatite, the needles of which run into the ground mass in some places, but are not found in the quartz.

On Twin mountain a very light gray quartz porphyry occurs, in thin sections of which the microscope reveals the presence of some light-colored garnets. These garnets are entirely irregular and formless, like the garnets found in granite.

A porphyry breccia or porphyry conglomerate occurs at Waterville. This is a rock which is entirely composed of pebbles or angular fragments of red quartz porphyry, that have been cemented together into a very firm, hard rock.

From these descriptions, I think it will be plain that the quartz porphyries of New Hampshire form a group of rocks, which, though remarkably uniform in general characteristics, are remarkably diversified in their details. This is a feature that is not at all peculiar to our state. Leonhardt says, in speaking of quartz porphyries,—"Who that has travversed regions of porphyry has not noticed how often each hill and rock shows new peculiarities." This diversity, which is here so marked, and only the most general features of which have been pointed out, render these porphyries very interesting. One can read in the chapters written by Prof. Hitchcock how very widely distributed over our state are the porphyries, and how many mountains and cliffs are made of them. Many more might be described, but their differences are owing only to minor variations of the peculiarities already mentioned.

Orthoclase Porphyry. This rock differs from quartz porphyry in that no quartz is macroscopically visible. Under the microscope, the ground mass is found to consist of the same mixture of minute grains of quartz and feldspar, with which a larger or smaller number of accessories are intermingled. Typical specimens of these rocks are found in Albany, and at Mt. Pleasant, which is just over the boundary of our state in Maine. In Albany, some of these rocks certainly occupy dykes; and Mt. Pleasant, which is largely composed of this variety of porphyry, is regarded as an eruptive mass. The rocks are alike in both places, and one description will apply to both. They are either gray or very light red. The ground mass is usually very fine in its texture, but it is often porous and rough, and often very much resembles that of some modern trachytes. Were it not that the feldspar is opaque orthoclase instead of clear sanidin, one would immediately think of trachyte upon examining these rocks. At some points on Mt. Pleasant the rocks are cracked up into angular blocks and fragments, as are many modern eruptive rocks; and in other places large crystalline grains of hornblende are prominent, and cause other kinds of trachytes to be recalled. Trachyte is a newly erupted rock, which, in addition to its glassy feldspar, contains noncrystalline substances,—nephelin, leucite, and the like; and though in special varieties any or all of its distinctive features or characteristic minerals may be wanting, the rocks as a class are very well distinguished, and no one would wish to confound such old rocks as these that we are considering with them. Still, I think these orthoclase porphyries from Albany and Mt. Pleasant are very interesting, since, by their very close macroscopic resemblance to certain trachytes, they show the close relationship which exists between these rocks and their younger kindred. Under the microscope no peculiarities of note are developed. Hornblende is found to be a common constituent; the feldspar is usually troubled by impurities and decomposition, but in some specimens it is quite fresh, though never glassy. On the summit of the mountain the ground mass is reduced to a minimum in quantity, and the rock approaches sienite in appearance and composition.

Quartz-Free Orthoclase Porphyry. This rock has the same structure as the other porphyries, but possesses quartz neither among the macroscopic crystals nor in the ground mass. A rock of limited distribution anywhere, it is of no practical importance in New Hampshire, for it occurs as a mere exceptional variety in one or two places among the quartz porphyries. For example: a specimen of red porphyry from Waterville and another from Albany are remarkable because no quartz can be detected in them, while at the same time a triclinic feldspar, conspicuous in polarized light by its bands of color, appears as an ingredient, and by its presence suggests the more basic nature of the rock.

In these varieties of porphyry in which large crystals of quartz do not appear, no cavities containing fluid are found. It is considered that probably water played its important part in the crystallization of these rocks; but feldspar, even if it does imprison some water, does not often hold it, but allows it to escape through minute cleavages, or absorbs it into its decomposition products, while quartz holds what it contains through all time, and hence, even in the oldest rocks, the quartz is full of fluidal enclosures.

In dismissing this subject it will be well to mention two or three less typical varieties which indicate how narrow are the spaces which divide our great families of rocks. On Little Deer brook, in Albany, a quartz porphyry occurs, in the ground mass of which quite large grains of muscovite mica are developed. A specimen from Kirby, Vt., possesses but little ground mass, and what there is is coarse, and in it both muscovite and biotite are seen. A specimen from Newcastle is also largely crystalline, but hornblende, and not mica, is conspicuous in the thin sections. These circumstances indicate that between typical porphyries and typical granites, many intermediate varieties occur, which, from the nature of the case, are to be expected.

Granitic Rocks.

Under this head are included those massive acidic rocks which are entirely granular in their structure. They possess at times a pseudo-porphyritic structure, induced by the more prominent development of orthoclase crystals; but to the unaided eye, all parts of the rock are plainly granular. They have certain features in common, which may be mentioned before describing individual species. They all possess indications of having once been in a molten or plastic condition; and, like the rocks last described, the evidence they offer is not that of an igneous fusion, but rather of a plasticity induced at a low temperature, and under pressure, by the aid of water. Therefore it may be again remarked in this connection, that we may expect to find these rocks in the places where they originally existed as stratified sediments, in dykes intruding themselves through other strata, and in the most varied, apparently systemless forms which might happen to be imposed upon them by the circumstances that befell them while yet plastic; and all these differences, though of great geological interest, may be wholly unrecognizable in the lithological study of specimens. All the features referred to are very often found in our state. There are beds of granite which are conformable with associated stratified rocks. There are granites filling well defined dykes. There are granites which, so far as can be seen, are entirely void of structural relationships. There are granites which are mixed with other rocks, or which hold huge fragments of other rocks enclosed in their masses. All these features are often repeated; and when one wonders at their diversity, he has but to think of those tremendous movements which have taken place in the crust of the earth, and that any plastic materials which were influenced by these movements would take the forms and relationships to other rocks which local circumstances determined.

Dr. Hunt, who has made a careful study of the granites of this part of the world, has divided them into three classes. The first class embraces the granites which are in place among the strata, and which he calls indigenous granites; the second class embraces the intrusive granites, which are called exotic; and the third embraces granitic veinstones, which are called endogenous. The members of the last class are distinct in origin, and hence in lithological characters. The rocks of the exotic class, however, show just the same evidences of having solidified under pressure as do those in place. It is not claimed that they result from eruptions that reached the free surface where the pressure would be removed, but they entered cracks in overlying strata, and solidified like the others in the depths of the earth. Hence the members of the first two classes cannot be expected to be lithologically distinct.

The minerals of which the rocks of this group are composed are quartz, orthoclase, and plagioclase, of which, in variable proportion, the bulk of the rock is always composed; and muscovite, biotite, hornblende, augite, chlorite, tourmaline, graphite, and hematite, one or more of which may be present as characterizing accessories; and beside these, a variety of minerals, such as apatite, rutile, zircon, microcline, &c., are microscopically detected, and which are of interest, though they form no proportion of the bulk of the rock.

Authorities differ in sub-dividing this group. Some, considering quartz and feldspar as the essential constituents, sub-divide the rocks into granites which contain both feldspar and quartz, and sienites which contain only feldspar. The granites are then further sub-divided, according as to what mineral is present as the characteristic accessory, and the sienites are likewise sub-divided. Other authorities, considering the distinction between hornblende and mica as fundamental, divide them into granites which are micaceous, and sienites which are hornblendic. In this work the first method of sub-division is adopted, and the following kinds of granitic rocks have been identified in the state:

Granite.

Muscovite granite.
Muscovite biotite granite.
Biotite granite.
Mica hornblende granite.
Hornblende granite.
Chlorite granite, or protogene.
Granitell, or granite with no accessory.
Granite of veins.

Sienite.

Augite sienite.
Hornblende sienite.

GRANITE.

Although our granites can be sub-divided according as they contain muscovite, biotite, hornblende, or chlorite as the characteristic accessory, yet the dividing points between these sub-species can only be arbitrarily assumed, since most of our granites contain two of these minerals, many contain three, and some contain all four. It is therefore the predominance of one or the other that forms the species; and the intimate blending of these species causes them, together with the granitell, to form one well defined rock group, all the members of which are in common usage called granite. As the quartz and feldspar are light-colored minerals, the accessories are rendered very prominent, and determine to a great degree the color of the rock. The granites that contain no accessory or muscovite are white; biotite and hornblende granites are spotted black; and chlorite granites are spotted green. Not only is it difficult to generalize on the distribution of these granites, but more than one of them may occur associated together.

Some features which the granites possess in common may be mentioned before describing the peculiarities of our individual species, because they indicate the mode of formation of these important rocks. The relationship of the component minerals to each other as regards the order of their crystallization is the first and most evident feature to consider. When rocks which without doubt have solidified from a state of igneous fusion are studied, it is found that the least fusible constituents were the first to crystallize. They appear in well defined forms or perfect crystals, and the least fusible constituents fill the interspaces. But this is all changed when granitic rocks are observed. Quartz is commonly called infusible, and feldspar is easily fused, yet the feldspar was the first mineral to crystallize, and has obtained its well defined form apparently uninfluenced by the other minerals, while the infusible quartz fills up the interspaces, and was the last to solidify. Although microscopic sections are not at all necessary to observe this point, yet in them this relationship, which is so easily recognized macroscopically, is found to extend to the minutest structures. This is illustrated in Fig. 5 on Pl. 10, which is drawn from a section of a granite from Colebrook. The well defined orthoclase crystals are there shown, and the quartz fills the residuum of space. This fact was observed as long ago as 1822, when Breislak, in his treatise on the structure of the globe, argued against the igneous nature of granites on the basis of exactly these observations, yet it is only recently that these arguments have been regarded as conclusive. But observations in the field prove plainly that some at least of the granites have been in a fused or plastic condition. These circumstances must point, therefore, to a plasticity which was induced in some other way than by pure igneous fusion. The relationship between the crystallization of minerals and their fusibility extends still further. Granite often contains a variety of minerals, such as tourmaline, garnet, zircon, iolite, fluor spar, etc.; and although all degrees of fusibility are represented, no generalizations can be made upon the order of their crystallization. Such observations as these were the starting-points from which Scrope, Scheerer, and others, supported by Sorby and the microscopic geologists of later times, have developed the theory of igneo-aqueous fusion to account for the formation of granite, a theory about which so many observations have been accumulated that its truth is nearly demonstrated.

In granites, the feldspar is almost always troubled by the inclusion of impurities, by rifts and decomposition products, which in thin sections throw it into striking contrast with the clear quartz, which, though free from the cleavage and enclosures of the feldspar, always contains the cavities which are filled with water, and a bubble, and often crystals of salt.* The quartz, as the last mineral to crystallize, of necessity took in the fluid residue, and, being difficult to decompose, has held it. Sorby † has been led by his observations on these cavities in granites to believe that the temperature at which the quartz finally solidified is that which marks the critical point when compressed steam passes to water, which is at about the melting point of zinc (412 C). This is based on the observation that the few cavities that exist in the feldspar of certain granites contain but little water and no separated salts. This indicates that the *feldspar* crystallized at a temperature above the critical point of water, which in a gaseous state cannot dissolve salts, and hence the cavities are nearly empty and destitute of crystals. The abundant presence of salts suspended in the water contained in cavities in the *quartz* shows that the quartz, on the contrary, was still plastic at the temperature below the critical point of water, which as a fluid, when highly heated, is a most powerful solvent, and hence would dissolve soluble constituents from the other minerals, and on cooling it would be a supersaturated solution. This temperature agrees very closely with that deduced from his calculations made upon the measurements of the relative size of bubble and cavity. It is interesting, however, in this connection, to note that the temperature of 412 C. is the point at which substances possess a dull red heat; and Scheerer‡ deduced this same result from his studies on the pyrognomic minerals held in granite. He considered that the existence of certain minerals, such as gadolinite, allanite, &c., which at a temperature not above a brown red suddenly disengage heat, glow

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* See p. 183.

† *Mineralogical Magazine*, Nov., 1876.

‡ *Bul. de la Société Géologique de France*, second series, 1846, vol. 4, p. 487.

with brilliancy, and are then found to have suffered marked physical changes in color, specific gravity, deportment with acids, &c., to be proof that the granite must have formed at a temperature not above that indicated by a dull red.

Now, it has already been explained that the size of the bubble in a fluidal cavity is dependent on two factors, temperature and pressure, either of which being known the other can be calculated. Assuming the stated temperature as being correct, Mr. Sorby has calculated the pressure in a variety of cases, and finds it, though variable, to be always enormous. Mr. Ward* followed with more extensive calculations, using the same formulæ. Comparing the results with those obtained in the field, it was usually found that the pressures deduced from calculation are much larger than those which would result from the pressure of the superincumbent strata that can be proved to have rested upon the rocks investigated. If, for example, the calculations indicate a pressure equal to 50,000 feet of rock, but 30,000 can be found, etc. This indicates that granites are rocks which were formed deep down in the earth, and crystallized from a plastic condition, under pressure, which resulted in part from the weight of superincumbent strata, and in part from the lateral pressure which elevated the mountains. Although accuracy can scarcely be claimed for such calculations, their general agreement, when regarded as approximations, renders them valuable. Much more, which is very interesting, has been done to substantiate the accepted theory; and especially in this connection may be mentioned the experimental researches of Daubree, who has reproduced some of the circumstances in sealed tubes, and crystallized the minerals. Enough has been said, however, to define the method by which the members of our most important group of rocks were formed, and to explain the variety of circumstances in their mode of occurrence which is met with.

Muscovite Granite. This is an uncommon rock, and the one specimen that I have to examine comes from Newcastle, where it occurs sparingly. It is therefore a rock of little importance to us. It would seem as if the entire removal of iron from sediments was usually accompanied by the removal of so many other constituents as rarely to leave the material for

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* *Quart. Jour. Geol. Soc.*, Nos. 124 and 125.

granites;—therefore the micaceous rocks in our state which contain only muscovite are the more quartzose varieties of schist.

Muscovite Biotite Granite. The larger part of those fine-grained compact granites that are so extensively quarried in our state is of this kind. The Concord granite is a beautiful stone, which is fine in texture and light in color. Larger twin orthoclase crystals are sparingly distributed through it. Thin sections show some interesting features. Finely banded oligoclase crystals are common; and through some of the orthoclase crystals laminæ of a triclinic feldspar are arranged in two directions at right angles to one another. This kind of interlamination is frequently observed in free-grown crystals, in which case the laminæ are usually of albite; and it is very likely that they are of albite in this case, although proof of it is scarcely possible. A crystal of this kind, as seen in a section of Concord granite, is represented in Fig. 6 on Pl. 5. The quartz is very clear, and the cavities in it are very small; but every grain is penetrated through and through with the most minute dark needles of rutile, which look like the finest hairs. The larger grains of mica are not crystalline in outline; but some very perfect microscopic crystals are scattered through the quartz. Occasionally a hexagonal needle of apatite is found, which, though small, is recognizable. A bit of chlorite is rarely seen. The orthoclase is tolerably clear; and the structure and composition of the whole indicate a very durable rock.

This Concord granite is typical of a group of granites which are regarded by Prof. Hitchcock as belonging to the stratified series which forms the Montalban system. A number of thin sections have been made from members of this group (called Concord granites), and the variations in their microscopic characters are of an unessential nature. In sections of the Fitzwilliam granite, crystals of zircon are noticeable, which, though very minute, are quite perfect. Some of them have been represented in Fig. 1 on Pl. 5. The crystals of rutile characterize the quartz of this as of all the Concord granites. The crystals of interlaminated feldspar are not found, but others, with the very intricate basket-work structure that characterizes microcline, are seen. In another specimen, which is cut from what is called the best quality of the Fitzwilliam granite, a pretty microscopic structure is developed in some of the grains of feldspar, which is caused by the arrangement through them of laminæ of white mica, in two determinate directions. The same laminæ appear in the quartz, but there they lie scattered at hap-hazard through its mass. This granite contains a large proportion of quartz. The Marlborough granite is in all microscopic characteristics the same, but it is gneissoid in structure; and, indeed, it is said that all of these Concord granites show indications of a gneissoid structure in the quarries, although in specimens no structure whatever is to be seen. The Troy granite is like the Concord, but is lighter in color, and its thin sections are remarkable for the large proportion of microcline they contain. The structure of this microcline is very beautiful, and often its laminæ are of extreme fineness. Fig. 6 on Pl. 10 represents a section of the Troy granite. A grain of microcline is in the middle. The quartz shows its characteristic enclosures, consisting of cavities, needles of rutile, and mica. The light muscovite is seen on the right, the dark biotite on the left, and the orthoclase above. The Roxbury granite is characterized like the Troy by much microcline. The multitude of minute though very perfect muscovite crystals that lie scattered through some of the grains of quartz is noticeable. Fig. 2 on Pl. 5 is drawn from a section of this granite (see p. 86). Other specimens representing the formation of so-called Concord granites offer but little in addition. A specimen from Manchester, and another from Plymouth, are darker, because the muscovite nearly fails; one from Hooksett is lighter, because the biotite nearly fails. The Sunapee granites are in part light and in part dark. The beautiful Haverhill granite is very rich in quartz. A specimen from Effingham is very coarse and pseudo-porphyritic; but, with such minor variations, this granite, from all its localities, possesses the same distinctive microscopic structure and peculiarities.

Biotite Granite. The granites in which biotite alone appears as the characteristic accessory are very numerous. Prominent among these are the Conway granites, which are characterized by their ready disintegration. Any one who visits the region of Conway cannot but be struck with the immense amount of granitic sand and gravel which is there accumulated. Yards and streets are covered with the small fragments of disintegrated granites; and not being rolled or water-worn, these bits preserve their angular forms. All around the country in the region of Conway numerous large blocks of granite are lying about, which one can kick into a heap of sand. The rocks appear to have what was called by Dolomieu, "La maladie du Granite," which he supposed to be due to the action of carbonic acid issuing from a subterranean source, but the true nature of the disease is discovered by microscopic examination. When we look at thin sections of the granites that withstand the influences of time, or only wear upon the surfaces, we find that their grains of feldspar are clear, and contain but few impurities or cavities. But the feldspar of these Conway granites is filled with innumerable pores, and with dirty matters that make it milky and opaque. Fig. 1 on Pl. xi represents a section of one of the Conway granites. The grain of biotite, bent and twisted, as if acted upon by some force after it had formed, is noticeable: it includes between its laminæ quartz, pyrites, and magnetite. Such grains of biotite are not uncommon. The impurity and opacity of the feldspar is the chief feature, but to resolve the muddy mass, a much higher magnifying power is required. Such porous impure feldspars cannot withstand the influences of the weather. The water enters the cleavages and pores, and soon it needs but a blow to break it down. If one notice the pile of gravel that results from destruction of a block of this granite, it will be seen that the cleavage surfaces of all the feldspar crystals are covered with rust, which was carried into the cracks from the decaying mica, but the quartz grains will be found intact. Here is seen, in its simplest form, the first step of the derivation of soils from the disintegration of rocks. Further changes take place when the feldspar is entirely decomposed and converted into kaolin, for then it may be washed away and deposited in clay beds, or disposed of in other ways as circumstances determine. In regions below that of glacial action immense masses of such material occupy the place of the original granitic rocks, and the subject has been studied in tropical regions by Darwin, Agassiz, and others. In our parts, all products of decomposition that were loosened before the glacial epoch have been carried away, and only the granites that are peculiarly subject to decay are deeply disintegrated in their original beds.

The Antrim granite is a *pseudo-porphyritic granite;* that is, it is a rock in which large crystals of orthoclase are developed, not in a compact ground mass, but in an already coarsely crystalline mass. Many of our granites have this structure. Garnets are numerous in the Antrim granite. It is instructive to note how generally in our granites the garnets are entirely without outer form, while in the vein granites and crystalline schists they are so often quite perfect. A section of the Antrim granite, in which a garnet is included, is represented in Fig. 2 on Pl. xi. The form that the garnet takes seems to be entirely dependent on its surroundings, and it encloses in its mass portions of both the biotite and quartz. The Antrim granite contains apatite in little hexagonal prisms, and also in numerous radiating groups of minute needles. Hornblende enters sparingly into the composition of the rock; also, oligoclase, pyrite, and magnetite. Excessively fine and very long needles of rutile pierce the quartz.

But if, as has been shown, many of our granites retain traces of a stratified structure, which cause them to be referred to old sedimentary formations, in other places granite possesses the character of an eruptive rock. The most remarkable occurrences of this nature are at Franconia and the Notch. At these points a light-colored biotite granite occurs, and embedded in it are very numerous angular fragments of gneiss. Some of these fragments are small, some are very large; and thus there is formed an immense breccia, which cannot be represented in the cabinet on account of its great proportions.* This granite is called by Prof. Hitchcock the *breccia granite*. In the Notch, the point where this granite occurs is regarded by Prof. Dana as the axis of an anticlinal, as proven by the arrangement of strata, and the large number of granitic veins in the surrounding rocks. If, now, as suggested, granite was once plastic, under the combined influence of heat and vertical and lateral pressure, it is easy to suppose that, when an upheaval took place, and the rocks were rent into a mass of broken fragments of the overlying strata, the underlying plastic mass might be forced, and being thus partially relieved from pressure, would solidify about the fragments, and form a breccia such as there exists. These breccias are certainly grand and interesting lithological examples.

Many of the biotite granites are red, on account of the color which oxide of iron imparts to the feldspar. One variety of the Conway granite, and a granite from Percy peak in Stratford, are deep red; one from Twin mountain, and one from Stark, possess a beautiful and delicate pink tint, from the same cause. Some specimens of biotite granite are

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* For figures, etc., see vol. ii, p. 169, of this report.

nearly black, on account of the preponderance of biotite. Such is a very handsome granite from Newcastle.

A specimen of biotite granite from Franconia is somewhat remarkable, on account of the presence of fluor spar as one of its microscopic ingredients. A little hornblende is also present, which has a peculiar dichroism, being deep brown in one direction and dark blue in the other.

A specimen from Whitefield is remarkable for its large amount of magnetite. In it quartz largely predominates, and the mica is mostly in very minute grains. A specimen from Ossipee is remarkable for its large content of plagioclase and microcline, and which together outweigh in amount the orthoclase. It contains extremely long needles of rutile.

Mica Hornblende Granites. Granites are numerous in which both mica and hornblende can be seen with the unaided eye, but the microscope enlarges this class widely. In some of the mica granites a bit of hornblende is often found; but in those now to be mentioned the hornblende plays an important part.

As typical of one class of these granites, a light-colored specimen from Colebrook may be described. In this granite, biotite and hornblende are most intimately mixed together. Sometimes one of the black spots that dot this granite will be seen under the microscope to be all of one or all of the other of these minerals, but more often of both. The two minerals are both very strongly dichroic, both being deep brown when the light passes in one direction, and deep yellow when it passes at right angles thereto. This rock contains considerable oligoclase. Apatite crystals of perfect form are quite common, and some epidote is present as a decomposition product.

A number of handsome dark-colored granites, which are characterized by a kind of an olive-green color, are of this class. A specimen from Lightning mountain may be taken as typical. The rock is almost wholly composed of quartz and orthoclase, but the orthoclase is not of the white or colored opaque kind that is most common; it is the transparent variety that is called adularia. It has a very waxy lustre and a greenish tint, and imparts these characters to the rock. Under the microscope it is found to be much clearer, and more free from inclusions than our common feldspar. The quartz is of a dark, smoky color, and only on close examination are grains of hornblende distinguished from it; but in thin sections plenty of both hornblende and biotite are found between the larger grains of quartz and feldspar. The hornblende is very deeply colored, and the light that passes in one direction is green. Considerable magnetite and apatite and some oligoclase are present. A specimen from Iron mountain in Bartlett only differs in that the biotite and hornblende, being more abundant, are more conspicuous in the hand specimens; and the orthoclase possesses at times a pretty and striking opalescence, which is due to minute cleavages, as has already been explained. Very wide variations take place in the proportion in which the accessory ingredients are present, while the rock maintains unmodified its typical color and appearance. For example: biotite and hornblende are sometimes very conspicuous; but, again, as on Mt. Lafayette, these ingredients are very sparingly present, and macroscopically are scarcely recognizable, and the rock differs, therefore, but little from granitell. At Ossipee and at Frankenstein cliff the biotite is almost absent, while hornblende is prominent, and the rock becomes a hornblende granite. At Stark the quartz and biotite are both withdrawn, and the rock becomes sienite. These rocks, at all the localities mentioned, are regarded by Prof. Hitchcock as eruptive. From their peculiar appearance they have attracted considerable attention, and some doubts have been entertained in regard to their classification; but with the exception of the Stark variety they are simply granites, with unessential variations in the relative amounts of the accessories, and their only peculiarity is the constancy in the character of the feldspar, which in all is the preponderating mineral. The clearness and purity of this feldspar, which in thin sections is in marked contrast to that of the disintegrating granites, such as as those in Conway, indicate that these granites will remain firm and solid after time has worn away the Conway rocks.

Some granites occur in Albany, which have certain characteristics which extend over a class to which the name Albany granite has been given. They are very hard and durable rocks, and possess some of the peculiarities of the granites last described. The characteristic features of these granites are, that they are composed of a mass of minute crystals in which larger crystals of orthoclase are often porphyritically developed; and the black constituents, like little specks, are so scattered through the ground mass as to give rise to an appearance which has been compared to pepper and salt. These little black specks are found, on microscopic examination, to be in part biotite and in part hornblende, though, as in the last class, these ingredients are variable, both in their amount as relates to one another, and to the mass of the rock. At some points, as, for example, at Jackson falls, these rocks are characterized by their frequent inclusion of fragments of other rocks. This circumstance, among others, has caused them to be all considered as eruptive. Though this may not be improbable, this circumstance of itself is not sufficient to prove the eruptive origin of a granite, for it has been more than once pointed out that some granites are partially fragmental in their nature. The little grains of hornblende in thin sections often appear quite well crystallized. Plagioclase, and little crystals of apatite, are conspicuous.

A very peculiar granite has been cut by the railroad at Bemis station. It is fine in its texture, and light gray in color. In thin sections its accessories are found to be white hornblende and muscovite. Besides these, sphene, in irregular grains, is abundantly scattered through it. Plagioclase, pyrite, and pyrrhotite are also ingredients. This rock is, so far as I am acquainted, an isolated occurrence.

A granitic rock from Portsmouth contains green dichroic hornblende and muscovite, but so much plagioclase that it brings to mind the quartz diorites that are found in the region.

Hornblende Granites. The granites in which hornblende alone appears as the characteristic accessory are fewer in number than the last. Prominent among these is the Chocorua granite. In thin sections, the hornblende of this granite is very dark in color, and strongly dichroic. A little scale of mica is occasionally found. As accessory constituents, titanic iron, hematite in blood red, translucent grains, fluor spar in grains with an attempt at crystallization, and epidote in grains with a most delicate feathery fringe, are present. The orthoclase is quite pure, but is made up of those irregular laminæ which are represented in Fig. 1 on Pl. 8, and which are only seen in polarized light. They result from the circumstance that in the two interlaminated parts of the crystal the axes of elasticity are somewhat different in their arrangement, and hence the interference colors obtained in any given position between the Nicol prisms are different. This granite has a greenish tint, which is imparted to it by epidote.

Another of these hornblendic rocks from the top of Mt. Carrigain is very peculiar in its microscopic structure. Macroscopically, this rock is fine in texture and dark in color, and its individual constituents cannot be determined. Under the microscope its thin sections show that the dark constituent is greenish hornblende, though it is partially altered into epidote and chlorite; but the circumstance of note is, that many of the minute grains of feldspar are inlaid with quartz, in the manner peculiar to graphic granite. The rock is hence a kind of microscopic pegmatite. The figures that are formed are often of rare perfection. A grain of the orthoclase, much magnified, is represented in Fig. 3 on Pl. xi. Mr. Michel Levy* found this character in quite a number of French granites (granitoid porphyries, etc.) and considered this character, among others, in attempting to find constant relationships between microscopic characters and geological age. The pegmatitic character of a rock he regards as evidence of the simultaneous crystallization of quartz and feldspar, and this character separates such rocks from those in which one clearly solidified before the other, and indicates in a degree an approach toward those characters of crystallization that are peculiar to newly erupted rocks. Our rocks have not been sufficiently studied to enable us to say anything about such a matter; but though such investigations are very interesting, the results are, as yet, at least hypothetical.

A very fine-grained hornblende granite is found in a well defined dyke, which cuts vertically through the coarse-grained gneissoid rocks on the Swift river in Albany.

A light-colored hornblendic granite comes from Stark; a red variety comes from Jackson;—but an enumeration of any peculiarities that I have observed in these or other rocks of this class would be a mere repetition of what has gone before.

Protogene. This is a name given to those granites which, as an accessory, contain chlorite, talc, rotten mica, or other decomposition products, and which are made characteristically green by the presence of one of these ingredients. In the neighborhood of Littleton such rocks reach a considerable development. They are mainly composed of quartz, orthoclase, and chlorite, but in thin sections some hornblende is also seen. The little plagioclase that the rock contains is much altered. This

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* *Bulletin de la Soc. Geol. de France*, 1875, p. 199.

same rock is also found at Hanover, and it is a characteristic rock among the valley formations, varying in color from a light to a dirty dark green. At Lancaster a bright green variety is found, which contains many very large crystals of orthoclase porphyritically developed, and which are usually twins. It contains crystals of pyrites, which harm the utility of an otherwise beautiful stone. This rock at Lancaster becomes gneissoid in structure at some points, and it is everywhere plainly a member of the formation in which it occurs. At Lebanon a beautiful, green-spotted variety of this rock is quarried; but in the centre of each green spot scales of biotite are seen, which indicate that the biotite has furnished the decomposition product. In thin sections of this granite from Walling's quarry the green decomposition product is seen to be epidote, which in minute rounded grains is scattered most plentifully through the rocks in the neighborhood of the biotite. A chloritic granite also comes from Groveton.

Granitell. Granitell is the rock in which all the chief accessories of granite are characteristically absent. It therefore lacks the spotted character of ordinary granite. It is a rock of limited distribution, and in New Hampshire cannot be called typical of any great formation, as are some of the other varieties of granite.

On Little Ascutney mountain there are granitell rocks, which, on account of decomposition, are yellow in color, and which contain little else besides quartz and orthoclase. For microscopic study they furnish beautiful specimens, since the quartz is filled with cavities of unusual size; and in the cavities cubes of salt, also, of unusual size are found. It is interesting to note that some cavities contain a cube that fills half the whole space. The cube is packed into one end, while the bubble occupies so much of the other end that it appears as though the volume of the water were quite small. The apparent great variability of the relative amounts of fluid, salt, and space, would, however, make any generalizations impossible beyond such as were made by Sorby, that the quartz must have crystallized at a temperature below the critical point of water, in order to allow of such powerful solvent action as is indicated by the large amount of salt in solution.

At Bemis brook, in the White Mountain Notch, there is a granite with so little mica that it is almost granitell. Another, of but very local occurrence in the Notch, is composed of orthoclase, a little quartz, and many garnets, and is in composition like granulite, which, however, is a fine-grained and stratified rock.

A variety from Rye is very feldspathic, but when a thin section is examined quartz is found, forming a cement that fills all the interspaces between the well formed and often twinned feldspar crystals. As an illustration of the primary formation of the orthoclase, a section of this rock is interesting. In Concord, just over the border, in Vermont, another example of exactly the same kind is found. These rocks, being essentially all orthoclase, furnish an example of a mineral as a rock. Masses of granular orthoclase in connection with granitic rocks have been often before observed.

Pudding Granite. A most peculiar granite from Craftsbury, in Vermont, is included in the collections of the survey, and has been examined. This is a biotite muscovite granite, which contains concretions of biotite that are quite uniform in size, and usually about an inch and a half in diameter. They are spherical or spheroidal in form, and corrugated on the surface; and these black shining balls, scattered through the massive and light-colored rock, impart to it a most striking appearance. This granite is well known and widely celebrated as the *pudding granite,* a name indeed very appropriately suggestive. Desiring to know what could form the nucleus of these spheres, I sliced one of them through the middle, and of one half made a thin section which contained the centre. The interior of this concretion, as a thin section of it appears when slightly magnified, is represented in Fig. 4 on Pl. xi. The whole mass of the concretion is composed of strongly dichroic biotite, a little muscovite, and quartz. The section shows that it has nothing that can be called a nucleus, but is only a concretion of mica scales which began to be laid concentrically as soon as the first irregular beginning had grown sufficiently to form a basis. Zepharowich* has described such concretions, that occur in the mica schist of Herrmannsschlag in Austria, which in the interior are composed of concentric layers, as in this case; but when the concretions were half grown a sudden change took place, and the mica began to arrange itself radially, and so continued till the growth ceased.

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* *Mineralogical Lexicon, Austria,* p. 59.

Granite Veinstones. In reference to those great veins filled with granitic minerals, such as occur at Grafton, Alstead, Springfield, Acworth, etc., very little need here be said. Their distribution and mode of occurrence have been very completely described by Professors Hitchcock and Huntington in Volume II; and the texture of their material is so coarse that the study of it is more mineralogical than lithological, and hence much has been said in the first chapter of this volume in reference to them. In general, it may be stated that these veins were supposed to be fissures that were formed deep down in the earth, and into these fissures water, percolating through the adjacent strata, entered. This water at such a depth must have been under heavy pressure, and heated as well by the inner heat of the earth, and hence would have a most powerful solvent action, and would become heavily charged with the soluble materials of the strata. From this water, after entering these veins, the granitic minerals crystallized. The water from some distance all flowing into one reservoir, minerals rare in the strata were concentrated in the veins; and hence, mixed with quartz, orthoclase, and the mica which is so extensively mined, such minerals as beryl, columbite, and tourmaline, which contain rare elements, are common. These veins are characterized by large crystals of the granitic minerals; by the occurrence in them of graphic granite or pegmatite, which is a granite in which the quartz is so arranged with reference to the feldspar as to produce the effect of oriental writing; and by the occurrence of a large number of well crystallized minerals. Remarks additional to those made in the previous chapter on minerals, and in the preceding volume by Prof. Hitchcock, will be found in the chapter on economic mineralogy.

SIENITE.*

Under this head are considered those massive crystalline rocks which are composed of orthoclase, with either augite, hornblende, or mica as a characteristic accessory. These form an interesting group of rocks, which in New Hampshire are much less widely distributed than are the granites, and which usually occur in plainly eruptive masses. In some of them biotite exists, but they all contain either augite or hornblende,

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* The mode of spelling adopted in the preceding volumes issued by this survey is adhered to.

and they will therefore be considered under the two heads of augite sienite, and hornblende sienite.

Augite Sienite. In the neighborhood of the town of Jackson there are some gray-colored eruptive rocks, the true nature of which has never been understood, because it is only revealed by microscopic examinations of thin sections. In the region of the so-called tin mines, rocks are abundant which are coarse in texture, and apparently composed of orthoclase and a dark fibrous hornblende. When a thin section of this rock is examined, it becomes plain that originally it was a compound of orthoclase and augite, containing also much apatite and titanic iron; but the grains that were at first augite, are now in some cases partly, in others wholly, altered into a fibrous green mass of hornblende. This hornblende, which results from the alteration of augite, was called uralite by Rose, because it was found abundantly in certain localities in the Urals. The augite is feebly red in color, and in all its cracks and cleavages the incipient alteration is seen, and from the outside the change is steadily progressing toward the centres. Fig. 5 on Pl. xi represents a grain of augite as it appears under the microscope. The well crystallized apatite prisms, the biotite, and titanic iron are also seen. The orthoclase is quite opaque, on account of its impure and decayed condition. In some cases chlorite and calcite are mixed with the hornblende. The iron oxide is often in those diffuse open forms which titanic iron usually takes. Some of the grains are, however, very compact. Almost every one of the larger grains of the titanic or magnetic iron is surrounded by foliæ of biotite radially arranged in fan shapes, with the iron oxide as a nucleus. One of these grains is represented in Fig. 6 on Pl. xi. It is possible that the mica scales grouped themselves about the grain while the rock was plastic, or that they were formed there by a reaction between the silicates and the iron oxide. This is no isolated occurrence. In our gabbros the biotite and iron oxide are almost always associated, and I think that the mica was formed by a reaction in which the iron oxide took part, and therefore the minerals are thus associated.

At a point one mile south-west of Mountain pond in Jackson, another variety of this rock occurs, which possesses some other features that are very interesting. This rock is finer in texture; the orthoclase is very much fresher and clearer; it contains some plagioclase, and also apatite, biotite, magnetite, and pyrite. Like the specimen last described, the augite is in process of transformation into hornblende; but in this case the resultant hornblende is not the green, fibrous, impure variety that is common under such circumstances, but it is a compact, homogeneous, brown, dichroic kind. The external hornblende is as pure and possesses as definite a cleavage as the augite within; and when the plane of the section intersects a grain at right angles to the vertical axis, the cleavages of the two minerals bear the same relation to one another as do the faces of their prisms, if constructed upon the same clino-diagonal as has been explained on page 57. Fig. 1 on Pl. 7 is drawn from a section of this rock, and shows a grain cut parallel to the base, and another cut parallel to the prism. The dichroism is much more marked when one Nicol is upon the instrument.

An augite sienite occurs upon Little Ascutney mountain. In a specimen from Columbia, biotite becomes a prominent ingredient. In the last case, some grains of augite are nearly intact; but it may be said, that in New Hampshire the augite sienites form a little group of rocks which only microscopic study could have identified, since the original characters are shown by the study of the cores of the mineral grains.

Hornblende Sienite. The members of this group are very diverse in their appearance, but are easily recognized, and present some very interesting characters. The augite sienites are entirely free from quartz; but in the hornblende sienites the microscope usually detects a little, and its presence indicates the relationship of these rocks to the granites. A beautiful variety comes from Red hill in Moultonborough. It is composed essentially of orthoclase, which exists in thin, tabular twinned crystal, which mostly lie in one plane, and consequently give to little specimens of the rock a stratified appearance. The hornblende, which is irregularly distributed, is black, but in thin sections it is deep yellow, and it encloses more or less biotite in its mass. Microscopic grains of blood-red hematite and black magnetite, and crystals of apatite, are detected, and by aid of polarized light some plagioclase is found to be present. Only a very little quartz is seen in some little angular corners made by the meeting of the straight edges of the orthoclase crystals. Little, partially crystallized grains of sphene are found; and some of the grains of hornblende are shown by polarized light to consist of two parts in twin relationship. As there are large accumulations of this rock, it is one of considerable importance.

A hornblende sienite much resembling this comes from Columbia. I would like to draw the attention of those interested in microscopic mineralogy to this rock, for in its sections a vast number of cavities filled with liquid carbonic acid are found, and, moreover, these cavities possess associations that render them very instructive. The rock is white in color, spotted with black, and macroscopically only orthoclase and hornblende are visible. In thin sections, plagioclase, biotite, quartz, and apatite are found; and, moreover, calcite is seen to be a constituent of the rock, a mineral which, I think, is not often found in sienites. Quartz is present only in small amount, occupying little angular corners; but every grain of it is filled with cavities which are quite large, all of which contain liquid carbonic acid: and this circumstance, in connection with the presence of calcite, is very interesting. Knowing that this liquefied gas had been found in granitic rocks, I had examined a very large number of sections with the idea in view of finding it in our rocks; but the tests indicated in all cases nothing but water, and I was therefore much pleased to find it in one of the last sections I had to examine, and in great abundance. Its presence in connection with the calcite may indicate that carbonate of lime was a constituent of the material from which this rock was made, and that, at the temperature at which recrystallization took place, a reäction occurred between the lime carbonate and the silicates, producing plagioclase and liberating carbonic acid; but the rock was under such pressure that it could not escape, and it was consequently imprisoned in the quartz, which was the last mineral to solidify, and the quartz, being small in amount, is correspondingly full of the cavities containing the fluid gas. The appearance of a section of a quartz grain, as it is seen when magnified 350 diameters, is shown in Fig. 1 on Pl. 12. These cavities are often arranged in rows, some of which are straight and some curved, and many more cavities are irregularly strown about. In the larger of them a double line is seen on the outer edge, and this line cuts off the corners and irregularities of the cavities, and indicates the presence of a very small amount of a second fluid, which is probably water. The bubbles are quite large in proportion to the size of the cavities, and one can immediately perceive that they lie in some other fluid than water; for the circles of their outer edges are not broad and black, as are those of bubbles in water, but their outlines are simply sharp lines; and this indicates that the bubbles are in a fluid, the index of refraction of which is less than that of water. On warming the section, the bubbles all simultaneously disappear at the temperature of 35° Centigrade, which is a trifle above that at which the disappearance has been usually noticed. There are two ways by which such bubbles in liquid carbonic acid disappear: the first is, when the relative size of the bubble to that of the cavity is small, and then the fluid expands and fills the space, below the critical point of the fluid; and in this case the bubbles begin to grow small as soon as heat is applied. But when the size of the bubble is relatively large, when heat is applied the fluid evaporates into it; the bubble grows larger, and at the critical point suddenly expands and fills the space. In the cavities under consideration, the bubble disappears in this second manner. It is very interesting to watch this.* The increase in the size of the bubble at first can be detected; but the disappearance and reäppearance of the bubble are instantaneous, and nothing further can be seen than that at one instant the bubble is plainly there, and then it is gone, and, on removing the source of the heat, it shortly is there again.

In the figure the mineral above is orthoclase, which includes some apatite crystals ; the one on the left is hornblende including a mica scale, and on the right there is a grain of calcite. The minutest of the little cavities in the quartz, when very highly magnified, are found to contain the same fluid. Where the quartz is in contact with the calcite, it appears dirty and troubled; but this apparent impurity, with the highest magnifying power, is also resolved into a dense aggregate of excessively minute cavities. This, too, is significant.

Besides the carbonic acid, the presence of grains of calcite in an eruptive acidic rock is interesting. It confirms what has been said in regard to the mode by which such rocks became plastic. After a pure igneous fusion no such combination of minerals as is here found could exist, save as a result of some subsequent decomposition. It would seem that if the

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* A little apparatus has been contrived by which a section and a thermometer are warmed together on the stage of the microscope. This is accomplished by an electric current in Vogelsang's contrivance; but in a simple and inexpensive apparatus that comes with Mr. Rosenbusche's microscope that I have described, a current of warm air is carried across the stage in a chimney, and is brought in its passage in contact with the section and thermometer.

carbonic acid were generated as suggested, the conditions of heat and pressure were such as to bring about only a partial reaction; and the conditions under which granitic rocks have been recrystallized, as indicated by other circumstances, are just about such as would account for the associations observed in this rock.

Another sienite, which in most respects is exactly like this, occupies a dyke in Sandwich. Calcite is absent, and with this absence the quantity of carbonic acid decreases. In many cavities in the quartz, however, liquid carbonic acid is found, but in the larger number only water and the customary crystals of salt. These two rocks are our only ones in which I have found this interesting enclosure of liquefied gas, but they are remarkable examples.

On Mill mountain, in Stark, a dark-colored sienite occurs. Macroscopically, it appears as if wholly composed of orthoclase; but in thin sections considerable hornblende is found in small fragments, which are quite thickly distributed: if the rock were light-colored, as are the ones thus far described, the hornblende would be prominent enough. The feldspar is of that clear grayish waxy variety (adularia) which is so prominent in a group of granites which have been described, and to those granites this sienite is related. It contains also plagioclase, apatite, sphene, and epidote, besides a little microscopic quartz.

A very different kind of sienite is abundant about the town of Albany. This is a very fine-grained feldspathic rock which is found in small dykes. It is red in color, and full of minute black specks. When thin sections are cut, these specks are found to be of a very deep-colored hornblende with some little crystals of magnetite, while the mass of the rock is composed of small but well defined crystals of orthoclase, in the angles between which a little quartz is found. These rocks have commonly been called felsites; but in no respect do they differ from ordinary sienite, save in the fineness of their texture. On Sabba-Day brook there are favorable localities to see these rocks in place.

GNEISS.

Gneiss is in composition exactly like granite, being composed essentially of quartz and orthoclase as constant constituents, and muscovite, biotite, hornblende, chlorite, etc., as essential but variable constituents, and plagioclase, apatite, etc., as accidental constituents. The characteristic feature of gneiss is, that it possesses a stratified or laminated appearance, on account of the parallel arrangement of the individual crystals of the essential accessory. Like granite, gneiss is sub-divided, according to which accessory it contains, into as many kinds as are characterized by different minerals. The difference between gneiss and granite being therefore merely structural, all that has been said of granite may, with slight modification, be true of gneiss; and hence, though it is one of the commonest rocks in New Hampshire, and geologically one of the most important, it may be briefly treated here.

There are many structural varieties of gneiss. Sometimes the accessory, which is usually mica, lies in flat planes, and the rock appears to be uniformly foliated or stratified, while in other cases the mica is in most irregular wavy or twisted layers, of most complex structure; and many names of varieties have been suggested by peculiar characters of this nature.

The cause of the lamination has been made a study by many eminent geologists, and it is by no means certain that in all cases it is to be referred to the same one. There are some who still hold that the mineral arrangement is caused by the direct deposition of the minerals on the bottom of bodies of water which hold the constituents in solution; but the microscopic characters of the minerals and their inclusions, being the same as those of granites, point to formation and crystallization under enormous pressures and at elevated temperatures, and render this supposition untenable. Again: it is supposed that gneisses are made by the recrystallization of such sedimentary beds as argillites or clay slates, under the same influence of heat and pressure as made the granite, but that these influences were milder in their action, and the present condition is the result of the original stratification of the deposits. The plane of lamination of the gneiss is often found to be conformable with the strata of a region, and it cannot be denied but that original lamination may, in some cases, have had its influence. The third supposition is, that the stratified structure was induced by pressure, and by retarded movements in the once plastic mass. This theory was first advanced by Scrope,* in 1825, to whom the idea was suggested by the

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* Scrope. *Craters and Lavas. Jour. Geol. Soc.*, 1856, p. 346.

observation of exactly analogous structures in certain lavas and erupted masses, which occurred in such circumstances that the origin of the structure was plainly evident. To Mr. Scrope, gneiss is "squeezed granite." That mica will thus arrange itself under the influence of unequal pressure has been confirmed by Mr. Sorby,[*] who submitted a mass of pipe clay, in which he had mixed some micaceous hematite, to a pressure which extended the mass in one direction; and a subsequent examination proved that the scales of hematite had all arranged themselves in planes at right angles to the pressure, producing a schistose structure, and a more easy cleavage in the plane of the stratification. These experiments have been of late repeated, with some unimportant variations, by Mr. Daubree,[†] to show the effect of impeded movement. He forced a plastic mass under great pressure through an aperture, and thereby developed a schistose structure, the laminæ being parallel to the walls of the opening; and other results of the same nature were obtained.

All these circumstances demonstrate that pressure which acts in such a way as to produce lateral movements may be certainly effective in reducing any foliated or tabular minerals in a plastic mass to an approximate plane; and with our knowledge of the extent to which movements have gone on in the crust of our earth, and which have accompanied the elevation of mountains and contortion of strata, this circumstance furnishes the most satisfactory explanation for most of the facts observed. If the stratification of gneisses is an induced structure, then it does not follow that this stratification should always correspond with the original bedding; and the existence of eruptive masses of gneiss, in which the structure cannot be referred to original sedimentary conditions, as has been shown by Naumann,[‡] adds weight to the supposition. Mr. Charles Darwin has also noticed the gneissoid structure in certain Chilian eruptive granites. Neither does it follow, that if the lamination of the gneiss does correspond with the plane of the strata, the lamination is to be referred to the stratification of sediments, for the cleavage of some clay slates, which is admitted to be due to pressure, very often corresponds with the plane of the bedding. If a mass of granitic material is fused or

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[*] Sorby. *Origin of Slaty Cleavage. Edinburg Philos. Jour.*, 1853, p. 144.

[†] *Comtes Rendus*, March 27, 1876.

[‡] *Über die wahrscheinlich eruptive Natur mancher Gneisse und Gneisse-Granite.* Prof. C. F. Naumann. *Jahrbuch für Min.*, 1847, p. 297.

plastic under the influence of great pressures, which are partially due to the weight of superincumbent strata and partially to lateral pressures, then, in the disturbances which occur in the course of the elevations of mountains, the lateral pressures are the ones which naturally are first relieved by fractures of the earth's crust; and impeded movements, therefore, are very liable to take place in the plane of the strata, and all the conditions are fulfilled for the formation of gneisses, with the plane of lamination parallel to the strata of the region: this is the position which the laminæ of most gneisses occupy. All these suppositions are quite old, as will be noticed, yet they have received but little attention in this country. They are also applicable in the study of the structure of other crystalline schists; and in general, though the influence of original sedimentation upon rock structure is not to be lost sight of, and although rocks of this class are generally considered to have resulted from the recrystallization of stratified sediments, it seems certain that the present condition of all the crystalline schists is largely owing to the effects of the pressures to which we know they have been submitted.

At the time the last report upon our geology was made (in 1844), the metamorphism of the crystalline schists was generally supposed to be due to the heat which was communicated to the strata by fiery masses of molten material which was erupted through them. In a small dyke of trap or granite, cause sufficient was seen to spread metamorphism far and wide through the surrounding strata. This idea is not yet entirely passed away, although the real effects, which can be produced in sediments by the influence of *immense* eruptive masses by simple contact, are evidently small, as can be seen in many places,—for example, in the Connecticut valley, where the great dykes of diabase cut the red sandstones. The microscope points to the action of the same forces in the recrystallization of the schists as in the case of the granites, though acting perhaps less efficiently in their fusion.

Muscovite Gneiss. Pure muscovite gneiss, like granite, is comparatively rare, because the entire removal of iron from sediments is usually attended by the removal of so many other constituents as to produce the composition of some other rock. A bed of pure muscovite gneiss occurs at Chesterfield. The rock is white, glistens with its mica, and contains many light red, poorly crystallized garnets. The mica lies in very regular and even planes, but the individual laminæ are much bent and twisted. A specimen from Rye contains numerous microscopic apatite crystals, which are visible in thin sections.

Biotite Gneiss. This gneiss is much more common. Like all our gneisses, it varies in structure from the very schistose kinds to those in which the lamination is invisible in small specimens, and only faintly visible in large masses, and which are called gneiss granites. I will mention only a few prominent peculiarities of individual specimens, none of which are uncommon. A gneiss from Swanzey is very uniform in its texture, and a thin section shows that its feldspar is largely oligoclase. It would be called oligoclase gneiss. It contains garnet and epidote, and also a few crystals of apatite. Some grains of oligoclase are twinned in two directions, and the striæ are very fine, making most beautiful objects of the crystals. The biotite is very deeply colored, and strongly dichroic. A gneiss that underlies the schists on the Saco river is very feldspathic, but the feldspar is mostly orthoclase. It contains magnetite, and also microscopic cubes of pyrites. A variety from Eagle cliff is pseudo-porphyritic in structure, some of the crystals of orthoclase being very large. A specimen from Tripyramid is remarkable for the large number and large size of the fluidal cavities in its quartz. It also contains large grains of titanite. Another specimen from the same locality contains numerous microscopic scales of hematite, which in the thin sections appear of a deep red color. A specimen from Holderness is very black on account of the preponderance of biotite. A kind quarried at Enfield is very light, because the amount of mica is small. A variety very coarse in texture comes from Wolfeborough. A variety with a very dark green shade comes from Whitefield. This shade appears to result from the original color of the mica, and not, as it often does, from decomposition. All these peculiarities are combined in various ways in other specimens.

Biotite Muscovite Gneiss. This is the most common variety of gneiss, and the larger number of our specimens are classed here. Prominent in this group are the old pseudo-porphyritic gneisses that characterize the formations that are referred by Prof. Hitchcock to the Laurentian. These gneisses are mostly dark in their color, since the biotite preponderates over the muscovite. In them large orthoclase crystals, which are often two inches long, are developed. These crystals are commonly twinned, and usually, though not always, lie with their long direction in the plane with the mica. Very often these crystals are ill formed, and lenticular in shape; and the black mica surrounding such crystals gives to them the appearance of eyes, whence the German name "augen gneiss." Such gneisses occur at Newbury and Antrim. This formation reaches it northern limit at Bethlehem. At this point the gneiss is much lighter, on account of the greater abundance of muscovite. At New London some of the mica, by decomposition, has acquired a brilliant golden yellow color. Inexperienced persons have often had their curiosity excited by such mica in certain of our gneisses. This porphyritic gneiss is a very important and widely distributed rock.

The members of the group of rocks to which Prof. Hitchcock has given the name of *Bethlehem gneiss* belong mostly in this place. They are in general characterized by a faint green tint that is due to the presence of some chlorite, which is a decomposition product, and which allies them to the protogene gneiss. At Hanover this rock contains epidote, and crystals of tourmaline are found by an examination of thin sections. It also contains pyrrhotite, which does not appear to be an objection to its employment as building material,—for the base of the fine Culver Hall, one of the Dartmouth College buildings, is made of it, and none of the stains are found which some expected would shortly appear. A specimen of this gneiss from Bethlehem is almost white, and only faintly and irregularly streaked with micaceous layers.

Most numerous appearances are presented by gneiss, which are dependent on the color, structure, and arrangement of its constituents. A kind from Carroll is what is called wavy gneiss, because the layers of mica are undulating. Such and numerous other structures are induced by the same agencies that crumple up strata. A kind from Marlow contains andalusite, and also many red garnets, which dot the black surface, making a very pretty rock. A gneiss from Ossipee contains numerous and quite perfect rhombic muscovite crystals. And so we might continue;—but the causes of the great number of variations to which gneiss is subject are self-evident, and need no elucidation.

Hornblende Biotite Gneiss. In some gneiss, hornblende is visible to the unaided eye, as, for example, in one from Frankenstein cliff; but more often it is found, by the aid of the microscope, as a constituent of rocks which are apparently biotite gneiss. In a thin section of a gneiss from Mt. Franklin in Swanzey, deep brown hornblende, epidote, garnet, and plagioclase, in addition to the other regular constituents, are found. In a handsome black gneiss from Littleton, the proportion of ingredients is reversed, and the biotite almost disappears, while hornblende becomes very prominent. In thin sections this hornblende is very deep green in color, and plagioclase and epidote are found.

Protogene Gneiss. Associated with the chloritic granites, in the same localities along the Connecticut valley, there are green gneisses which differ from the granites only in structure, and need no further consideration. These are the granitic members of the group of *greenstones* which are characteristic of the valley. In this region, hornblendic and chloritic rocks are particularly abundant; and it is interesting to note that the associated granites and gneisses partake of the same general nature.

By the gradual withdrawal of the feldspar from gneiss, this rock approaches in composition towards mica schist, which is next considered.

MICA SCHIST.

This is essentially a schistose mixture of quartz and mica; but variations in the structure, in the size of the constituent crystals, in the proportion of ingredients, and in the presence of accessory minerals, make of the rocks of this class a most diversified group. The mica is often muscovite, often biotite, and often both. The usual accessories are andalusite, cyanite, fibrolite, staurolite, garnet, and tourmaline, which are often so abundant as to give a character to the rock. The following are the principal varieties:

Ordinary Mica Schist. In the most common kinds of this rock the mica is in quite large scales, and as the rock cleaves in the plane of its lamination, the glistening mica is much the most prominent ingredient. The quartz is most plainly seen on the rough fractures across the laminæ, where it appears in lenticular grains about which the mica bends. Though biotite is usually present, muscovite predominates. The mica, if tested, usually gives some water, as does margarodite. In thin sections under the microscope, magnetite, apatite, orthoclase, hornblende, and chlorite are very often found. Tourmalines abound in the schists on

Mt. Washington. The lamination is sometimes quite even; but, again, its plane is waved, twisted, bent, and knotted in various ways. This variety of mica schist is the ordinary one among the highly crystalline strata.

At some points, as, for example, at Bedford, the mica is in little scales, and is mostly biotite. This brings the quartz into prominence by the contrast of color. Sometimes, as at Wakefield and Epping, the crystals of the ingredients are so small and so intermingled, that the rock becomes nearly massive, and resembles certain basic eruptive rocks in hand specimens. A glance with the microscope tells the true nature. This type is more characteristic of the valley formations, where all the rocks seem to have been recrystallized under gentler agencies than were those which have heaped up the most highly crystalline strata in the mountains. Some schists in this valley appear to be half fragmental in type, and consist of schistose masses of sand bound together by scales of mica, and resemble itacolumite in a degree.

Andalusite Mica Schist. In this rock crystals of andalusite are prominent and characteristic. Such schists abound in the mountainous region. Rarely the andalusite is quite well crystallized. Often it exists in rounded nut-like forms in the rock, which are very hard, and become prominent on weathered surfaces on account of their greater ability to resist decay. Often it is in long rude imperfect crystals, which are heaped together in tangled web-works. These crystals often decay in a peculiar manner. Sometimes the centre rots away and a cylinder is produced, and sometimes both centre and outside resist while the rest of the crystal gives way. At some points the macled structure is very prettily developed, but where this is the case the schist loses its marked micaceous character and becomes argillitic. The condition of internal alteration, which is shown by the microscopic structure of andalusite crystals, has been already pointed out on page 106. In a microscopic section of a schist from the Notch, it is seen that besides the large crystals there are very minute crystals of andalusite.

Fibrolite Mica Schist. Mica schist full of fibrolite is abundant in the same regions as is andalusite schist. Fibrolite appears to be much more stable than is andalusite, and consequently its fibres appear very clear and fresh in thin sections. Fig. 3 on Pl. 8 represents a section of a fibrolite schist from the Notch, as it appears between crossed Nicols. In the figure the planes of vibration of the light are represented by the cross lines. The fibrolite pierces the scales of biotite, and takes its straight course, regardless also of the quartz, and its orthorhombic character is shown by the circumstance that all the fibres which are parallel to the plane of either Nicol are black. On the top of Mt. Washington fibrolite is very prominent in the schists, and the masses that are formed by aggregations of its fibres are quite striking in appearance.

In the neighborhood of the Crystal cascade a fibrolite schist occurs, which is black in color, and so nearly massive that it has never been distinguished from the diabase that is found near it. The fibrolite is, however, easily seen on close examination, and a thin section shows that the rock is a fine mixture of quartz, biotite, and muscovite, with less of magnetite, pyrite, and chlorite. Through this mixture fibrolite and garnets are sprinkled. Many of the garnets are zoned by the arrangement of impurities. They mostly have clear centres and impure rims. This rock appears spotted on fresh fracture surfaces, and darker parts are included in the lighter in such a way that it has been called a trap conglomerate. It being understood that the rock is of sedimentary origin, its structure is not peculiar, for such features are not uncommon in crystalline schists.

Staurolitic Mica Schist. Mica schists, in which staurolite crystals are so abundant as to give character to the rock, occur at Enfield and many other towns along the Connecticut river. The staurolites are usually but poorly crystallized, though exceptionally good crystals, which are sometimes an inch in diameter, are found. As mica schist gradually loses its micaceous character and becomes argillitic in a formation at Charlestown, the staurolite becomes macled, and presents itself in the peculiar form that is described on page 110. In the mica schists of the Connecticut valley, the staurolite crystals are usually large and twinned. In the argillitic schists, they are often very small and simple.

Garnetiferous Mica Schist. Mica schists, characterized by the presence of many garnets, are abundant. At Springfield, well crystallized garnets compose more than half the bulk of some schists. In other rocks, fewer but still large crystals are found; and in many rocks, which are not characteristically garnetiferous, this mineral occurs abundantly as a microscopic constituent. Garnets are found in the same schists with andalusite, staurolite, etc.

ARGILLITIC MICA SCHIST.

In mica schist, by insensible degrees the scales of mica lose their individual character, till at last nothing that can be distinctly recognized as a scale or crystal can be seen. All the constituents are very fine, and the rock becomes argillitic mica schist. The rocks of this class, however, possess a glistening lustre which is suggestive of mica, and which is due to its presence, as the microscope indicates. With a high magnifying power, they are seen to be composed of an entirely crystalline mixture of quartz, feldspar, mica, and chlorite, with various accessories. They are distinguished from real argillites and slates by this crystalline type, but the metamorphism has been of such a gentle nature that it has left the ingredients in a fine condition, and has not entirely removed the argillitic character. The condition of the ingredients and the presence of accessories create many variations in this rock. When much chlorite is present, the schists are greenish in color. Excessive fineness and a preponderance of the micaceous ingredient give a soapy feel to the rock. Contortion of the laminæ produces wavy, woody, and other imitative structures. But under the microscope, these rocks are all essentially alike, and are characterized by their very fine yet entirely crystalline type and micaceous appearance. Here are included the rocks called phyllite, and the larger part of those called hydro-mica slate. The rocks called by the Germans old clay slates (urthonschiefer), as distinguished from the newer slates, are of this class, and many local names have been given to varieties. Just as intermediate kinds bind this rock to mica schist, so other varieties, which are not so entirely crystalline, bind it to the clay slates. In general, however, it is very well characterized, and quite distinct from these related rocks.

Argillitic mica schist is very abundant in New Hampshire, particularly in the Connecticut valley. For special examination, I have selected a specimen from that region, which is as typical as possible of the whole group. It is what is called by Prof. Hitchcock the Lyman schist, which by itself composes the larger part of a formation. The specimen was collected at Woodville. It is gray in color, very schistose, but not at all friable. It is in appearance perfectly homogeneous, and no constituent can be detected with the eye or pocket lens. It is somewhat glistening in its lustre, and rather soapy in its feel. I analyzed the rock, and the following was the result:

Silica,	60.49
Alumina,	19.35
Iron sesquioxide,	.48
Iron protoxide,	5.98
Lime,	1.08
Magnesia,	2.89
Soda,	2.55
Potash,	3.44
Water,	3.66
	99.92

This analysis indicates that the rock has the composition of an ordinary clay, minus the larger part of its water. It is plain that, acccording to the efficiency of the forces that act in recrystallizing such sediments, material of this composition could be converted into a slate, a granite, a porphyry, or one of several other rocks. That such rocks as these schists are particularly characteristic of the valley, is to be referred to the feeble action of the same metamorphic agencies that in the interior regions have created the coarsely crystalline type, which here is largely replaced by the fine-grained and the half fragmental type.

When a thin section of this schist is examined with the microscope, it appears to be made of an extremely fine aggregate, but with a high magnifying power it is seen to be composed of white transparent quartz and a fine foliated substance, most of which is apparently mica in a very fine state of division. These parts are brought into sharpest relief in polarized light, for the micaceous constituent assumes the brightest colors. As the section is revolved between crossed Nicols, the foliæ become dark when in the plane of either Nicol, as does mica, and as the foliæ are mostly in one plane they nearly all become dark at once. The examination of the section shows besides, that some green chlorite, some trifling bits of calcite, and minute grains of iron oxide are scattered about, and some bits of the granular substance have the white semi-transparent appearance of feldspar. A section of this rock, as it appears when magnified 600 diameters, is represented in Fig. 2 on Pl. 12. It is introduced to show that these rocks, though so fine in texture, are composed of recrystallized minerals, and do not share at all the fragmental character of the rocks like clay slates, which are composed of the merely cemented particles that constitute clay beds. To these rocks they are, in composition and physical characters, so nearly related that they are appropriately termed argillitic mica schist, and they form the connecting link between mica schist and argillite.

No analysis can be called typical of such rocks as these, for the proportion of silica in them is as variable as it is in beds of clay. With further increase of the micaceous constituent, the rocks become more glistening in lustre and softer to the feel. A schist of this nature at Lyman is commonly called the copper schist, because it contains considerable chalcopyrite and bornite. Pyrites is a common constituent of this class of rocks.

Some of these schists are very dark in color, and thin sections of such are filled with an opaque, apparently amorphous substance. A specimen from Dalton is an example. When a fragment of this rock is heated, the coloring material is destroyed; and this indicates that the black particles are of some bituminous substance. In these black varieties the glistening appearance is often nearly absent, but, with a pocket lens, in no variety can the mica be more clearly distinguished.

Like mica schist, this rock species is varied by the abundant presence of certain accessories. As often as mica schist is characterized by andalusite crystals, so often is argillitic mica schist by *chiastolite;* and chiastolite seems to be confined to rocks of this class,—for when the micaceous character of the rock is well defined, the macled character of the crystals is absent. A macled variety of staurolite characterizes an argillitic schist at Charlestown, and being an isolated occurrence this *staurolite schist* has attracted much attention (see p. 110). At this locality the argillitic rock gradually passes into a well defined mica schist, and, as before stated, with this passage the macled structure disappears.

Some other striking peculiarities in the nature of this rock are seen in certain localities. At East Hanover, for example, some of the schists are mottled by what are apparently pebbles of various sorts and sizes that have been flattened out between the layers. This circumstance was, I think, first noticed by Prof. E. Hitchcock,* in 1833, and was mentioned

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* *On the conversion of certain conglomerates into mica schists, etc.* E. Hitchcock, *Am. Jour. Science,* ii, vol. 31, p. 372.

by him in his report on the geology of Massachusetts. Subsequently, aided by his son (the chief of our survey), the subject was more thoroughly investigated by him, and it was found that the flattening of pebbles between layers of schistose rocks had taken place at many localities, and that a geological significance was to be attributed to the circumstance. Since that time analogous phenomena have been found all over the world, so that it is no longer a novelty; but it is well understood that pebbles of quartz, or of other substances, may be variously altered in form by the processes of rock metamorphism, which are not of that degree of efficiency that entirely obliterate all signs of the original constitution of the sedimentary mass. In limestones, well known fossils, which are flattened and contorted, are found between the strata; in conglomerates, two pebbles, one of which has forced itself half way through its more yielding neighbor, are sometimes found in juxtaposition; and in a mixture of fine and coarse material, the finer part may be converted into mica schist, while the pebbles do not enter into the mass, but are softened and flattened into thin discs. These facts are again brought forward by those who think that the stratification of such rocks is partially or wholly due to pressure acting at right angles to the plane of the lamination; and they point very definitely to the circumstance that though, in these rocks now under consideration, the stratification is parallel to the original bedding, yet pressure must be considered as a very efficient agent in inducing a schistose or finely laminated condition.

At some places in New Hampshire the strata of the schistose rocks are most curiously broken. On Mt. Pequawket a huge breccia occurs, which is composed of large broken and angular fragments of argillitic mica schist. These fragments lie in all directions, and at all angles with one another, but are firmly consolidated into a compact mass. This is not so difficult to understand, for at some other points the fragments are found cemented together by a felsitic mass, and at others quartz porphyry constitutes the bulk of the rock, and in it the fragments of schist lie embedded. It therefore appears that the strata of schist were crushed and broken by the force that opened a way for the eruption of the quartz porphyry, which forms a large part of the mountain. But the cause of the broken condition of these schists is not always so plain. In the south-western part of the state, such appearances are not rare.

Dr. Jackson describes one such broken mass of slate in Gilford, in which the strata were likewise entirely broken to pieces. The effect was attributed to an immense iceberg which was stranded there while the land was submerged, and by its movements and its mighty weight broke up the rocks. Although such accidental causes might produce these and many other results, in the more general and efficient action of the great movements that have taken place in the crust of the earth, a more reliable explanation is found for all such varied and often peculiar effects.

Novaculite. (Oil Stone.) This is a variety of schist in which the quartz very largely predominates, and the rock therefore loses its schistose character, becomes nearly massive, and breaks with a conchoidal fracture. It is usually of a gray color, and forms layers of greater or less thickness among the other schists. These rocks have not been well understood, and have been called quartzite, siliceous limestone, and felsite; but the microscope shows that they possess the same structure, and the same ingredients arranged in the same way, as the argillitic mica schists, and that the proportion of ingredients is all that constitutes a difference.

As tpyical of these rocks, a specimen from Littleton will be described. This rock is light gray in color, massive, and so fine in its texture and so homogeneous, that no ingredient can be macroscopically detected. It looks like a gray felsite, and like felsite it fuses before the blow-pipe. A study of a thin section shows that it is an excessively fine-grained mixture of much quartz and little orthoclase, among which the little fibrous and scaly crystals of mica that characterize the argillitic mica schists are thickly scattered; but these scales are much smaller, and do not constitute an ingredient of any importance. Grains of calcite are also seen. The constituent minerals bear a recrystallized character, and none of them appear fragmental. The rock has, therefore, all the characters of argillitic mica schist; and the massive condition is due to the excessive amount and fineness of the quartz, and the small amount of the micaceous constituent. Its fusibility, which first caused it to be called felsite, is in part due to the calcite, which forms a flux for the silica, and in part to the orthoclase, for it is well known that a mixture of quartz and orthoclase will fuse as easily as orthoclase alone. A specimen from Tamworth is black, and contains chlorite and iron oxide. Other specimens differ in color and in proportion of ingredients; but I think this description may be regarded as representing them all fairly. This is the novaculite, or oil-stone, that is so highly prized for sharpening tools.

QUARTZ SCHIST (QUARTZITE).

Almost all kinds of schists, by the elimination of the minerals which characterize them, graduate into quartz schist. Very siliceous varieties of mica schist, argillitic schist, chlorite schist, etc., stand between quartz schist and these various rocks; and therefore this rock, which typically is a pure schistose mass of quartz, possesses a variety of characters that are given to it by its accessories, and which relate it to other rocks that have been and are to be described. The rocks abound in the Connecticut valley and geologically related areas. They show very various degrees of metamorphism; and although, as a rule, their structure indicates a complete recrystallization of the materials that formed the sedimentary beds, still cases are not wanting where remains of the fragmental character are maintained. It is understood, that in this place the rocks with the latter character are not considered, but are included among the descriptions of half fragmental rocks that follow. In texture, all grades occur between coarse granular and cryptocrystalline varieties; and in structure, all grades between very schistose and almost massive rocks.

The most common kind of quartz schist is micaceous. A white mass, consisting of granular quartz, shows on its schistose cleavages flakes of a glistening mica, which is usually all muscovite, and rarely is partially biotite. This is in contrast to most of the micaceous rocks; for though a little alumina and potash may remain, usually but little iron exists in such highly siliceous sediments. The reverse is, however, shown by a specimen from Newcastle, in which a very fine-grained quartzite is traversed by multitudes of black, parallel lines, which on investigation are found to be made by the arrangement of minute grains of magnetite.

A micaceous quartz schist from Hinsdale is composed of a very pretty bluish opalescent quartz, and its mica is more fibrous than foliated. In some other varieties, the presence of mica is only indicated by that glistening lustre that characterizes the argillitic mica schists.

Orthoclase often appears in these rocks, but only as an unessential accessory, though sometimes it is macroscopically visible. Plagioclase is not at all rare. Apatite is found in a section of a Portsmouth quartz schist. Pyrites is a very common ingredient. It occurs in both microscopic and macroscopic crystals, which though so small are often very well formed.

A quartz schist from Connecticut lake is very fine in its texture, and contains, as accessories, calcite, plagioclase, biotite, magnetite, and chlorite. Calcite is not rare in these siliceous schists. Its common presence in such acidic rocks points toward the gentle action of the forces that have effected their recrystallization. This is apparent in all the rocks of the region where these schists are most common.

GREENSTONES.

Under this head it is proposed to describe those interstratified rocks which are so prominent in the valley of the Connecticut, which are intimately associated together, and which, in common, possess a more or less green color that is induced by the presence in them of hornblende or chlorite. No especial significance is intended to be attached to the word greenstone, though efforts have been made to dignify it with a meaning. I use the word simply to connect together for discussion certain rocks, which in any lithological classification would be widely separated. As warrant for their union under this term, there is their close geological association, and the precedent established by all those who have written upon the geology of the valley region, who have so constantly spoken of greenstone that all will understand what rocks are here referred to.

All along the valley of the Connecticut, from its source to its mouth, there are large accumulations of green rocks, and so characteristic are they of the region, that the area has always been colored green on geological maps. These rocks are of several kinds, and are interstratified with one another, with argillitic schists and with other related rocks. One kind is the light green chlorite schist, which the microscope shows is essentially composed of minute grains of quartz with chlorite. Another is the amphibolite, which is composed of amphibole mixed with more or less quartz. In others a triclinic feldspar becomes prominent, the schistose character disappears, and a diorite composed of plagioclase and hornblende results. To these three species,—diorite, amphibolite, and chlorite schist,—all these greenstones may be referred, but the variations in the proportion of ingredients and the presence of accessories diversify the rocks to that extent which is to be expected in sedimentary formations. They form a group which has excited much interest, and some general remarks in reference to them will be made after they have been described.

As a formation these rocks are widely distributed. Dr. Hunt described their occurrence and geological relationships in his report on the geology of Canada, and Prof. Dana[*] has pointed out their stratigraphical relationships in the New Haven region. Mr. T. B. Brooks[†] has found them widely distributed over the southern shores of Lake Superior, and has described and classified them. Our particular formation was first noticed by Prof. E. Hitchcock, who called them all greenstones. Prof. Hitchcock, of this survey, has studied our formation with great care, and referred the rocks to the Huronian age. Other investigators have determined like formations also to belong to the Huronian. In Europe, rocks thus associated frequently build formations; but I think that enough has been said to indicate that these rocks form a defined group, the members of which are very likely to be associated together, and that therefore anything that can be deduced from the study of our rocks may be quite generally applied.

METAMORPHIC DIORITE.

This is essentially a compound of hornblende and a triclinic feldspar, and is therefore of the same composition as the rock which has been described as basic eruptive. This variety, however, is found interstratified with schists of various kinds. It bears at times marks of stratification itself, and has been repeatedly shown to belong to the formation in which it occurs, although the existence of diorites other than eruptive is not as yet generally admitted. It is not at all surprising that two rocks of the same composition should originate in very diverse ways, for among

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[*] *American Journal of Science*, iii, vol. xi, p. 119.

[†] *American Journal of Science*, iii, March, 1876.

rocks other than basic this is known to occur constantly; but we may suppose that when this does happen, the two rocks will have certain general characters stamped upon them by the different forces that have acted on them, and which will distinguish them from one another. I shall, therefore, at first, point to certain fundamental differences in the microscopic character of eruptive and metamorphic diorites, which, so far as New Hampshire rocks are concerned, are general, and which therefore may be regarded as confirmatory of the stratigraphical researches that have been already referred to.

In examining sections of eruptive diorites, the sharp, definite crystallization of the hornblende is the first thing noticed. It may not assume a definite form, but if irregular, the grains are compact, and possess well defined outlines. As opposed to this, the hornblende of our metamorphic diorites, as seen in thin sections, is found in most diffuse and uncompact forms, which are in marked contrast to those of eruptive diorites. Instead of defined crystals and compact grains, we have fringed masses, aggregates of needles, and minute, disseminated crystals, as the characteristic condition. It will be shown that the agencies which have been effectual in recrystallizing these rocks were gentle in their action; and this microscopic distinction is what might be expected as the result of a gentle metamorphism as compared with an igneous fusion. This difference may be noted on comparing the sections represented in Figs. 3 and 4 on Pl. 12, with the sections of eruptive diorites represented in Figs. 5 and 6 on Pl. 9. There are other differences which are less fundamental, but still general in New Hampshire. The hornblende of the eruptive diorites is deeply colored, appears black in the rock, is strongly dichroic in sections, and gives no brilliant colors between crossed Nicol prisms. The hornblende of our greenstones is not so deeply colored; it is light green in thin sections, is not so dichroic, and gives brilliant polarization colors. In other words, the hornblende of the eruptive rocks is the so-called basaltic variety; and of the metamorphic rocks it is the common variety. The analysis of the hornblende of the green diorites has been given on page 66. This analysis was made on quite pure material, and shows that it is the aluminous variety called pargasite, a fact which has been often enough shown before in studies on like rocks. I would like to call attention in this connection to the analyses of hornblende and pyroxene, which were made with the idea of indicating why hornblendic rocks are so predominant among the stratified schists in New Hampshire (see p. 65). Among these analyses one will be found which indicates the composition of the hornblende from the eruptive diorite at Dixville notch. A comparison of this with the pargasite will give the essential chemical differences between the hornblende of our two kinds of diorite.

Some of the metamorphic diorites are free from quartz, and some include quartz in their composition. On this basis, they are sub-divided into plagioclase diorites, which are compounds of plagioclase and hornblende, with certain accessories, and quartz diorites, which contain quartz in addition, but not in preponderating amount.

Plagioclase Diorite. These rocks are light green in color, and are granular and massive. Sometimes they form thick beds, and sometimes only thin strata among other schistose rocks. They are much less numerous than the quartzose varieties, and in composition they are very complex. In a specimen from Pittsburg the hornblende is in such large grains that it can be macroscopically recognized. Thin sections show that this hornblende is of a light green kind, in which the dichroism and absorption are marked. As usual, the grains of hornblende are fibrous in their nature, and are all fringed out on the edges. In some grains which are cut at right angles to the prism, the characteristic cleavage is very plain; but other grains appear to be made of a mere mass of needles, and the fibrous structure prevents any such character as cleavage from being recognized. I have represented a section of this rock in Fig. 3 on Pl. 12, but have introduced only the most general features that characterize it, and have left out the rare or accidental constituents. The mass of the white portion of the rock is a triclinic feldspar, which is characterized by the wide bandings that polarized light develops. These bands are often indistinct, on account of the decomposition to which the feldspar is very subject. As a result of this decomposition, epidote is a never-failing constituent of the rock. This epidote is light yellow, somewhat dichroic, and gives most brilliant colors in polarized light. By its abundance, and by the presence of multitudes of little hornblende crystals, and of other small minerals, the bands of color in the feldspar are sometimes nearly obscured. Peculiar forms resulting from the decomposition of titanic iron are also characteristic of this rock. Gray masses filled with remnants of the black iron oxide are scattered about, and in some cases the titanic iron has entirely disappeared, leaving only the gray material. This substance is usually traversed by lighter lines, which being determined by the cleavage or lamination of the original mineral, are regular in their directions, and therefore symmetrical forms are produced which, in some cases, are remarkably like fragments of organisms. One of these forms, which is represented in Fig. 5 on Pl. 2, has been already spoken of. Titanic iron is a mineral which is not easily decomposed; but its decay is a characteristic feature of the diorites, and has resulted from a reaction which has taken place between the lime, separated from the feldspar, and the titanic acid (see p. 40). The iron has perhaps entered into the composition of the chlorite, which is sparingly present. Some sections of this rock contain grains of augite. This augite is of a light red color, but I have not introduced it into the figure, for although occasionally present in quite large grains, it is in no sense characteristic of the rock, and is usually absent.

A specimen from Littleton is much more compact, and is so fine in texture as to appear like a homogeneous mass. In thin sections it is, however, nearly the same as that last described, but is more decomposed, and hence contains more chlorite, epidote, and altered titanic iron. Biotite and calcite are also present.

These two specimens from Pittsburg and Littleton, both having a specific gravity of 2.96, were analyzed with the following results:

	Pittsburg.	Littleton.
Silica,	48.79	45.56
Alumina,	16.97	16.57
Iron sesquioxide,	1.69	.36
Iron protoxide,	8.97	9.40
Manganese protoxide,	.20	.20
Lime,	9.98	8.01
Magnesia,	6.98	10.34
Potash,	....	1.20
Soda,	3.30	2.55
Titanic acid,	1.10	1.20
Water,	2.65	3.93
Carbonic acid,	....	1.02
	100.63	100.34

On account of the complexity of this rock, it would be difficult to calculate what species of feldspar is present. As the percentage of silica in the rock is below that shown by the analysis of its hornblende, it certainly is quite basic. The chief value of these analyses is in showing the ultimate composition of the original deposits from which these rocks were made, and it is interesting to note that the analyses do not differ in any respect from those of certain basic eruptive rocks.

Quartz Diorite. By far the larger part of our green diorite is quartz diorite. In some specimens, quartz is present only in the most insignificant amount, but in others its quantity is increased till it greatly preponderates, and the dividing line between diorite and amphibolite is reached. As distinguished from the quartz-free diorites, these rocks appear to be more fresh and undecomposed; chlorite is not so common, and augite is entirely absent. Their color is darker, and the hornblendic character is more evident to the unaided eye. I have selected for illustration a quartz diorite from Lisbon. The rock is dark green in color, but is spotted with white spots, which can be in part recognized as feldspar by the cleavage. In a thin section, the hornblende appears in large fibrous masses, in bunches of radiating needles, and in minute separate crystals. This hornblende assumes the most brilliant colors in polarized light. Its appearance is represented in Fig. 4 on Pl. 12. This will make plain what I have said in reference to the condition of the hornblende in metamorphic diorites, as contrasted with the eruptive rocks.

The triclinic feldspar appears in quite large crystals, which mostly show wide bands in polarized light. What species it is, one cannot say. From the siliceous nature of the rock, it might be supposed to be oligoclase or albite, and this has commonly been assumed as the fact; but in this case the conclusion would scarcely be justified, for the region is one of low metamorphism; and under such circumstances, reasoning from the probable conditions of chemical stability is of doubtful weight. It is enough to call it plagioclase. The quartz fills up the interspaces, and sits in all the little corners. Grains of titanic iron and bits of biotite are present.

In a specimen of this diorite from Northumberland the feldspar is entirely altered into an aggregate in which epidote is prominent. Sphene is also quite abundant.

A specimen from Hanover (boulder) is typical of many others. It is fine in texture, but the development of larger feldspar crystals makes it porphyritic. In thin sections, the hornblende is entirely of a fibrous character; the feldspar is very impure, both as a result of decomposition and original inclusion of impurities. The quartz is tucked away in little corners. In this rock the titanic iron assumes the most fantastic forms, but it is mostly altered into the gray product which is characteristic of all these diorites. This subject, however, needs no further illustration. Epidote, chlorite, and sphene are present in small amount. Pyrite is abundant. Apatite, which is so prominent in the basic eruptive rocks, is here but rarely seen.

At Lancaster these rocks are abundant. Some are very dark in color when hornblende predominates; some are yellowish-green when feldspar, filled with epidote, predominates, and all those variations in composition are met with which might be expected as a result of the metamorphism of sedimentary beds.

AMPHIBOLITE.

Amphibolite is a granular massive or schistose rock, which is composed of amphibole with more or less quartz. Accessories, as usual, are present. We have the following varieties to describe:

Amphibolite (massive hornblende rock).
Hornblende Schist.
Actinolite Schist.

These rocks are very prominent among the greenstones. Their hornblende possesses the same crystalline character as that of the diorites last described. Their relation to the diorites is shown by the frequent presence of triclinic feldspar. Indeed, some of the rocks rich in plagioclase might be called quartz diorite if one chose to draw the line at a different point. This is not an unusual circumstance, for such gradations have been elsewhere observed. For example: among the so-called ophites of the Pyrenees there are amphibolites, which, by the gradual introduction of plagioclase, are stated to pass by insensible stages into typical diorites;—and so we have a familiar association of rocks here.

Amphibolite. This rock is a very nearly massive aggregate of hornblende crystals, or of hornblende and quartz. It occurs in the same localities as the quartz diorites. Lancaster and Littleton are favorable places for its observation. Specimens from these places show, in thin sections, much hornblende, and variable amounts of quartz, and plagioclase which is at times quite prominent, but is subordinate to the quartz in amount. Decomposing titanic iron, epidote, and sphene are present, and hence our amphibolites differ from the diorites only in the elimination of the feldspar. A specimen from Northumberland is entirely composed of hornblende, with the exception of some microscopic biotite and pyrites. The hornblende of all these rocks is of the green fibrous variety. Its crystals lie at all angles and in all planes, and in this it differs from the schists next to be described.

Hornblende Schist. This is a very prominent rock in the greenstone series. It is usually very dark in color, and is composed of deep green hornblende, the needles or crystals of which mostly lie in the plane of lamination of the rock, and considerable quartz is interspersed with it. This quartz is often very conspicuous in thin sections when it is scarcely recognizable in the mass. The hornblende, which usually is in long, irregular, and fibrous crystals without definite form, does sometimes, in the more quartzose varieties, assume the outlines natural to its crystals. Fig. 2 on Pl. 7 is drawn from a section of this schist from Cornish. The hornblende is trichroic (see p. 61), and its crystals, though possessing in some cases well defined prismatic planes, are always entirely lacking in terminal planes. This schist contains, in addition, microscopic magnetite, garnet, biotite, plagioclase, and epidote. The last four ingredients are not represented in the figure. Other specimens, in addition, contain orthoclase, titanic iron, and pyrite. A variety from Stewartstown is remarkable for the large amount of epidote that it contains, which, though only microscopically recognizable, impresses its color on the rock. A variety from Hanover is celebrated for its garnet crystals, which are very perfect little dodecahedrons of a deep red color. Sprinkled so abundantly through the almost black hornblende, they make a very pretty rock. Though apparently so clear and pure, these garnets in reality are quite largely composed of quartz, as is shown by Fig. 5 on Pl. 4, which is drawn from a section that passes through one of them. This is a fair representation of the garnets as they ordinarily appear in sections of the greenstones. They are like crystals that form in a plastic mud, rather than in a more mobile or homogeneous mass. Many of these schists contain numerous biotite crystals, the bright cleavage faces of which are all parallel to the plane of stratification, and they dot the dark rock with black shining spots. Such a specimen comes from Berlin station. The crystals of biotite are sometimes very much lengthened in one direction, and then the rock is streaked with bright black lines. A rock of this kind occurs at Dummer. Some specimens are almost all hornblende, and others are half quartz. Some specimens are almost massive, and others are very schistose. Some are almost black, others are light green, and when thin sections are cut from this latter class they are found to contain much epidote and considerable chlorite, by which the lightness of the color is produced. The hornblende may vary in color and give analogous results. Under the microscope all these varieties present the same fibrous structure, and no peculiarities that have not been mentioned. Hornblende schist is not confined to the valley of the Connecticut, but all the varieties that occur elsewhere are there to be observed.

Actinolite Schist. This rock contains the light-colored fibrous actinolite in place of the dark hornblende. It is therefore very light green; and in thin sections the hornblende is almost colorless. In an actinolite schist from Pittsburg, quartz, and some plagioclase, biotite, and chlorite, are included between the needles of actinolite; but the numerous crystals and needles of rutile that it contains form a striking feature. This mineral is present both in the quartz and in the actinolite, but its condition is different in the two minerals. In the quartz, it exists in extremely fine, long black needles, which run in all directions, sometimes in straight lines and sometimes in curves. In the actinolite, on the contrary, it exists in much larger, deep yellow crystals, which are in part very well crystallized, and which often show the peculiar geniculations to which the species is subjected by its mode of twinning. A thin section of this rock is represented in Fig. 1 on Pl. 4.

CHLORITE SCHIST.

This rock is related to the argillitic mica schist that has been described, and is often associated with it. Intermediate varieties between the two rocks are abundant; and they differ only by the substitution of chlorite for mica. It is therefore composed of quartz, or quartz and feldspar, mixed with chlorite. It is light green in its color, and does not possess the soft feel and glistening lustre that characterize the micaceous schists. It is a common rock; but though the proportion of ingredients may vary widely, and accessories may be present, the rock always has the same color and appearance. It is always fine in texture, and none of the ingredients are macroscopically recognizable. It is easily distinguished from the hornblende rocks, because, in all the amphibolites, fibrous or radiated crystals, which prove on examination to be hornblende, are always macroscopically recognizable.

A variety of this rock from Pittsburg, when microscopically examined, is characterized by the presence of much plagioclase in minute grains. Chlorite, orthoclase, quartz, and epidote make the rest of the rock. The chlorite is distinctly foliated, and assumes brilliant colors in polarized light. Another specimen from Connecticut lake in the same town contains more quartz, less plagioclase, and much pyrites, and is otherwise the same.

A variety from Diamond pond in Dixville consists mainly of chlorite and quartz, and contains hornblende, titanic iron, epidote, and calcite, as accessories. Calcareous chlorite schists are not uncommon; and whenever the calcite is in grains of sufficient size to show any properties, the polysynthetic structure of the grains, which has been shown to be caused by pressure, is very conspicuous (see p. 128).

A variety from Lebanon is dotted with black shining spots, which are due to magnetite that has made an effort to crystallize. Very large and perfect crystals of magnetite are found in chlorite schist at many localities, though not, as I am aware of, in our state. In varieties from Lisbon and Raymond the chlorite is recognizable as a green, foliated mineral. Various sulphurets are liable to occur in chlorite schists. For example: about the Dalton copper mine the schists are filled with sulphurets of copper.

Remarks concerning the Greenstones. I think it has been already plainly shown that the prevalent rocks in the valley of the Connecticut possess a type that separates them quite sharply from those that occupy the interior of the state. The interior is characterized by rocks which, whether massive or schistose, are highly crystalline; but the valley region is just as distinctly characterized by fine-grained argillitic rocks and green schists, and I am going on to describe other schists and slates that are widely spread over this region, which have only attained a half crystalline condition. Now, though quite coarse-grained crystalline rocks occur in this valley, still, when a rock which has the same ultimate composition as a granite is found, it is usually an argillitic schist or clay slate. The most interesting exceptions are the coarse-grained and massive diorites, which, on account of their condition and composition, were long held, and are still held by some, to be eruptive rocks. Though their relationships to the surrounding stratified deposits have been clearly pointed out by the geologists already quoted, I would point to the following confirmatory circumstances, which are drawn from the lithological study of them, and which also explain in some degree the reason for their massive condition.

In the first volume of the report of this survey there is a series of maps prepared by Prof. Hitchcock, which indicates that the strata that form the interior of the state were first accumulated and elevated, and the valley of the Connecticut was left as a long open sea, in which the sediments which now form these schists and greenstones were deposited. Therefore they were not subjected to the powerful influences, the operation of which in the interior is shown by the highly crystalline rocks which are much folded, elevated into mountains, and very frequently cut by eruptive masses. In the valley region eruptive rocks are rare, and in marked contrast we see what can be accomplished by gentle metamorphic action on stratified sediments; and the study of lithological specimens indicates that the following results have been produced by it.

In the case of pure clays, but little more was accomplished than the consolidation and production of very minute and formless crystals. The same influences seem, however, to have been quite sufficient to develop hornblende crystals of considerable size, though the form of these crystals is imperfect. The amphibolites can therefore always be recognized macroscopically. Again: when triclinic feldspars appear in these rocks, they, too, commonly form crystals of considerable size, which are often well developed in an otherwise very fine mixture of minerals. If, then, the composition of the sediments were such as might be entirely recrystallized into triclinic feldspar and hornblende, we might expect a massive and comparatively coarse-grained rock as the result of the metamorphism; and as less basic strata are little modified by the same metamorphism, we might expect that such massive crystalline diorites would appear between layers of less crystalline slates and schists. We might expect, also, if the composition were such as to convert the larger part into hornblende and triclinic feldspar, these predominant minerals would determine the structure, and the excess of quartz might be included between the crystals of a massive quartz diorite. It is well known that in still waters fine sediments are deposited, and that these may possess a very basic or a very siliceous character, as has been shown by the study of the composition of the materials on the bottoms of bays and harbors and on the ocean's bed. Such a variety of sediments, when subjected to the influences that have operated on the materials of the White Mountains, would all be changed into highly crystalline rocks; but under these more gentle influences, only those rocks would reach a highly crystalline state which are composed of minerals most easily developed. The gentle nature of the metamorphism in these regions is indicated by the stratified, almost fragmental character of rocks of the same nature as granite, and the very common association of basic and acidic elements, which under the influence of greater heat or pressure would react on one another.

Hence, as sediments of almost all varieties, from pure carbonate of lime on the one hand to pure sand on the other, are found at the bottom of still waters, it is natural that among them there will be some deposits of the composition of diorites; and as diorites are easily made, then they may be expected at times among stratified deposits. The assumption, that diorites are all eruptive because the larger part of them are so, is a position to which exception can well be taken.

Again: by some, rocks of this class, when plainly stratified, have been claimed to be the consolidated tuff or débris of basic eruptive rocks. Of course this may be true in some cases, yet I think that no such direct origin is to be attributed to these rocks which are so widely distributed in localities all over this part of America. The question of chief interest is, What is the difference in microscopic structure, or other characters, between metamorphic and eruptive diorites? This question, so far as New Hampshire rocks are concerned, I have attempted to answer.

In view of the fact that rocks of this class have been shown to be widely distributed over the earth, forming the strata of the Huronian period, Dr. Hunt suggests it as desirable that those who investigate these rocks should study them with the view of finding whether certain characters cannot be found to exist in them, which are so general as to serve as an equivalent to a determination of their age. I wish to recognize fully the value of such considerations, and the interest attached to the problem of the kind of changes that may have taken place in sediments at different periods of the earth's history; but it will be noticed that the result of these studies has been, to lead to the conclusion that the nature of these rocks is simply dependent on the geographical location of the Connecticut valley with reference to the surrounding land, which determined the nature and condition of the original sediments. The composition being thus fixed, their present condition is dependent on their location with reference to the action of the forces producing metamorphism. As sediments of the same nature are accumulating to-day, it therefore appears plain that location with reference to surroundings might produce the same kind of rocks in any era which is characterized by crystalline schists; and therefore the problem of the determination of age is thrown entirely upon geologists in the field, for in this case lithology can point to no reason for the maintenance of uniform conditions in different localities. To me, Dr. Hunt's studies on the condition of sediments, as regards their permeability by water, is a more important consideration in the study of these rocks, for the fineness and argillitic nature of many of the strata are indications of impermeable sediments which would protect the soluble materials in included basic layers, and preserve in them the conditions that are necessary for the formation of the basic rocks which are now found among the strata.

CLAY SLATE (ARGILLITE).

Between argillitic mica schist and clay slate or argillite, no dividing line exists. Typical clay slate is a fragmental rock, which consists of the consolidated, nearly dehydrated material of clay beds; but the application of microscopic study to these slates has indicated that they do contain certain crystallized elements, which though very minute show that something more than the mere cementation of the angular grains that constitute clay has taken place; and the rocks are therefore classified as half fragmental. The amount of this crystalline product varies; and when it becomes prominent, and the fragmental character is no longer apparent, the rock becomes argillitic mica schist. The laminated structure has been induced in slates by pressure, and it may coincide with the bedding, or it may not, according to the direction in which the pressure was applied. This lamination is usually more regular, and is confined more strictly to a level plane, than is that of the other schists, and the ready separability of the laminæ produces what is termed the slaty cleavage. Since this cleavage is always in a plane at right angles to the pressure, the direction of the pressure which produced it may be assumed from its plane. Therefore those argillaceous rocks in which the recrystallized elements are not so prominent as to impress their character upon the rock, and which possess a slaty cleavage, are considered as clay slates.

The so-called roofing slates are typical of this class, and of them a specimen from Littleton has been selected and examined. It is nearly black; and only with difficulty can a section be made sufficiently thin to allow of satisfactory study. It is then seen to consist of a mixture of quartz and feldspar in fragments as fine as dust. The mixture is rendered black by the inclusion of a considerable quantity of some amorphous coaly matters; but all through this formless mass of materials little needles or fibres are seen, which are brightly colored in polarized light, and which constitute the crystalline portion of the rock. As to the nature of these minute crystallites that are always found in clay slates, no certain conclusion has been reached. Mr. Zirkel thinks that they may be hornblende, and says that every careful investigation of their mode of arrangement points to the fact that they were formed previously to the consolidation of the rock. As no softening of the rock by the processes that have operated in the crystallization of the schists is evinced in the structure of the slates, this must be true; but that the needles in our slates are of hornblende, I doubt, for where good opportunity for examination is found, their optical behavior is not that of inclined crystals, but they act much more like the fibres of mica, which in the argillitic schists become so much more prominent and easy to recognize.

In New Hampshire, the larger part of the rocks called clay slates are on the boundary between clay slate and argillitic mica schist, for the crystalline ingredients are quite abundant. They possess in a slight degree a micaceous lustre, and in them a variety of minerals are developed. For example: the clay slate from Hanover is all filled with minute crystals of staurolite and garnet, and such rocks are very common in the valley region. These minerals seem to have the capacity of developing under influences that are insufficient to crystallize the other ingredients, but when cut, their sections show them to be extremely impure. The staurolites, under these circumstances, have not assumed their usual twinned forms, but are simple crystals. Some of them are represented in Fig. 4 on Pl. 8.

A clay slate from Pittsburg is all covered with round spots suggestive of garnet. When a section of this slate is examined, these spots are seen to be caused by a deposit of hydrous iron oxide, which probably has resulted from the decomposition of minute grains of iron pyrites, which is not uncommon in these rocks.

The Dixville notch is a good place to note the character of the scenery among slaty rocks, as compared with that of granitic regions. Although there may be exceptions enough, the granitic hills are rounded. In the White Mountain notch, the view, though grand in its immensity, is made by gently curving lines of beauty. The Dixville notch, on the other hand, is rude, jagged, picturesque; for while granite wears with difficulty and loses its corners first, the slaty rocks, when on edge as in the Dixville notch, cleave and break down, leaving sharp points and jutting edges. The difference in the character of White Mountain and Alpine scenery is here illustrated.

QUARTZ SCHIST.

Quartz schist has already been referred to in the descriptions of the crystalline schists; but some of these rocks bear a resemblance to sandstones or conglomerates, and though in part composed of crystalline materials, they are also in part composed of angular grains or fragments, and thus they form another connecting link between fragmental and crystalline rocks. The half fragmental character, though often visible in the mass, is much more satisfactorily seen in thin sections; and in Fig.

5 on Pl. 12, a section of such a quartz schist is represented. Several large fragments of quartz and one of plagioclase are seen, but they are all surrounded by a perfectly compact mass of quartz, which without polarized light shows no granular structure, or any divisional lines which might indicate the cementation of grains, and between crossed Nicols it appears as usual like a complex aggregate. The large quartz grains have been somewhat affected, for their edges are sometimes indistinctly blended with the mass; and their interior structure often appears complex in polarized light, as if, by the influences which must have acted upon them, they had been altered from homogeneous grains into aggregates of granules. The mass of the rock around these grains is clearer than elsewhere, and the impurities that are contained in the rock bend about these fragments in something of the way that the little crystals in basalts are arranged around the large ones.

With these half fragmental rocks our studies come to an end, for the characteristic rocks of New Hampshire are crystalline. In this connection, the great granite breccias at the Notch and at Franconia should be called to mind as most wonderful examples of half fragmental rocks, in which, however, the fragments are so immense that they and the ground mass in which they are imbedded have both been considered under granite. The slates of Mt. Pequawket, which are all cemented together by a paste of quartz porphyry, should also be recalled; but this rock, also, has been made by such an exceptional method, that it is much more instructive to consider it among the quartz porphyries.

FRAGMENTAL ROCKS.

Our consolidated rocks being therefore exclusively crystalline, it will be profitable to consider, for comparison, a really fragmental rock. The Connecticut red sandstone extends up the valley from the Sound, and reaches the border of our state, and should receive some attention. This rock is often quite hard and compact; and I have filled the last space on the last plate with a representation of a thin section of the finest variety of the celebrated and beautiful Portland building stone as it appears in polarized light. It will be noted, then, how marked is the contrast between a truly fragmental rock and all the rocks which have been considered or illustrated. In the thin section of the sandstone are seen fragments of quartz, apparently two kinds of plagioclase, orthoclase, decomposed hornblende, biotite, and magnetite. The grains of all are round or angular, and are packed together at hap-hazard, and the interspaces are empty or filled with dirt. In no case do the constituent fragments modify their forms to fill the spaces. All the grains are coated with red oxide of iron, which cements them together and determines the color of the rock. Further mineral constituents are also found in this same section, which are not represented in the figure;—for example: bits of microcline, decomposed muscovite, scales of hematite, and chlorite can be identified, and calcite, in one place, forms a part of the cementing material.

In New Hampshire, all former fragmental deposits have been so pressed, softened, and recrystallized, that all marks of a loose open-work of cemented grains have been obliterated, and all the material has been brought into its most compact condition. The process by which this has been effected has been one of the prominent subjects that has been studied and illustrated in this work.

All those loose deposits which constitute the glacial drift, terraces, gravel, sand, clay, soil, etc., are classified as fragmental rocks. These materials are, however, so fully discussed under the head of Surface Geology, by Prof. Hitchcock and Mr. Upham, that anything more than a reference to their chapters is unnecessary.

MINERALS AS ROCKS.

In order to render repetition unnecessary, anything that I had to say on simple rocks was included in the chapter on Mineralogy, in which some remarks will be found concerning limestone, soapstone, and talc schist, beds of various ores, the quartzite that is so abundant in veins, the beds of infusorial earths, and whatever other minerals in New Hampshire are aggregated in such amounts as to form geological features. The subject may therefore be dismissed at this point, for, though necessarily incomplete, all that has been accomplished has been stated.

* * * * * * * * *

Conclusion. In a retrospect of the course that has been followed in this work, it will be noticed that a large number and a large variety of rocks have been classified under a small number of heads. The effort has been made to show that by the introduction of the microscopic method, many of the difficulties which have complicated the study of our crystalline rocks disappear, while its interest and beauty are increased; for not only are the compositions and present conditions of the rocks easily determined, but the thin sections contain a chapter of their histories and a record of the changes through which they have passed. I wish to recall again the scope of the work. It has not aimed to be a description of the rocks of the state, but has rather aimed to be a study of specimens which have been carefully selected, with the hope that all our important rocks would be represented among them. As, now, each new section that has been prepared has almost always presented some new features, I am certain that those people in the state who may be encouraged to pursue these studies will find in the specimens they examine, even from the very ground that I have traversed, as many other things of interest as have been here developed. New Hampshire is grand in her rocks, and it has been an object of this treatise to show that the beauty of them is not confined to those modes of arrangement which cause our state to be filled with the most picturesque scenery that this part of the country has to offer, but that our rocks, in their minutest structures, are beautiful, and possess features which, though small, are of remarkable interest and of geological significance.

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Arrangement by Formations.

For the convenience of those who wish to study the rocks in their stratigraphical relations, Prof. Hitchcock adds the following numbers, to correspond with the classification of the formations in Volume II, beginning with the lowest one:

Pains have been taken to have all the specimens exactly alike, so that those who obtain duplicate collections, by purchase or otherwise, may be sure that Mr. Hawes's accurate descriptions in the chapter on Lithology are applicable to their set. A. A. Julien, of the School of Mines at Columbia college, New York, has for sale, prepared at our request, thirty microscopic sections cut from the following numbers: 1, 3, 6, 8, 10–12, 14, 16, 19–21, 23, 26, 29, 32, 44, 46, 49, 57, 62, 76, 79, 83, 128, 94, 96–98, 107, 126, 139, 164, 178, 179, 212, 217, 225, 240. Many of them have been figured in our plates, and are further explained in a descriptive commentary accompanying the slides and specimens purchased.

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Bethlehem Gneiss. Nos. 102, 103, 111, 112, 113, 119, 124, 126, 133, 196, 244, 218, 220.

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Helderberg. Nos. 152, 176, 205, 209, 245–247.

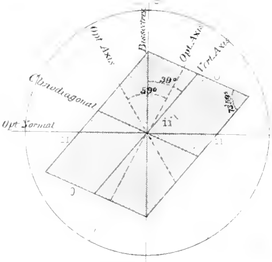
To Conway granite are referred Nos. 62–65, 67, 81, 82, 86;—cut by Nos. 4, 5, 25.

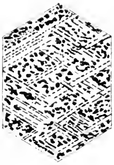
Albany Granite. Nos. 39, 79, 86, 87, 88.

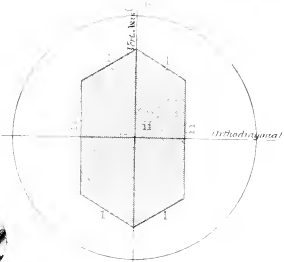
Chocorua Granite. Nos. 76–78, 80, 90.

Exeter Sienite. No. 71; other sienites, Nos. 95, 96, 85, 97.

Pequawket Breccia. Nos. 40–44. Granite cutting Coös group, No. 57.







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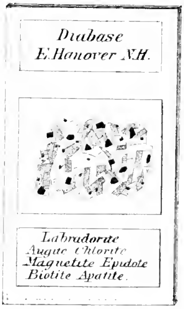
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E. Hanover N.H.

Labradorite
Augite Chlorite
Magnetite Epidote
Biotite Apatite.

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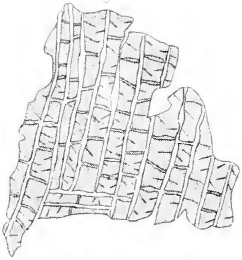

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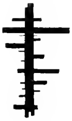

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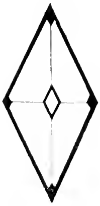

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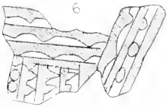

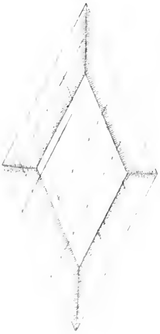

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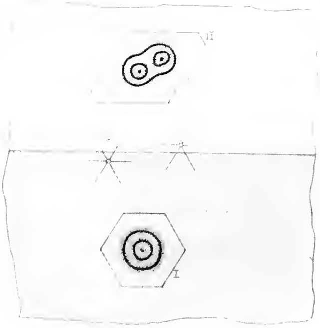

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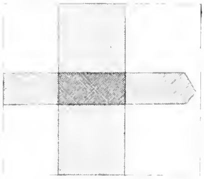

[illegible] lith. New Haven.

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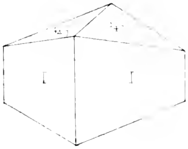

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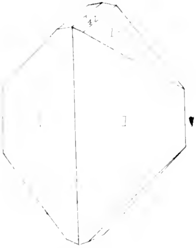

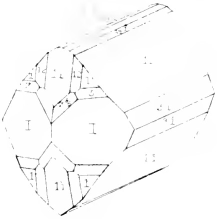

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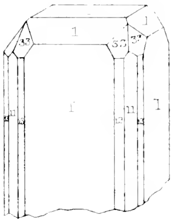

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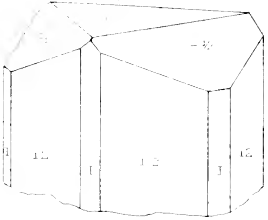

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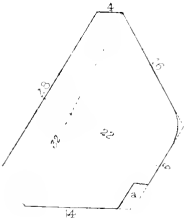

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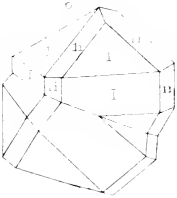

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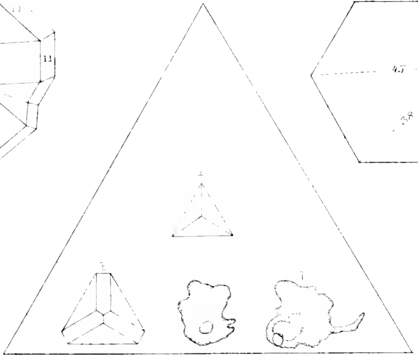

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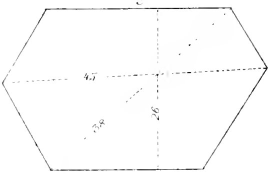

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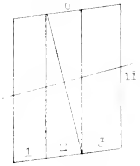

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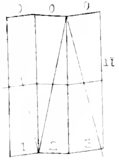

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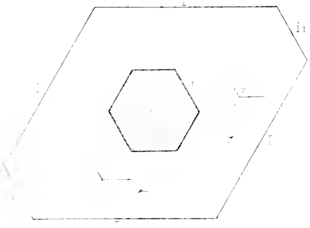

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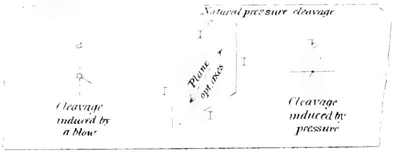

E. Crisand, lith. New Haven

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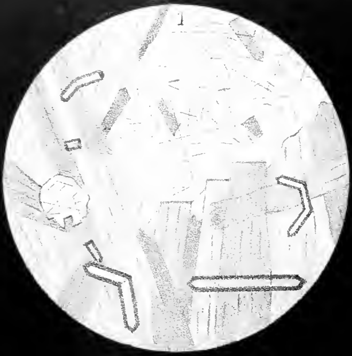

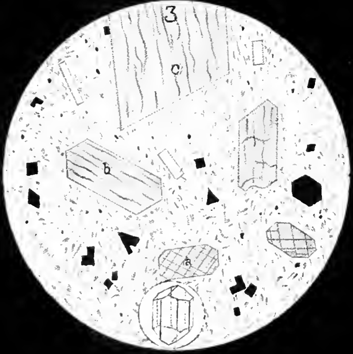

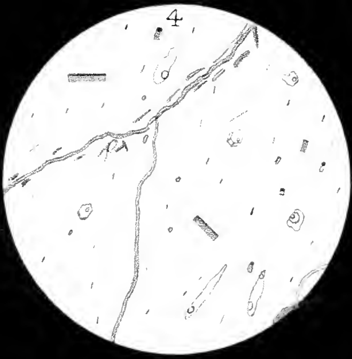

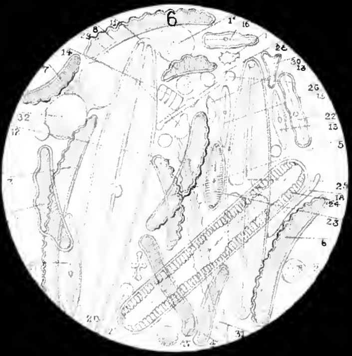

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E Crisand, lith New Haven

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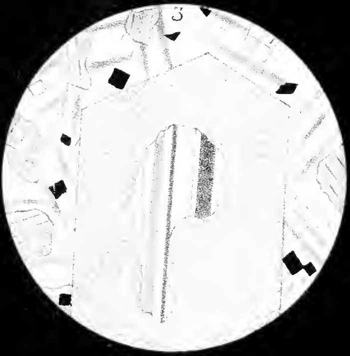

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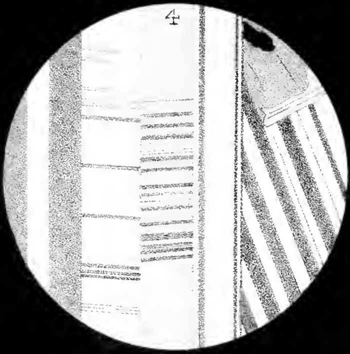

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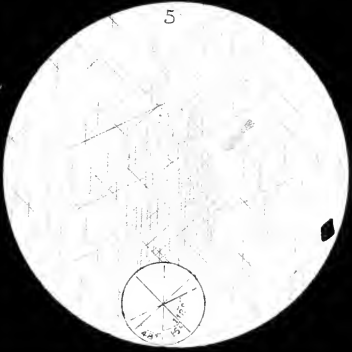

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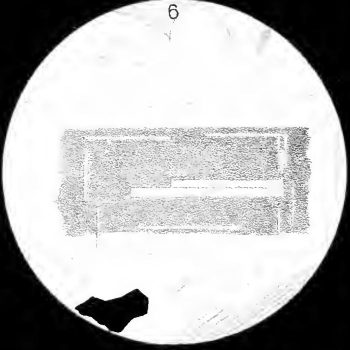

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G.W. Hawes del.

E. Crisand lith. New Haven

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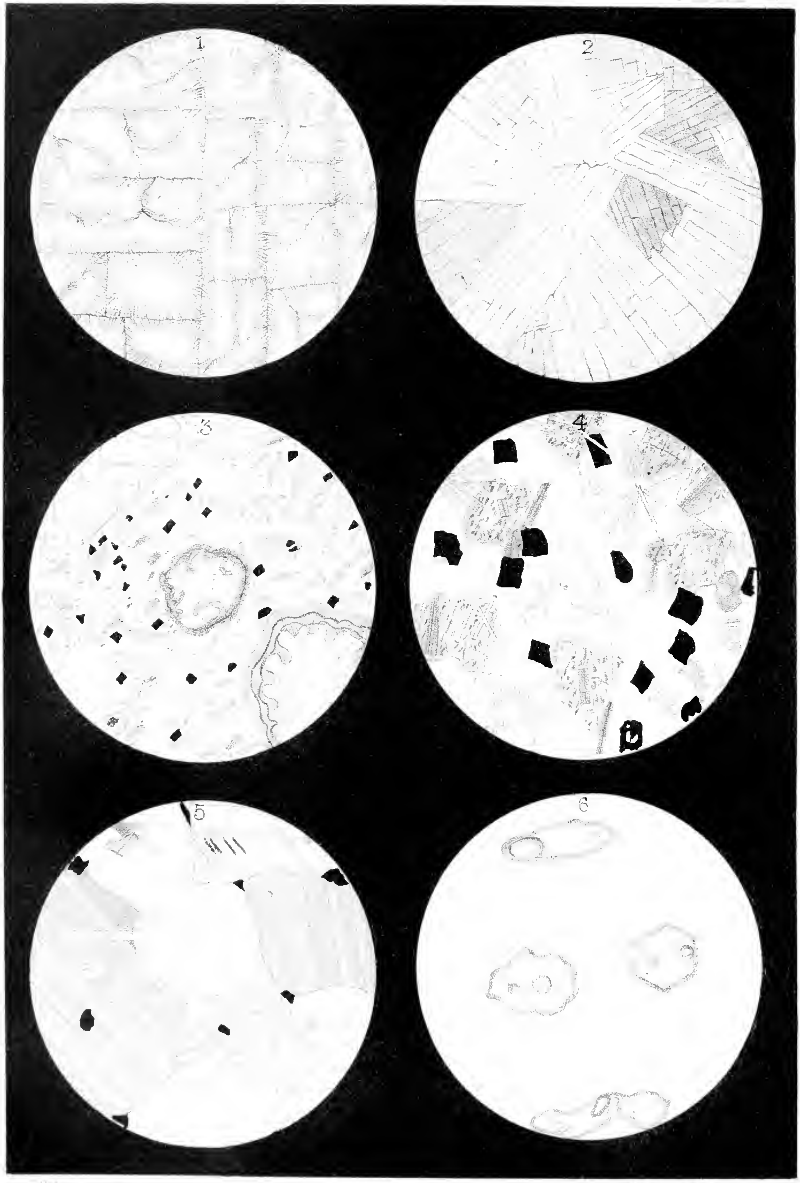

E. Crisand lith. New Haven

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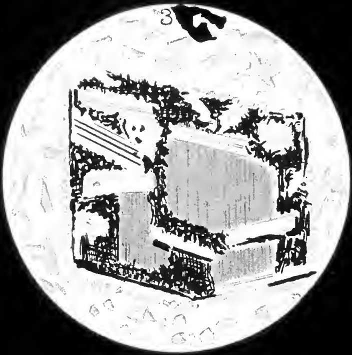

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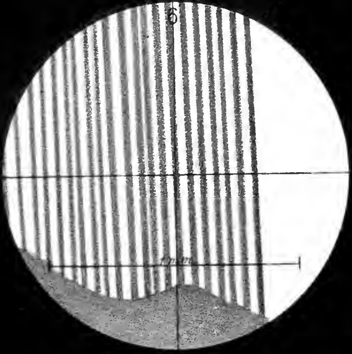

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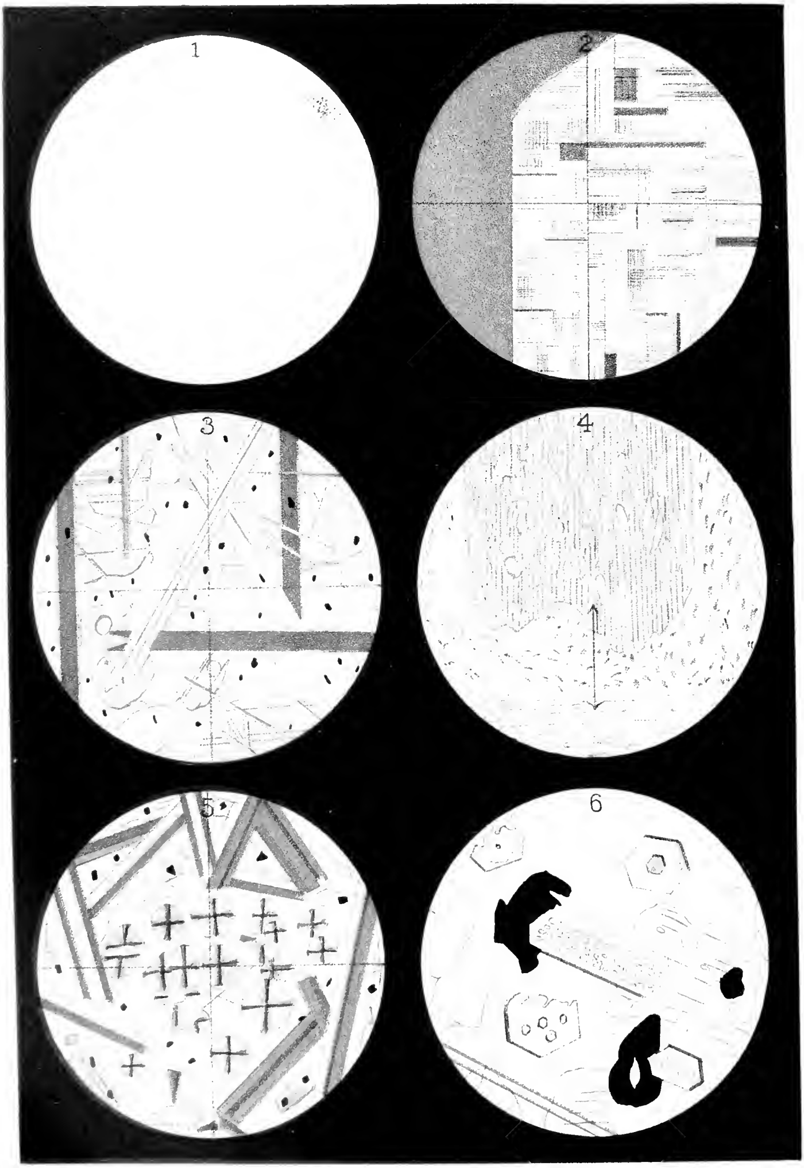

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E. Crisand, lith. New Haven


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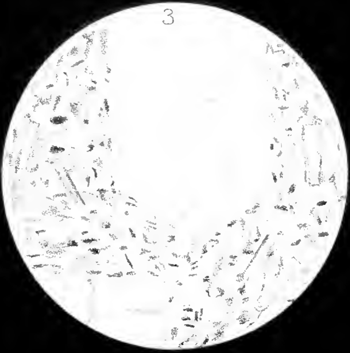
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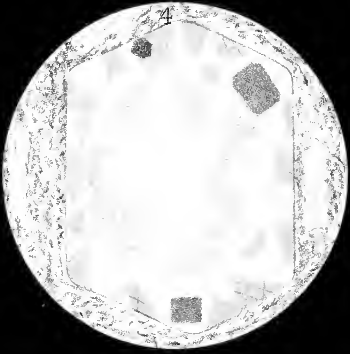
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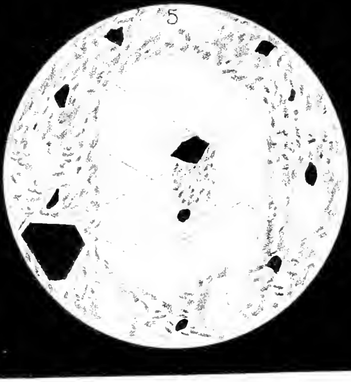
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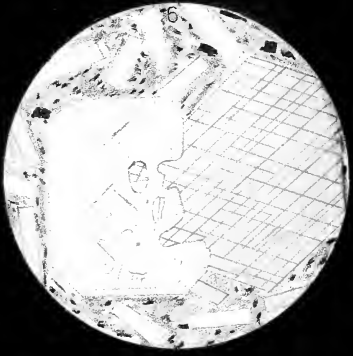
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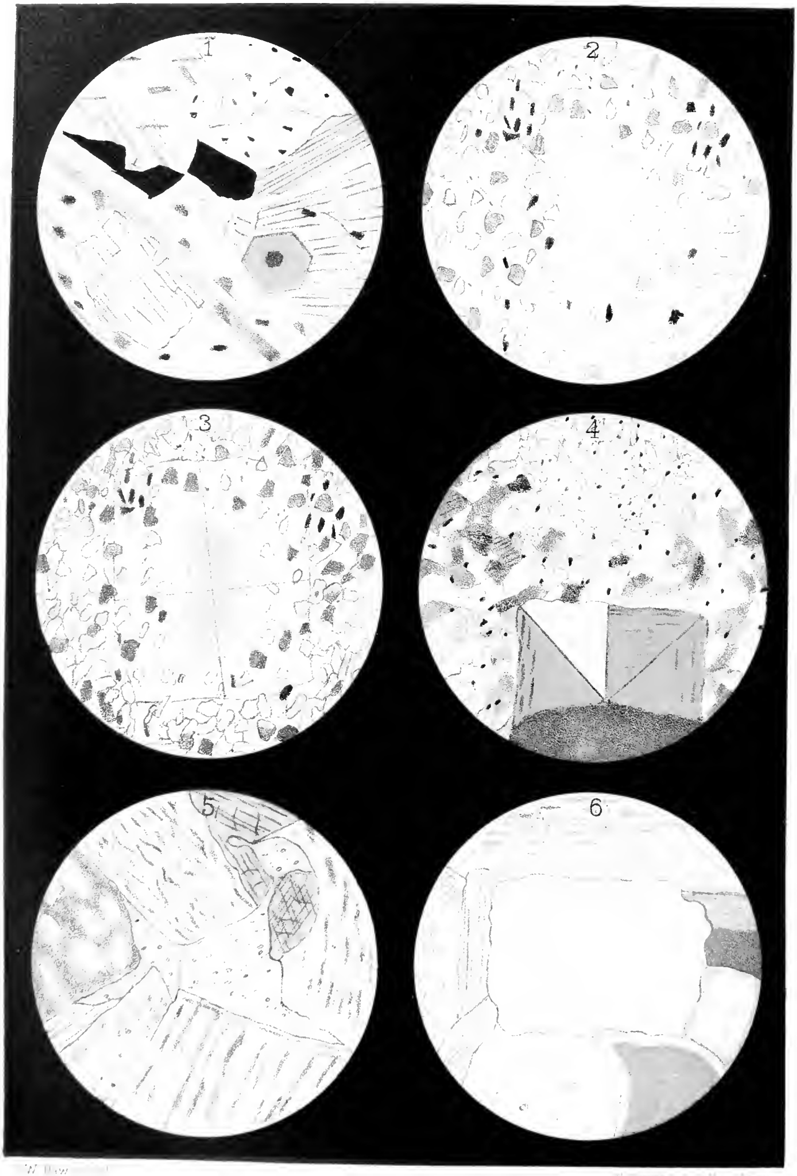

W. Dew [illegible]

E. Crisand, lith. New Haven

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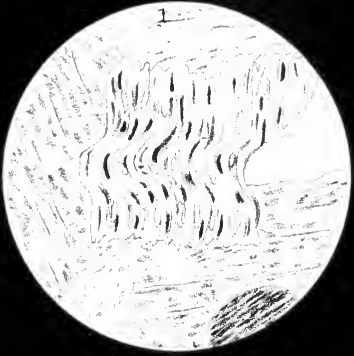

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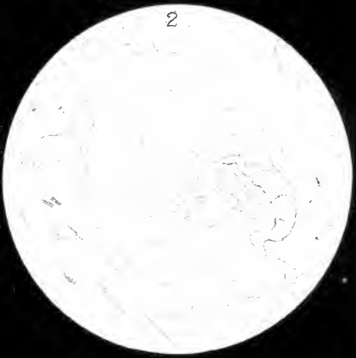

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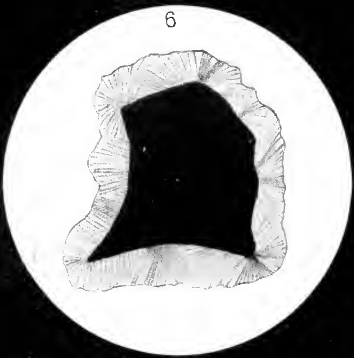


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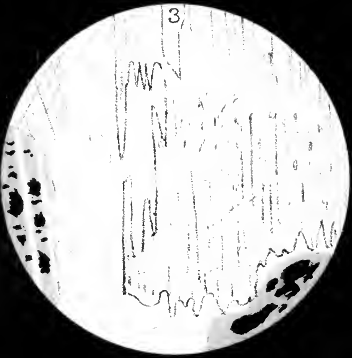
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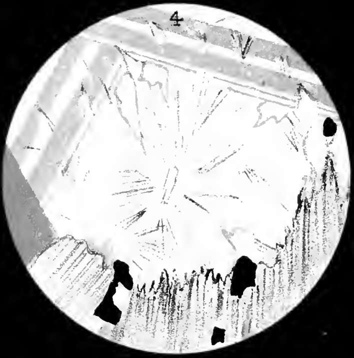
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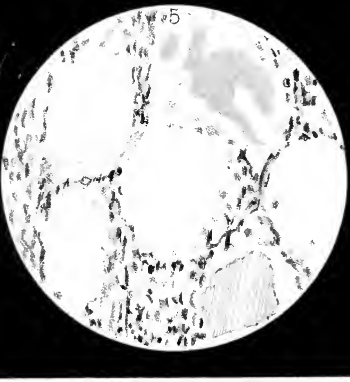
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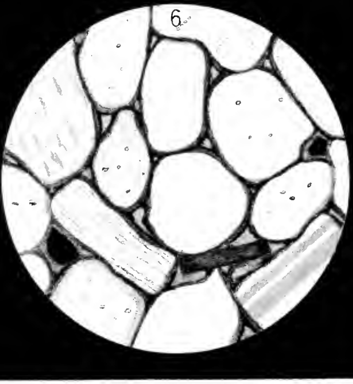
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E Crisand, lith New Haven.

PART V.

ECONOMIC GEOLOGY.

CHAPTER I.

METALS AND THEIR ORES.

ECONOMIC geology is an account of rocks with reference to their pecuniary value, or immediate application to the wants of society. A full treatise would include a description of the methods of mining, quarrying, and metallurgy; chemical processes for the manufacture of various salts; account of the manufacture of quicklime, glass, and earthenware; the discussion of the nature and origin of metalliferous deposits; the uses of peat in agriculture, etc. Our work will be mainly the description of the localities, modes of occurrence, and quantity of materials valuable for economic purposes. Very few of the industries involved in the manufacture of mineral materials have become thoroughly established in New Hampshire, so that our contributions to the perfection of the processes employed cannot be extensive. Allusion will be made from time to time to methods of manufacture or processes of reduction, so far as seems desirable. For convenience, this part will be divided into three chapters,—first, that relating to the occurrence and extraction of the metals; second, facts about the supplies of mineral materials used for building and the manufacture of useful articles; third, an account of deposits serviceable to the interests of agriculture. A part of this topic has been already discussed in the chapter upon Agricultural Geology in Volume I.

The following metals occur in considerable abundance in the state (insomuch that the question will be raised with each, whether its ores can be mined advantageously): Gold, silver, copper, iron, lead, zinc, tin, bismuth, manganese, arsenic, and molybdenum.

GOLD.

Dr. Jackson discovered minute quantities of gold in the magnetic pyrites of Canaan and Enfield. He made very extensive examinations of several lots of the ore, and thoroughly satisfied himself that the metal existed in too small amount to be of any practical value.

I have had specimens sent me from a great many towns in the state, believed to contain gold, and find most of them of no value. Those who are inexperienced mistake yellow pyrites and mica for gold. In other cases, as quartz is known to carry this metal in auriferous countries, people are convinced that, if a vein of this substance is found in their neighborhood, it must be rich in gold. In Volume II we have described enormous beds or veins of this rock, some of them traceable for a hundred miles. These have been opened at several places, but have nowhere been found profitable, if, indeed, the presence of gold in small amount is not a delusion. The wishes of the proprietors, coupled with duplicity on the part of prospectors or speculators, may often lead to false reports of the presence of gold. I have seen nothing to convince me that gold exists in the following large beds or veins: The Hooksett and Manchester ranges of quartz, seen between Royalton, Mass., and Denmark, Me.; the beds in the Rockingham mica schist in Londonderry, Raymond, Northwood; the smaller patches in Concord, Holderness, Sandwich, Warner; those on the west side of the state, in Richmond, Keene, Surry, Acworth, Alstead, Croydon, Newport, Grafton, etc. Add to these the beds of quartz found in the Bethlehem, Huronian, and Coös groups.

I have notes of operations upon some of these beds. In Sandwich, some openings were made in 1877, in the "White ledge," one mile north-west of Sandwich centre, with the high-sounding name of "Diamond Ledge Gold Mine." No pure gold is visible. The operators claim an average yield of $49 to the ton.

In Ossipee, a quartz band from four to eight rods wide occurs on the south side of Pocket hill, near the house of Obed Sanders. The quartz is unusually crystalline and open, traversed by numerous veins of the same material, and also by granite. No metals or ores are seen in it.

The "silver mine" in the same town, on the land of Jonathan D. Sias, presents similar lithological features and dimensions. The metalliferous part is on the south-east wall of the quartz, separated by a width of eight inches of fuller's-earth from a trap dyke. A shaft has been sunk 36 feet. The adjoining rock is granitic gneiss. The ore is scantily disseminated through a width of four to seven feet, sometimes pinching out entirely. It consists of galena, magnetite with blue stains, copper and iron pyrites, and zinc blende. This opening was made in 1876.

In the north part of Wakefield, on the land of Ira Hammond and S. B. Ames, is a similar band of white quartz with scanty veins of galena, blende, iron and copper pyrites. Mined in 1876, and two shafts sunk to the depth of 10 and 17 feet.

In the north-west part of Strafford there is another opening in one of these beds, much talked of by the prospectors. I have seen the beds, but not the openings. The quartz is of remarkable extent and purity. I should not expect any of these "mines" to prove profitable.

The following is the report of Mr. Huntington upon the prospect of finding gold in Pittsburg, made in 1871. There is reason to believe that explorations for gold in this town may be successful:

Alluvial Gold of Indian Stream.

In that part of Quebec Province that lies between the St. Lawrence, Maine, New Hampshire, and Vermont, the existence of gold in the alluvium has been known for many years. It is estimated that the area over which it extends comprises more than ten thousand square miles. The gravel containing gold rests generally upon metamorphic schists, some of which are associated with diorites and serpentines. Mr. A. Michel compares the gold deposits of Lower Canada with those of Siberia. In the Ural and Altai mountains the auriferous gravels are almost always found reposing on schistose rocks, very rarely granitic or sienitic, as along the Pacific in North and South America. He further says, that the gold in Quebec Province, "whether in large or small grains, is generally so smooth, so much rounded and worn by friction, that it appears to come from some distance." * * * "The condition of the gold shows it to have been, for the greater part, at least, detached, rounded, and ground by erosive action of currents of water."

In the town of Ditton, which borders on New Hampshire, and is immediately north of the head waters of Indian stream, alluvial gold washing, by sluicing, has been carried on for several years. The place where the most extensive operations are is on a branch of Salmon river, three and a half miles from the boundary. The stream at first runs a little south of east, but at the point where the principal excavations have been made it turns and runs northward. So that here there is a basin in which the drift has accumulated to the depth of fifteen or twenty feet. The upper portion, which consists of a very coarse gravel and has a thickness of three or four feet, was probably deposited by the stream, and it contains no gold. The portion below consists of both coarser and finer material, from clay to boulders eight or ten inches in diameter. Through this the gold is irregularly distributed, but it is most abundant near the bed rock, which here consists of an argillaceous schist, quite fissile, and containing numerous cavities filled with a yellowish powder. This mine has been worked during the summer months every year since 1866, and from ten to twenty men have been employed by the proprietor, J. H. Pope, M. P.

As gold was found immediately north of New Hampshire, and since the drift through which it was distributed came from the northward, the drift striæ where they were noticed being S. 28° E., there is every probability that gold will be found within our limits. But prospecting in a wilderness ten or fifteen miles from the habitations of men, where the places can be reached only on foot, requires a great amount of time and labor, and therefore our explorations have not been so thorough as they might have been under more favorable circumstances.

In my explorations on Indian Stream, I employed an Indian, Mr. A. A. Annance, who was formerly a student at Hanover, but who now prefers hunting moose and trapping sable to studying calculus and reading Greek. The points examined were on and near Indian Stream, about three and a half miles from the boundary. The stream here is quite rapid, and on either side the hills rise three and four hundred feet above its bed, while every few rods, either from the east or the west, it receives a tributary. The rocks here, as elsewhere on Indian Stream, consist of argillaceous schists. These are often so wrinkled and corrugated that it is difficult to determine the dip, while elsewhere, especially where the rock is of a coarser texture, the flexures and contortions are not seen. In every respect the rocks are similar to those of Ditton. Immediately on Indian Stream the gold is chiefly found in the fissures of the schist, which is here so fragile that it is easily broken up by picks. A quarter of a mile from the stream we found the characteristic drift of this section. It consists of a bluish clayey gravel, and contains boulders of schistose rocks, and it has a depth, where we excavated, of three and four feet. The gold seems to be distributed through the entire mass, though it is nowhere very abundant; yet, when the road that was several years ago projected from Connecticut lake to the boundary is constructed, this section will be well worthy of a thorough exploration, especially as the streams are rapid, and the descent of the bed-rock is sufficient to carry away the loosened sand if the hydraulic process is used. It has been estimated* that "earth which contains only the twenty-fifth part of a grain of gold, or about two mills' worth in a bushel, will pay about two dollars a day to a pipe."—J. H. H.

THE AMMONOOSUC GOLD FIELD.

Under the appellation of *Ammonoosuc Gold Field* is included the territory occupied by the auriferous slates and schists along Connecticut river, supposed to belong to the Huronian and Cambrian series, lying mostly in New Hampshire, but partly in Vermont, and possibly extending beyond the sources of the Connecticut into Maine and Canada. The southern limit is near Bellows Falls. Explorations of this field have been desultory and disconnected. The earliest discovery of free gold in any part of it, so far as can be ascertained, was made by Mr. Hanshet, in Plainfield, not later than 1854. This was but a short time before Moses Durkee, of Lebanon, washed gold out of alluvium in both Hanover and Lebanon. In the report upon the geology of Vermont,† published in 1861, Springfield, Vt., is given as a gold locality. It was obtained from the gravel, and but a short time previous, according to my note-book. No other proof of the presence of gold in the Connecticut valley is cited in that report, though its existence there is "strongly suspected."‡ In 1858, while acting as assistant on the Vermont survey, I measured a section, from Lake Champlain over Camel's Hump and Mt. Washington, which crossed this auriferous field in Littleton.§ The similarity of the ledges to those in the great talcose schist and gold-bearing formations just east of the Green Mountains led us to regard them of the same age

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* *Mining Statistics west of the Rocky Mountains*, 1870, p. 478.

† Page 683. ‡ Page 849. § Page 521.

and character. In my report on the geology of Maine, I have described the supposed continuation of this formation as probably auriferous; and it may be connected with the gold rocks upon the Upper Chaudiére and St. Francis rivers of Canada, described by Sir W. E. Logan, and said to have yielded masses of gold weighing 126 pennyweights.[*]

The first discovery of gold in Lyman was made by Prof. Henry Wurtz, of New York, in August, 1864. Prof. Wurtz visited the locality and the neighborhood in July and September, 1864, and in December, 1866. He sent several specimens of galena to Dr. John Torrey, to be assayed, requesting that they might be tested for gold as well as silver. The third sample submitted to Dr. Torrey, coming from the Orchard vein of the New Hampshire Silver Lead Company, contained silver at the rate of 56.95 ounces, and gold at the rate of 1.006 ounces to the ton of 2,000 pounds. Wurtz's reports were issued by the Silver Lead Company in 1864; and subsequently he prepared for the *American Journal of Mining*[†] a full account of his connection with the discovery, and suggested very appropriately that the whole auriferous district be called the Ammonoosuc Gold Field, as it is drained by the Ammonoosuc river and its tributaries. He remarks of the Lyman district, that the "history of this gold field presents, probably for the first time, the peculiarities of a first discovery in the *solid rock*, and not, as usual, by the tracing up of gulch gold to its home in the lodes." The appropriateness of the name, coming from so high an authority as Prof. Wurtz, led us to extend it over the whole area of the group in New Hampshire and Vermont, as has been often mentioned in the previous volumes of this report.

In 1865, both J. Henry Allen and Charles Knapp, independently of each other, discovered free gold on the David Atwood estate in Lisbon. This led to the organization of the Lisbon Gold Mining Company, on the 28th of February, 1866, with a nominal capital of $240,000. Previously to this organization a little work, or "prospecting," had been done, and subsequently three considerable excavations were made in the vein. The first is in a swampy piece of land on George brook. This has been sunk to the depth of 94 feet, the first 35 vertical, and the remainder at an angle of 45° or more, upon the supposed dip. It is said that a dyke

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[*] *Geological Survey of Canada. Report of Progress from its Commencement to* 1863, p. 437.

[†] Sept. 12, 1868.

of trap is connected with the vein in the foot-wall as low as fifty feet. The greatest amount of free gold showed itself within twenty-five feet of the surface. The gangue of the vein is quartz, about one twentieth part being composed of magnetic iron pyrites or pyrrhotite, with a slight sprinkling of yellow copper pyrites or chalcopyrite. The assays of the rock were said to indicate at least $60 to the ton. It is probable that the pyrrhotite contains gold, as the best specimens show free gold intermingled with it. It is estimated, by good authority, that about three hundred dollars have been obtained practically by milling from this mine.

The second opening, a few rods up the hill on the south bank, was sunk 30 feet. The third, much farther south, was sunk 25 feet. All the openings indicate a vein over four feet in thickness, similar to that already described, and bounded by a hard quartzite resembling gneiss. The vein is about an eighth of a mile removed from a clay slate.

The company were not very successful in extracting the gold from this mine, and ceased to excavate in December, 1866, allowing the opening to become filled with water. They then bought one half of what is known as the Dodge mine, and since the abandonment of the first, have wrought the second diligently. Their capital stock has been reduced to $48.000.

The Dodge Mine. In June, 1866, Mr. J. H. Barrett, while laboring on the Dodge farm in Lyman, nearly two miles by road from Lisbon village, discovered a stone projecting from the wall which contained a yellow substance resembling gold. The specimen was sent down to S. K. Fisk, of Lisbon, who pronounced the yellow mineral iron pyrites; but upon cleaning the other face of the stone discovered a large sprinkling of gold, the finest specimen ever found in New Hampshire. This discovery led to a search for the vein. Three or four shallow openings were made, and an association formed to work one half the property, known as the Dodge Gold Mining Company, with a nominal capital of $75,000. The Lisbon and Dodge companies have worked this mine jointly since the early part of 1868, each transporting its share of quartz to the mills at Lisbon village. The Dodge mill commenced operations March 12, 1868, on the north side of the river. Each mill has ten stamps, and is capable of crushing and amalgamating eight tons in twenty-four hours.

The history of the operations of the Dodge and Lisbon mines has been quite varied. The Dodge company worked the mine and milled the quartz from the date just mentioned to the last part of 1869. B. F. Martin, the president, states that the sum of $24,500 was obtained while it was under his care. For the six months from December, 1869, to June, 1870, the property was leased to E. L. Hall and John McCall. Dr. Rae says they obtained $6,570 during this time. Others estimate the amount higher,—about 30 tons per week of ore, valued at $12, for 26 weeks, making over $9,000. Messrs. Fay and Wilmarth next leased the property for six months in 1870–71, and are thought to have taken out $2,000. In the spring of 1873, Dr. Julio H. Rae leased the property, and applied a process of his own to the separation of the gold from the quartz. He claims to have taken out $3,500 in July and August of that year. He found an average of $25 to the ton at first, but afterwards only $18 was obtained. Up to the time of the formation of the Electro-Gold Mining Company, the entire amount of gold milled was $36,570. Dr. Rae says it would be proper to add $5,000 for the supposed stealings, and half as much for the value of the specimens that have been carried away.

This new company wrought the mine and mill successfully for two or three years. From several letters written by the president, Dr. Rae, I cull the following:

Under date of October 17, 1873, he writes:

> Enclosed please find copy from book of one week's run, made while experimenting:

Monday, one ton gross yielded	1550 grains of gold.
Tuesday, " " "	1620 " "
Wednesday, " " "	1850 " "
Thursday, " " "	2240 " "
Friday, " " "	1790 " "
Saturday, 600 pounds yielded	1220 " "
Monday, 1750 " "	1590 " "
Tuesday, one ton gross "	2000 " "

Under date of March 25, 1874, he writes,—

> Our ore has averaged $19 per ton, the finest varying from 930 to 955, gold,—silver, 42 to 65. The ore has run down to about $1.25 per ton, and the richest of which I run, probably about three tons, went as high as $95. The mean average of the ore can be

safely estimated at $19 per ton, if judgment is exercised in culling. The vein being very wide—18 feet—mining is cheap; but we cull our ore about fifty per cent., making the ore cost, for mining and culling, about $2 per ton. Add $1 for cartage, and $1.50 for milling, or work in mill in reducing ore to bullion, and you will find that the cost of mining and milling is $4.50 per ton of 2,240 pounds.

The director of the U. S. Mint reports the receipts of gold from New Hampshire for the year ending June 30, 1875, to be $5,200.92. For the year following, the amount was $2,731.74. A figure given in the director's report for the amount received from New Hampshire up to the last mentioned date probably denotes the total received from the Electro-Gold company: it is $10,233.68. If this sum be added to the total known to have been extracted prior to 1873, viz., $36,570, we shall have $46,803.68 as the total amount of gold mined at Lyman prior to 1876. Mr. Willard Parker, of Lisbon, who has been familiar with the whole history of the extraction of the gold in Lyman, estimated the whole amount extracted to the same date at $48,000. The close coincidence of our two independent estimates leads to the belief in their essential correctness. There has been some gold taken from the vein since 1876, so that it may be proper to say, in round numbers, that $50,000 of the gold coin in circulation in the United States has been derived from New Hampshire during the past ten years.

The tract of land occupied by the Dodge and Lisbon companies comprises about 170 acres in the east part of Lyman, and is defined upon the map opposite page 296, Volume II. The companies are engaged in litigation at the present time rather than in the development of their mines. The land has been divided into sections of 500 feet each, that at the southern end being owned by the Dodge company, and the second by the Lisbon company; the third by the Dodge, the fourth by the Lisbon, and so on. The improvements made are upon the first sections respectively.

The Dodge mine was leased for a time to J. H. Paddock & Co., from about March 1, 1874, who used the mill upon the east side of the river at Lisbon village. I have no facts about the production of gold by this firm, nor of that obtained by the Lisbon company after the Electro-Gold company ceased to operate.

The Dodge Vein. The formation carrying the auriferous veins of this type has been described in Volume II as the Cambrian clay slate. There is little mention made of the veins, save in the catalogue of the specimens obtained from the Ammonoosuc district, and their delineation upon the map on page 296. The quartz is somewhat glassy, whitish, except where it has been stained by the decomposition of pyrites, and nearly pure. Masses of slate, crystals of pyrites, ankerite, and galena are scattered through it. It is common to find spangles of free gold in the quartz, most conspicuously at the boundary between the quartz and fragments of slate in it. The ankerite is a characteristic mineral of all the auriferous veins of the Connecticut valley clay slates.

The question arose early as to the proper source of the gold. All that can be seen macroscopically is in the clear quartz. In 1869, I had the general average of the vein assayed, and also each constituent by itself, except the galena, which was of rare occurrence. The average was taken twice;—first, a picked sample from the vein; second, a portion of several hundred pounds' weight that had been pulverized in the mill for practical extraction. According to Prof. C. A. Seely, the amount of gold in both the averaged samples was essentially the same, or $18.90 to the ton. Of the constituents examined separately, taken from the same pile, the clear quartz yielded $18.11 of gold to the ton. The pyrites occurring in the quartz and in the slate both yielded traces of gold, but not enough to be measured, the latter affording the greatest amount. Neither the slate nor the ankerite afforded any trace of gold. If it were allowable to generalize from these single determinations, it were easy to say that 95 hundredths of the gold comes from the clear quartz, and the balance from the pyrites in the vein. There is not very much of this mineral present, but sufficient to attract attention, and to be saved by some of the manipulators. Seeing a pile of this pyritiferous residue in the rooms of the Electro-Gold company's mill, I begged samples for assay. Prof. Blanpied found no gold in it. The species seems to be the common bisulphuret,—not the magnetic variety, nor mispickel, which is auriferous in this neighborhood.

The gold, as obtained from this vein, is very pure. I examined twenty-four of the returns from the mint, and found the average of them to be 916.8 parts of gold to 83.2 of silver. This is purer than the average of this metal in auriferous countries; that of California is 880 in 1000;

Australia, 925.; the Chaudiére region of Canada 885 to 900; while from Nova Scotia the gold is very nearly pure.

The method of extraction first employed is the ordinary stamp process, ten small stamps rather lighter than usual, with copper and blanket amalgamation. It is thought by those much experienced in quartz milling to have been carried on in a crude manner, yet the amount saved has been a fair percentage of the assay yield. There were two of these mills, one on each side of the river at Lisbon village.

With the advent of the Electro-Gold company the Thunder-bolt crusher replaced the stamps. The rock was heated, or partially roasted. It was then crushed dry, and the powder placed in cylinders with water and quicksilver, thirty pounds to a ton of ore. This cylinder revolves four hours, and the sands flow into a dolly tub, afterwards passing over blankets. The sulphurets are caught mostly in the tub, and saved for further treatment. The blankets catch the fine gold, and are changed every four hours. This mill could treat five tons of rock in ten hours. It was the most successful of the various methods tried in New Hampshire. It has since been used more extensively in Virginia. Being of little use for the extraction of gold from sulphurets, Dr. Rae has added a desulphurizing furnace to his works, enabling him to treat ores otherwise intractable. We present herewith the original specifications of the patent describing this process.

123,932. United States Patent Office. Julio H. Rae, of Syracuse, New York. Improvement in Voltaic Amalgamators for Gold and Silver.

Specification forming part of Letters Patent No. 123,932, dated February 20, 1872.

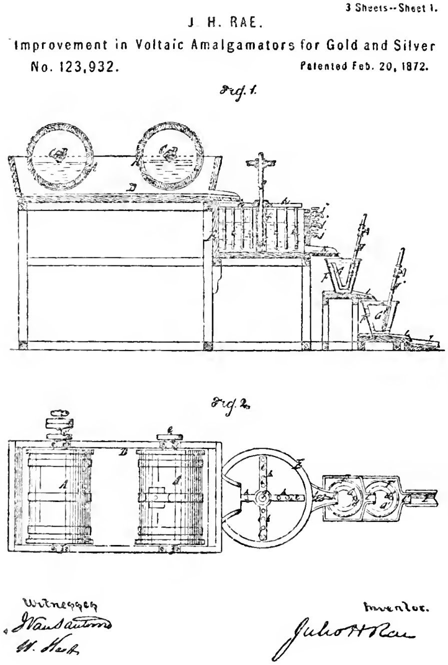
To all whom it may concern:

Be it known that I, Julio H. Rae, of the city of Syracuse, in the county of Onondaga and state of New York, have invented a new and useful improvement in voltaic amalgamators for ore; and I do hereby declare the following to be a full, clear, and exact description thereof, which will enable those skilled in the art to make and use the same, reference being had to the accompanying drawing forming part of this specification, in which drawing,—

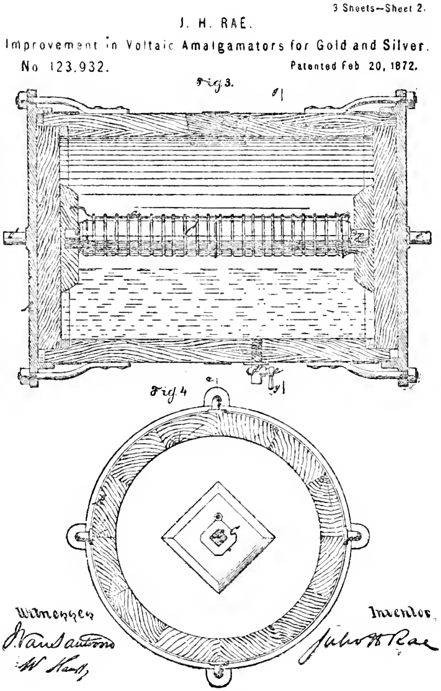
Fig. 1 represents a longitudinal vertical section of my invention. Fig. 2 is a plan or top view of the same. Fig. 3 is a detached longitudinal central section of the voltaic cylinder, which forms one of the principal parts of my amalgamator, in a larger scale than the previous figure, the line *x x*, Fig. 4, indicating the plane of section. Fig. 4 is a transverse section of the same in the plane *y y*, Fig. 3. Fig. 5 is a detached section of the washer in a larger scale than the first two figures. Fig. 6 is a plan or top view of the same.

Similar letters indicate corresponding parts.

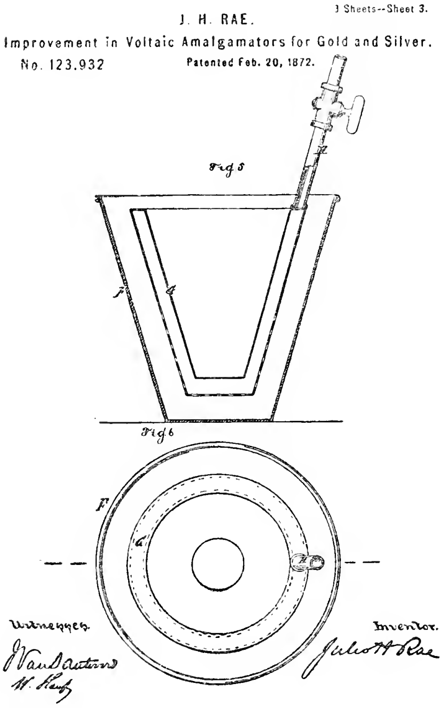
This invention consists in the arrangement of a voltaic pile in the interior of an amalgamating-cylinder in such a manner that, when said cylinder is charged with the pulverized ore, quicksilver, and proper chemicals, and then revolved, the galvanic current excited in the pile materially promotes the amalgamating process. Also, in the arrangement of a rod extending centrally through the amalgamating-cylinder, and forming the support of the voltaic pile, the copper elements of which connect with one head, and the zinc elements of which connect with the opposite head of said cylinder, in such a manner that the elements are securely retained and not liable to get out of position by the revolution of the cylinder; and at the same time the voltaic pile offers the least possible obstruction to the revolving motion of the cylinder. Further, in the arrangement of one or more voltaic cylinders in a receiving-tank which connects with an agitating-tub in such a manner that the pulp discharged from said voltaic cylinder or cylinders can be washed, and the floating particles of quicksilver contained therein can be saved. Also, in combining the voltaic cylinders, the receiving-tank, and the agitating-tub with one or more washers, composed of conical copper-lined vessels, each of which contains a hollow inverted truncated cone suspended from a water-supply pipe, and provided with a large number of small holes in the bottom and lower part of its outer shell, in such a manner that, by the up current of the jets of water discharging from said holes, the particles of mercury still mixed with the tailings received in the washer are recovered, while the tailings flow off through a copper-lined gutter, the copper lining of which retains the last traces of mercury which may be still mixed with the tailings.



In the drawing, the letters A A designate cylinders, each of which is constructed as shown in Figs. 3 and 4 of the drawing. Through the centre of each of these cylinders extends a rod, B, the ends of which have their bearings in sockets formed on the interior of the heads of the cylinder, and on this rod are secured the elements of a voltaic pile, C. All the copper elements of this pile are connected by a wire, *a*, which is in contact with one of the heads of the cylinder, while the zinc elements are connected by a wire, *d*, which is in contact with the opposite head of said cylinder. By this arrangement I obtain a voltaic pile of great power in a comparatively small space; but it must be remarked that one or more voltaic piles might be arranged in the interior of the cylinder in any desired position, and I do not wish to be confined to the precise arrangement of the voltaic pile which I have shown. Each of the cylinders A is provided in one side with a man-hole, through which the cylinder can be charged and discharged, and which can be firmly closed by a man-hole plate *c*. Through the side of the cylinder opposite the man-hole extends a pipe, *d*, which can be opened and closed by a stop-cock, *e*, and which serves to draw off the quicksilver at the proper time, as will be hereafter more fully explained. From the outer surfaces of the heads of the cylinders project gudgeons, *e'*, which have their bearings in the edges of a tank, D, which is intended to receive the pulp and conduct it to the agitating-tub E. From the bottom of this tub rises a tube, *f*, to a level with the top edge, and this tube forms the bearing for a vertical shaft, *g*, from which extend radiating arms *h*, carrying the agitators *i*, which extend down near to the bottom of the tub E, as shown in Fig. 1. In the side of this tub are three pipes, *j*, one above the other, and each provided with a stop-cock; and from the bottom of the tub, just beneath the pipes *j*, extends the discharge-pipe *k*, which leads to the first washer F. An enlarged



view of this washer is shown in Figs. 5 and 6 of the drawing. It consists of a conical tub, lined with copper, and in this tub is contained a double-walled inverted truncated cone, G, which is suspended from a water-supply pipe, H, and which is perforated with a number of small holes in its outer bottom and in the lower portion of its external jacket, so that the water admitted through the pipe H discharges from the cone G in a large number of fine jets, producing an upward current. The washer F is placed on a table, with a spout, *l*, extending over a second washer, F′, which is constructed like the first washer, and the discharge-spout *l*′ of which extends over a gutter, I, lined with copper.



In using my invention I first reduce the ore to a fine powder, and then I introduce the same, together with a suitable quantity of water, quicksilver, and suitable exciting chemicals, into the cylinder or cylinders A. The chemicals which I use are common salt, or such acids which, when brought in contact with the voltaic pile, will excite a galvanic current. In regard to the quantity of quicksilver and the character and quantity of the exciting agent used, reference must always be had to the nature of the ore and to the electric affinities of the metals contained in the ore about to be washed. After revolving the cylinder or cylinders from three to four hours, the quicksilver is drawn off through the pipe or pipes *d*. Then each cylinder is again revolved for a few minutes for the purpose of fluidizing the pulp, when the man-hole plate is taken out, and the whole contents of the cylinder discharged into the receiving-tank D, whence the pulp gradually discharges into the agitating-tub E. In this tub the pulp is agitated, the amalgam being precipitated, while the tailings are drawn off through either of the pipes *j*, according to their specific gravity. The amalgam which collects on the bottom of the tub is removed from time to time, while the tailings pass into the first washer, F, where small particles of mercury, still mixed with the tailings, are precipitated or retained by the copper surface of the washer, while the light tailings are carried up by the up current of water produced by the jets of the cone G, and discharged over the edge of the washer F upon the table *l*, whence they run down into the second washer F′, to be treated in the same manner as above. From this second washer the tailings pass into the gutter I, the copper lining of which retains the last traces of mercury which may be still mixed with the tailings.

What I claim as new, and desire to claim by letters patent, is,—

1. The arrangement of one or more voltaic piles in the interior of an amalgamating cylinder, substantially as described.

2. The rod B, extending through the centre of an amalgamating cylinder, and supporting the elements of a voltaic pile, in combination with wires *a b*, one forming a connection between the copper, and the other between the zinc elements of the pile, substantially as set forth.

3. The arrangement of one or more voltaic cylinders in a receiving-tank communicating with an agitating-tub, substantially in the manner shown and described.

4. The combination, with one or more voltaic cylinders, a receiving-tank, and an agitating-tub of one or more washers, F F′, substantially as set forth.

5. The double-walled hollow inverted cone G, communicating with a water-supply pipe, and provided with jets in its bottom and outer jacket, in combination with a washer, F, constructed substantially as described.

JULIO H. RAE.

Witnesses:
W. Hauff,
J. Van Santvoord.

A gentleman familiar with milling has written the following sketch of the practical working of Rae's process in Virginia:

The first important difference between this and the common milling process is, that no water is introduced into the mortars, and the rock to be crushed must be perfectly dry. In all mills the degree of fineness to which the rock is powdered is regulated by a screen, through which alone the pulverized ore finds egress from the mortars.

In Rae's method, very fine screens are used, so that the rock is reduced to a very minute powder before it escapes from the batteries. It is then carried by an elevating belt to a platform above the battery, where it is emptied into a car large enough to hold one ton of crushed rock. When this amount is received, the car is removed and another placed in its stead. The car already charged with the ton of powdered rock is rolled forward till it is above the amalgamating machinery.

This consists of a large tank so inclined that fluids will readily flow from it through a vent in the lower end. Across this tank, their axis resting on journals supported by its sides, are two cylinders, each seven feet long and four feet eight inches in diameter.

On one side of each cylinder, half way between the ends, is a large opening called a manhole; on the other side, opposite, is a large faucet. By an ingenious contrivance, the manhole can be closed with absolute tightness. Inside, upon the axis of each cylinder, is a voltaic pile. Below the vent of the tank is a circular cistern, five feet in diameter and one foot six inches high, called a dolly or agitating tub. An upright shaft, standing on the centre of the bottom of this tub, is made slowly to revolve. From a horizontal cross-piece placed on this shaft, a little above the level of the top of the tub, iron teeth one foot six inches long descend. On the side of this tub opposite the vent of the tank are four holes, one above the other, through which fluid may pass into an amalgamated copper vessel, in shape an inverted hollow truncated cone. In the centre of this copper vessel, called a washer, is a hollow sphere pierced with small holes. In this sphere terminates a water-pipe connected with a reservoir above, and provided with a stopcock to regulate the flow and pressure of the water. Below this washer is another, smaller, but in every respect similar in shape and arrangement. Such is the amalgamating machinery. The amalgamation is effected as follows: From the car above the machinery the pulverized ore is, by a shute, emptied into one of the cylinders through the manhole. Water is then introduced till the cylinder is two thirds full. Any necessary chemicals, and from fifty to one hundred pounds of quicksilver, according to the richness of the ore, are added at the same time. The manhole is then closed so tight that nothing can escape; and the cylinder is revolved from three to four hours. Then the faucet is opened, and ninety to ninety-five per cent. of the quicksilver runs out into a vessel ready to receive it. Another vessel is substituted for this, and receives a large portion of the amalgam. The remaining contents of the cylinder are then allowed to flow out into the tank, and are washed down into the dolly-tub, where they are constantly agitated by the teeth on the cross-piece before mentioned. From this tub they pass into the washers, in which the jets of water from the holes in the hollow sphere keep the mass constantly in movement, so that any amalgam quicksilver or gold which shall have escaped from the cylinder and the dolly-tub sinks to the bottom of the first, or, at any rate, of the second washer.

The Dodge shaft was sunk 17 feet in 1867; and the rock taken from it yielded $6.25 per ton in the mill. After that, the whole vein on both sides was excavated for a length of several rods to the same depth, the rock yielding only $3 or $4 per ton. After the return to sinking the original shaft, $10 per ton was obtained immediately; and the yield for about two years subsequently was nearly the same, averaging $14, and in one instance reaching $19. The shaft had been excavated to a depth of about 70 feet in 1869; and there are drifts at about 60 feet depth in both directions, particularly to the east. The vein is 16 feet wide here. The rock from this depth seems to have been most productive. It is probable that not less than one fourth or one fifth of the total amount of gold present in the vein has been lost in the milling process, so that the actual results obtained do not fairly represent the true value of the rock.

Since 1869 three shafts have been sunk upon this vein, two of them to the depth of 100 feet, the third about half as much. The quality of the rock at various parts of the shafts and cuttings is not uniform. Some who have engaged in milling the quartz became discouraged on account of the small yield. By protracting on a scale, when the facts were fresh in my mind, the rich and poor portions of the quartz, I discovered a uniform method of arrangement. The richer portions occupy a definite part of the vein called a "shoot" or "chimney" by miners. The vein-sheet dips north-west, but the chimney dips to the north-east. It cannot be distinguished in the rock except by those handling it every day. In other kinds of metaliferous veins this phenomenon is very distinct, showing itself in a swelling of the mass, forming a *bonanza.* The thickness of the quartz vein is constant, and where it increases in richness the bulk is the same as before. The best method of discovering the rich and lean ore is by experiment.

There is a second quartz vein upon these properties, about eighty feet to the north, but it has not proved productive. Excavations made to the south-west upon the first Dodge lot have shown the presence of the original vein nearly to the edge of the property.

I learn that operations upon this vein are to be resumed immediately, or in the spring of 1878.

Other Quartz openings. A few other veins similar to the above occur in Lyman and its vicinity. One of the most noted is the Bedell mine, about a mile farther west. The mineralogical character is the same as that just described. It is two feet wide. Specimens showing much free gold are easily obtained. I panned out several pieces of gold from a shovelful of earth scraped from the top of the ledge, and saw much richer yields in the hands of others. A reliable assay of it in 1869 showed $12 to the ton of gold present. There is more galena than usual in the vein, carrying $33 of silver to the ton. A shaft has been sunk to the depth of 20 feet.

Near the Haviland copper mine is the Hartford or Moulton mine. A shaft has been sunk about 100 feet. At the depth of 23 feet the quartz vein, not of much width, is said to have assayed $30 in gold and $10 in silver to the ton. I have seen specimens of free gold from this mine.

Other openings are upon the clay slate area close to the conglomerate near stakes V 14 and 15 (Vol. II, p. 296), or the Bartlett mine; the west part of Jason Titus's farm in Lyman; upon B. Dow's land, near stakes B 19 and 20; and in Bath, near the east border of the slate area. Here Smith brook falls over a ledge, at whose base is a tunnel, about twenty feet long, made many years since. I found a few specks of free gold in the quartz in small veins just below the tunnel. Other quartz veins have been recognized while collecting specimens in the field, none of which are known to be auriferous by actual test.

Gold in the Conglomerate. Attention was very early called to the presence of gold in the interesting band described with minuteness in Volume II as the auriferous conglomerate. It is regarded as older than the veins in the clay slate, and for that reason perhaps is not so rich. No extensive excavations have been made in this rock, but it is very commonly slightly auriferous. Almost every section of it will furnish auriferous samples. Authentic assays have been made from several localities, such as the following:

A sample from the field north of the Cook and Brown mine (Hiram Knapp's land), afforded to Prof. Seely gold at the rate of 90 cts. to the ton. Another determination from a neighboring locality showed 75 cts. to the ton. A well known auriferous ledge of this sort is at the house of Jacob Williams. A ledge of quartzose conglomerate crops out by the roadside, perhaps forty feet high and equally thick. This ledge, two hundred and eighty-two feet in length, is one outcrop of a very interesting division of the gold rocks, whose windings and faultings have been carefully studied by us and represented upon both our maps. It is an ancient gravel, now consolidated, but it is not known whether the gold was deposited in the original placer, or introduced in small veins at the subsequent period of elevation. The company's statement represents that assays of from six to eight hundred pounds of rock have given them from five to seven dollars* of gold to the ton, and on account of the facility with which thousands of tons can be obtained from the mass, think that an average yield at these rates would be remunerative. The

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* In one case, $9.99 in currency. The latest experiment shows $3 per ton.

whole width is traversed by segregated veins in which pyrites and ankerite are abundant, while specks of galena and copper have been seen.

An opening once greatly talked of is situated on the Steery farm east of Williams's. It has been known as the "Dow ledge" at the Pittsburg mine. It is a cliff of the same conglomerate, 50 or 60 feet high, and has been opened slightly.

On the most eastern band of this rock is the "Gordon mine." There are conspicuous masses of pryites, probably magnetic, in this opening upon the top of the hill. Only a few blasts have been put in here. The conglomerate has assayed from $3 to $10 to the ton. On the west side of the crest of this hill a larger excavation has been made in a better appearing part of the rock.

What I conceive to be the same conglomerate has recently been discovered in the edge of Landaff, about a mile and a half east of Lisbon village, and known latterly as the Allen mine. The ledges of it are exposed upon the "poor-" or town-farm for more than half a mile in length, with the usual north-east strike of the country, dipping 50° or 60° northwesterly. Upon this farm are several alternations of rock,—five or six of quartz, four of slate, two of conglomerate, and a siliceous limestone, possibly encrinital. The county rock is regarded as the lower part of our Huronian, though resembling the Lyman group. The most valuable vein here is from two to four feet wide, carrying much of a dark pyrites, staining the hands. Much free gold has been found in it. I have visited it twice, and obtained gold readily by washing the crushed selected fragments. I saw three small excavations. More recent cuttings have been made; and the parties interested claim that the quartz averages about $30, while the selected specimens of pyrites have yielded at a rate of $700 to the ton. They have uncovered the vein for a distance of 100 feet, and excavated occasionally to the depth of 8 feet. The gold occurs mostly in small grains in the decomposed rock, in company with a little galena.

The same conglomerate I have discovered north of the Atwood mine, and it is undoubtedly continuous to the similar outcrop on Salmon Hole brook (Vol. II, p. 324). It runs towards the coarser conglomerate of North Lisbon. It is claimed to extend in the other direction—the southwest—towards North Haverhill.

THE GRAFTON COMPANY.

One of the curiosities of mining in New Hampshire has been illustrated by the history of the Grafton Gold Mining Company, organized near the beginning of the year 1869. The property is near the west corner of Lyman. It was first known as the Davis & Thayer, and afterwards as the Wiggin & Davis property. I visited it September 14, 1868, and May 10, 1869. It lies in the Huronian rocks east of Gardner's mountain, the material being dolomitic and somewhat slaty. At the surface three veins, each about a foot in width, showed themselves, with narrow slaty partings, which became smaller at 25 feet, and are said to have entirely disappeared at the depth of 76 feet,—the bottom of the shaft,—and to be 8 feet wide. The veins incline south-easterly 55° at the surface, and 10° less at the depth of 25 feet, the lowest point at which I have seen it. The vein is of limpid quartz, with many crystals of quartz, dolomite or ankerite, iron pyrites, and galena, besides some free gold, the latter most abundant in the upper vein. An immense number of segregated quartz veins ramify through the dolomitic mass that is brought to the surface.

From several statements shown me by officers of the company, it appears that the earlier assays gave over $7 of gold to the ton of rock; and at the depth of 76 feet, out of a mass weighing 50 pounds, Dr. Torrey, of New York, obtained gold at the rate of $62.17 to the ton, and of silver, $1.33. An examination of the pyrites showed no gold present. About forty per cent. of the gangue was shown to be of quartz, and the balance chiefly dolomitic. A careful examination of a similar sample by T. C. Raymond, of Cambridgeport, Mass., gave the following result: Silica, 30.3; protoxide of iron, 6.27; lime, 20.6; magnesia, 11.17; carbonic acid, 32.11;—total, 100.44. This composition led the company to believe that the pulverized rock might be used advantageously as a fertilizer after the extraction of the gold; and some experiments were instituted to show its value.

The proprietors drove a thriving business in selling this pulverized siliceous dolomite for a fertilizer. Even those reputed agricultural writers of eminence became interested, and saw great benefits to the soil in the application of this powder. No doubt some benefit came, from the fact that finely divided materials have the power of absorbing moisture from the air; but such unscientific statements as appeared in the testimonials foreshadowed the withdrawal of the substance to serve for a fertilizer. The following extracts will illustrate:

> *Dear Sir:* I very gladly write you a statement of the effects of the "Grafton Fertilizer" as seen in my garden. Two quarts of "Fertilizer" were placed about the roots of a grape-vine which had never borne more than a plateful. It is covered with bunches of fruit now of a very large size, which will ripen much earlier than usual. I think the chemical properties contained in this "Fertilizer" will serve to hasten the period of ripening of all fruits and vegetables. Melons, cucumbers, and squashes flourish finely under its influence. Last year the vines were riddled by the striped bug; this season, when they appeared, handfuls of the "Fertilizer" were scattered over the vines, and they rapidly "vamoosed the ranch." Not one bug remained! We gathered the first cucumbers grown in the town. Melon vines are a mass of yellow blossoms and green fruit, and they are not usually prolific so far north.
>
> The "Fertilizer" is death to all the insect tribe. Carbonic acid is fatal to animal life, while it is highly essential to the growth of the vegetable world. The "Grafton Fertilizer" possesses 32.11 per cent. of this desirable constituent,—solidified,—which, added to the lime, protoxide of iron, and silica contained therein, must prove one of the most valuable mixtures hitherto discovered.
>
> For peach-trees, it will undoubtedly be of eminent service. The peach borer can, by its aid, be driven from its haunts, and the pear-blight remedied.

The success of this fertilizer led E. C. Stevens, of Lisbon, to provide a similar material from Lyman, which also had a considerable sale. An analysis of it shows it to contain,—Silica, 90.60; lime, 3.27; sesquioxide of iron, 3.06; alumina, .31; magnesia, .38; carbonic acid, 1.35; water, 1.06; alkalies, a trace; gold, a trace.

Gold in the Sulphurets.

Scarcely any topic connected with mining in New Hampshire is of greater practical value than the presence of gold in the various sulphurets, particularly those utilized for the extraction of lead or copper. It may frequently be the case that the expenses of mining will be just about met by the sales of copper or lead, with little or no margin for profit. Should it appear that gold or silver may also be extracted from these ores, this fact may insure a profit where otherwise none could be obtained. In other auriferous districts, gold is often obtained in abundance from sulphurets, and requires peculiar processes for its extraction. I have many statements of proprietors and prospectors, to the effect that our sulphurets are auriferous and argentiferous. If they are assuredly correct in their estimates of value, a wide field is opened for profitable investment. Several circumstances must qualify the value of the estimates made:—First, all chemists do not agree in obtaining the comparatively large results asserted by some. We have to consider whether this is the result of greater skill, on the one hand, or, on the other, to a readiness to stimulate their business. Second, the specimens assayed are usually the best of their kind. Third, if several trials have been made, the proprietor usually mentions only the best, neglecting to state how many have proved unfavorable. We should, however, remember that the precious metals may occur in chimneys throughout the sulphuret veins as well as in the quartz, so that it is easy to explain a varying richness in them.

First of all, is the statement of Prof. Wurtz, previously quoted, that galena at the east base of Gardner's mountain contains $18.63 of gold to the ton of sulphuret. This ore is not very abundant,—not sufficiently so to be worth working, in the estimate of the present proprietor. Several of the copper properties along the Gardner Mountain range have been found to contain gold, up to $15 to the ton, by Prof. F. L. Bartlett, of Portland, Me. Such are the Stevens mine in Bath, and the Gardner Mountain mine in Littleton. I have had a similar statement as to the value of the Paddock copper ore, from C. H. Crosby.

A friend of mine interested in this question has investigated it quite thoroughly for his own satisfaction. It had been stated that the Vershire copper ore frequently carried $60 of gold to the ton. Others claimed a higher figure. He selected for the test a beautiful piece of iron and copper pyrites from Corinth, as rich as any that could be found, and apparently perfectly free from silica. It was placed in the hands of a skilful analyst, with a full statement of the question at issue. In order to ensure accuracy, the best method of analysis, at double price, was employed. The report states that the amount of gold contained in the Corinth ore is 27-100 of an ounce to the ton of 2,000 pounds. This would be, in round numbers, about $5 to the ton. The result is valuable, both disposing of the wild statements afloat as to the great richness of many of our sulphurets, and indicating that the Vermont copper ores are somewhat auriferous. I think I have been told that the Vershire copper ore has been tested by the company many times, and that it may be relied upon to furnish $7 in gold to the ton. J. W. Cleaveland, of the Copperas Hill works in Strafford, informs me that several dollars' worth of gold to the ton have been found in the refuse heaps of his establishment, and a much larger amount in the fresh specimens of copper ore.*

Capt. Edgar has stated that the zinc blende of Warren carried $60 of gold to the ton. This has not been verified in a practical way.

An interesting question, of both theoretical and practical interest in this connection, relates to the chemical condition of the gold in the sulphurets. Is it a sulphuret, or the element itself, free from all combination, as in the quartz veins? The fact of the absence of any free gold in the pyrites, and its sudden appearance after decomposition, led one modern author to revive the ancient alchemistic notion of the derivation of gold from the baser metal. It is said by chemists that the pente-sulphide of potassium has no effect upon free gold, but will dissolve the sulphuret. This reagent has been brought to bear upon auriferous sulphurets, with the results claimed; and hence it seems evident that the gold occurs in pyrites in combination with sulphur. This latter element needs to be carefully eliminated from all gold-bearing ores before the precious metal can be amalgamated.

Cook and Brown's Mine. In 1875 I found renewed activity upon the opening called the Cook and Brown mine, by parties known under the name of the New England Mining and Reduction Company. About five tons of the ore had been worked in Boston, yielding $23.59 to the ton; and they desired to test certain improved processes for extracting gold from its combination with sulphur. Before thoroughly testing the vein, the mill was erected just above Young's pond; and after its completion, owing to irregularities in the vein, not enough ore could be raised to supply the works. A very few feet below the surface, a quartz vein

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* He says,—"We have found that the yellow deposit from the water flowing out of the adit contains gold in small quantities. It has been known for several years that the ore from this mine contains gold; but I was not aware that we had silver until Prof. Bartlett, of Portland, Me., made an assay of some of the old spent heaps, and found, from the top of a heap that has been undisturbed for twenty years, that it contained four dollars and fifty-five cents' worth of silver and ten dollars of gold to the ton. H. F. Carpenter, of Portsmouth, R. I., has been experimenting with the pyrites for the past year, and reports that, from seventy-five to one hundred trials, he is able to get sixty dollars of gold per ton; but the gold is an ore, and not in condition to be extracted profitably." April 11, 1878.

about ten inches wide was cut into, showing free gold, and that in respectable quantity. The vein was followed down, and, with several feet of the adjoining rock, proved to be highly auriferous. Mr. Hawes's assay of samples selected by me showed the presence of 20 ounces of silver, and 2.5 ounces of gold to the ton. Trial with a pan revealed considerable gold before the decomposition of the pyrites, and much more after calcination. From $70 to $80 to the ton seemed to be a common yield, judging by the eye. The material examined was a soft, argillitic schist, full of crystals of arsenical pyrites. Massive layers of this same mineral an inch thick had been noticed in the quartz vein.

After descending 25 or 30 feet, the vein and its accompanying auriferous bands disappeared, and has never been found again, and consequently mining operations ceased. This opening is almost on the line of fault described in Volume II, page 305. The magnitude of the throw—nearly 1,200 feet—shows that the disappearance of the vein by faulting is not singular; but the richness of the auriferous deposit would render it desirable to search for its continuation.

The presence of so much gold with arsenical pyrites, here and at the Atwood and Allen mines, has suggested to me the probability that this may indicate the natural affinities of the metal in this district. The formation in which the Cook and Brown mine is located is the Lyman group,—unlike the Dodge vein in the clay slate. Future explorers will do well to remember these facts, and not neglect the arsenical ores, as they may prove to be the best in the state.

The mill has been abandoned, after it was discovered that the supply of auriferous material from this mine could not be depended upon. A lot of fifty tons of auriferous mispickel from Ontario was afterwards milled in it, apparently successfully.

The following sketch of the Crosby process is taken from a prospectus issued by the company owning the mill.

> The Crosby mill contains 1 engine of 50 horse-power; 1 donkey-engine, 10 horse-power; 1 Dodge crusher; 1 pair Cornish rolls; 3 roasting cylinders; 4 Burr mills; 4 amalgamating tubs; 4 washing tables,—besides elevator, quicksilver strainers, etc.
>
> The ore is pulverized by passing through the Dodge crusher and through the Cornish rollers. The pulverization is however incomplete, a large part of the ore going through, as gravel cannot be thoroughly roasted, and must cause loss. A dry stamp-mill would

crush the rock perfectly, or perhaps an additional pair of rollers might answer the purpose. From the rollers the ore is carried as a powder to the roasting cylinders. These cylinders are made of boiler-iron, and are placed in an almost horizontal position on friction rollers, and heated to redness from the outside. Inside the cylinders are flanges or shelves fixed to the shell, and running parallel with its axes. The ore drops in at the feed end; and as the cylinder revolves, is lifted by the flanges, dropped, and thoroughly stirred. From the declination of the cylinder, the ore slowly works its way down to the discharge end, roasted or desulphurized.

The ore is now cooled, ground to a fine powder in the burrhstone mills, washed, to free it from soluble metallic salts, and amalgamated. The amalgamation is performed in tubs provided with stirrers; and by an ingenious arrangement the quicksilver is strained, the amalgam separated, and free quicksilver continuously passed in a fine shower through the pulp in the tank.

To test the efficiency of the process, I caused 174 pounds of sulphuretted ore, assaying $56.15 in gold, to be worked, and obtained 80 per cent. of the assay. Had the ore been properly crushed previous to roasting, the returns must have been larger. The powdered ore was of all degrees of fineness, from a fine powder to a gravel the size of coffee beans. Of course the latter were not desulphurized; and that we should obtain 80 per cent. of the gold with such imperfect crushing was a matter of surprise. The cost of reduction at Gold Hill, N. C., the mill working 18 tons a day, and allowing one dollar per ton for wear and tear, is $3.27½ per ton.

GEORGE CLENDEN, JR.

The results of twelve different trials with the same apparatus are also given in the prospectus. The sum total was 96 tons; the product was $1,629.29; the average value of the sampled assay, $17.69; and the product, 80 per cent. of the assay value.

ALLUVIAL WASHINGS.

In all gold-bearing countries it is common to resort to the hydraulic process for the extraction of the precious metal. Two circumstances have stood in the way of its use in New Hampshire, where it might serve an excellent purpose: first, the land in the Ammonoosuc field is valuable for farming purposes, and the farmers do not desire to have it torn up; second, there were operations of this nature upon Salmon Hole brook in Lisbon, in 1866, whose managers "salted" the sluice-boxes, and thus falsely obtained a large yield. There is no reason why a judiciously selected locality would not furnish profitable results, particularly in Pittsburg, where the value of the land is but a trifle.

Hydraulic processes have been thoroughly perfected in California. Canals, many miles in length and passing over ravines 200 feet deep, have been constructed to convey the water, so that by a large hose-pipe it may be brought to bear upon the auriferous gravel in the right place. That gravel is commonly as hard as rock, the pebbles being too firmly set to be broken apart by hand. Detailed descriptions of the processes are unnecessary; but I will mention the cost of excavation in different parts of the country, as presented by several experts. Prof. W. P. Blake estitated, from work done in North Carolina in 1859, that earth containing only the twenty-fifth part of a grain of gold, or two mills' worth in a bushel, will pay about two dollars a day to a single pipe. In California, about 1868, the same gentleman estimated that, with certain conveniences described, 1,500 tons of earth could be removed in a day's time with the labor of two men. This result has been actually obtained there under favorable circumstances.

M. Laur, a French engineer, estimating miners' wages at twenty francs ($3.68) per day, found that the expense of manual labor necessary for working one cubic metre (38 inches) of gravel by the several methods to be the following: By the pan, about $13.80; by the rocker, about $3.68; by the long tom, about $0.92; by the sluice, about $0.31; by hydraulic washing, about $0.051. This would make the cost of a cubic yard about five cents. These estimates include the cost of the water.

The cost of hydraulic mining in our state ought not to be greater than in California. These estimates do not cover the cost of the canals and apparatus, though they do include the rents paid for the water, or the interest upon the capital. The profit arising from the employment of the hydraulic processes must depend upon the richness of the gravel and the expense of uncovering the "pay dirt." In Canada, as already stated, and in Vermont, the hydraulic methods have been employed successfully within the past dozen years.

Can Gold-Mining be made Profitable in New Hampshire?

We now possess the data needful to enable us to answer this question. After ten years' intimate acquaintance with all that has been done in the way of mining and milling gold in our state, I am satisfied that this business, if properly conducted, cannot fail to be remunerative. This is not true of any regions except the Ammonoosuc district, and the related rocks along the upper Ammonoosuc river and near the border of Canada. Several points of interest in this connection may be mentioned.

First. It is not intended, when it is said the gold business ought to be remunerative, that a multitude of people can engage in it and become wealthy in a short period. A false impression prevails as to the nature of gold deposits. In California, persons have been fortunate enough to strike "pockets" of gold in the gravel containing many thousand dollars' worth of metal. Those are the few and rare exceptions. Out of the hundreds of gold quartz mines wrought upon the Pacific side of the continent, there are no instances of similar "finds." The gold is obtained only through persevering, tiresome labor. Whatever will be obtained in our state, must come in the same way. No rich placer deposits have ever been discovered within our limits. Should any such be found, and the cost of their discovery be estimated, it will appear, as is the case with those in the West, that a fair proportion of labor has been expended for the result.

Second. We must not expect to obtain profitable results in gold mining without the expenditure of considerable capital. This is like all other business pursuits. For example: a farmer must purchase land, build houses, barns, buy horses, cows, sheep, etc., procure implements of tillage, etc., before he can produce articles of merchandise. He may expend, say, $6,000, which is his capital stock. He will not expect to realize from the sales of his produce the whole amount of his investment the first year. If he obtains produce worth one thousand dollars, he would do remarkably well. So in mining and milling gold, no one ought reasonably to expect to receive the first year a larger proportionate return upon his investment than the farmer has received from his capital,—say 16 per cent. The nominal capital of the Dodge and Lisbon companies is $123,000. During the ten years of their existence, $50,000 in gold has been obtained from them. This certainly represents more than the sum of actual payments in cash by the companies, and at the least showing would indicate a 4-per cent. annual dividend for the whole time.

The question arises, What is the proper capital required to carry on successfully a single mining and milling establishment in New Hampshire? The first item is the cost of the land, by lease or fee simple. This is a matter of special agreement between buyer and seller. I will assume that a section of the Dodge or Lisbon mine, 500 feet in length, or one of equal value elsewhere, may be obtained for $5,000. The cost of a mill-site depends upon the same considerations as that of the mine. Suppose the site and improvements, with buildings, to cost $8,000. The necessary machinery, such as that used most recently in Lisbon, can be put in by responsible parties for $2,500. Add $1,000 for opening the mine and various necessary expenses, and the amount of capital required, therefore, for the establishment throughout, would be about $16,500. The working expenses may be determined by what has been paid already. In 1875, the Lisbon company paid $1.50 per ton for mining, and $1 for the delivery of the rock at the mill. The Electro company, in 1874, paid for mining and culling $2 per ton, $1 for cartage, and $1.50 for milling. In 1869, I stated that the cost of mining and cartage was about $4 to the ton, and the expense of milling about the same, or $8 in all. This was estimated in a depreciated currency, and before the art of mining was well understood in Lyman. I suppose the first two estimates do not include the cost of superintendence.

Some of the best estimates of the cost of gold mills and of working them in California are given in R. W. Raymond's report on the *Mineral Resources west of the Rocky Mountains* for 1872. The cost of a complete mill, including engine and boiler, is usually estimated at $1,000 per stamp. In a large mill of as many as 20 stamps, this includes the concentrating and chlorination works. The same authority presents a detailed account of the entire cost of milling, including interest on the cost, repayment of cost, and management. In a 30-stamp steam-mill, with a crushing capacity of 72 tons a day, this expense is $2.04 per ton, not including the cost of concentrating the tailings and chlorinating the concentrates. The last item would not be of much account when very few sulphurets are found. It would correspond to the expense of working the sulphurets, such as was incurred in the Crosby mill in Lyman. I understand the entire cost of that mill to have been $18,000, and to be capable of working 20 tons of ore per diem. Mr. Crosby estimated the entire expense of milling to be $5 per ton, and $2 additional for mining and delivery,—making $7 in all.

Using these figures for a basis, and making allowances for apparatus and superintendence, the following may express the proper capital and working expenses for extracting the gold from the two classes of ore occurring in New Hampshire:

	Quartz mining.	Sulphurets.
Cost of mine,	$5,000	$5,000
Cost of mill,	10,500	18,000
Opening the mine,	1,000	1,000
Total capital,	$16,500	$24,000

Running expenses.	Quartz mining.	Sulphurets.
Mining and cartage, per ton,	$3.00	$3.00
Milling, per ton,	2.00	5.00
Superintendence, say—	.10	.10
	$5.10	$8.10

Should a company be formed to extract gold from the quartz or sulphurets, these figures express the capital absolutely necessary for the undertaking and the proper running expenses. Circumstances of various kinds might add to or diminish the amount of necessary capital; but there would not be much variation from the figures given for the running expenses.

It is easy, from these figures, to estimate the income which might be obtained from a single enterprise of this nature. If the ore averaged as high as $19 per ton, as stated by Dr. Rae, the profit on each ton milled should be $14.90. Eight tons were carried through the whole process daily in 1875. That should afford a daily profit of $119.20. Supposing that the daily yield be practically $15, which was the case in the earlier workings, and allowing $10 per ton for the net income, we should have $80 as the daily return to the company, or $20,000 for the year of 250 working days. These figures are indications of what the gold mining business might become in our state when properly and economically conducted. A larger capital, mills of greater capacity, and the reduction of a greater number of tons daily, by employing night labor, would add very much to the amount realized. I have not given the results obtained from working the sulphurets. Those given from essentially actual experience are to be preferred; and they will afford a method of estimating the possible merits of the gold mining and milling business.

SILVER.

Several veins of galena afford valuable percentages of silver. The only one that has been milled is from Madison. According to Prof. Seely's assay, this contains 94 ounces, 11 pennyweights, and 5 grains of silver to the ton of lead. This is the old Eaton mine described by Jackson. I understand, from the late H. J. Banks, the manager of the mine, that during his administration $55 per ton was obtained by actual sale for the silver contained in the ore. The mine itself will be described under lead.

Near the summit of the road over Gardner's mountain, in the southwest corner of Lyman, are veins of argentiferous galena, owned by J. H. Paddock, of St. Johnsbury, Vt., which have been exploited slightly, and are worthy of further attention. I examined them first in 1869. The earth and a little rock were removed, exposing a vein of clear pyrites and galena over four inches thick. This was traced for five or six rods, cutting the strata at an angle of 70°, the dip of the strata being 62° easterly, and the vein 50° S. 20° E. In 1875 I found that additional excavation had uncovered the vein down to 16 inches in width, the principal portion being galena. Returns from the assay office show from $15 to $36 of silver to the ton.

One of the first mines opened in Lyman showed both silver and gold in the galena. It is not worked for either of these metals at present. The property is a part of the Paddock company, and had originally the name of the New Hampshire Silver Lead Company, with a nominal capital of $500,000. From Prof. Wurtz's reports upon this property, made in 1864, I have condensed the following statements:

> There are two groups of veins, called the West lodes and Orchard veins, the former cupreous, the latter of lead and silver. The west group consists of three "heavy quartz outcrops," one of them, 10 feet wide, containing numerous strings and bunches of galena, with copper pyrites, gossans, and honeycombed cavities, including "*vugs*," or cavities lined with crystals of quartz, rarely containing indigo copper. It was traced 300 or 400 yards in length. The schists adjacent are greatly stained and incrusted with limonite or iron ore, indicating a highly metalliferous condition for the country.
>
> The second, or Orchard group of veins, consists of two, each about two feet wide, and apparently true fissure veins, with the compass course N. 50° E. They contain

chiefly galena and zinc blende. The quartz is "comby," carrying much gossan; and the walls, which near the surface are very rotten, become hard and quartzose several feet down, and well charged with iron pyrites. Several assays of the different galenas have been made by Dr. Torrey, and the results tabulated as follows. He supposes the galena to contain only 80 per cent. of pure lead, allowing for impurities; and the ton is taken at its full value of 2,240 pounds.

	Ounces of silver.	Ounces of gold.	Value of silver in coin.	Value of gold in coin.	Total.
In 1 ton of galena from					
West lode—dark	55.877	....	$72.24	....	$180.00
" light	35.716	....	46.18	....	154.00
Mean of west lode	45.798	....	59.21	....	167.00
Orchard vein	51.027	0.9014	65.98	$18.63	192.50
Mean of the three	47.540	....	61.43	....	175.50

An adit has been driven 300 feet into the hill to drain the west lodes.

Argentiferous galena has recently been discovered by Capt. F. Bennett, superintendent of the Paddock mines, at both the 60- and 120-feet levels, and from the shaft to the end of the drift, a distance of some 60 feet. It occurs continuously along the foot-wall of the copper beds in considerable amount. The best assays show the presence of 89 ounces of silver to the ton, worth $89.73 at present prices. The value of this discovery consists in the fact that all the silver and lead found will be put to the account of profit, as the copper will meet the expenses of mining.

The Stevens copper mine in Bath has a vein of argentiferous galena upon it, separate from the copper, about 18 inches wide. It is said to carry fifty dollars' worth of silver to the ton. I do not know of any other instances of silver in the Gardner Mountain range; but its importance will lead the proprietors of the other mines to search for it. The facts stated about its occurrence are sufficient to justify further exploration; and it will not be strange if the further developments would make the silver business more prominent than the copper mining.

Farther east in Lyman, mention has already been made of galena in the gold mines. That from the Bedell mine is said to yield thirty-three dollars' worth of silver to the ton. In the Dodge, Hartford, and Titus properties it also occurs, but not extensively. It should always be saved, as it is argentiferous, if not auriferous also. Any of the lead ores in the state are likely to prove argentiferous. Such are at Warren, Shelburne, Hooksett, Rumney, and Woodstock, besides recently discovered outcrops in Madison.

In this connection, I will present a brief sketch of the famous silver mine of Newburyport, Mass., just over the New Hampshire line. It was discovered in 1874. The high prices paid for lands in the neighborhood have excited the minds of many of the inhabitants of Rockingham county; and specimens of lead, pyrites, or mispickel found in that part of the state have been carefully preserved, and the ledges exploited. I have examined several openings in that county, as in Newmarket, Exeter, Epping, Fremont, and Raymond, but have not seen anything of value. The veins are of quartz, with a little pyritous ore, imbedded in one of the schistose formations. The Newburyport mine is in sienite; and therefore one would look for corresponding veins in the Exeter range rather than the Merrimack or Rockingham groups, as many have done. I looked over the Newmarket mine, and perceived that some galena had been taken from it, apparently not a great amount. A dry looking quartz, and considerable tourmaline like that occurring in Lebanon (see p. 104, Part IV), were also observed in the opening. The Exeter range is like the Newburyport rock, but parallel with it.

The Merrimack Silver Mine, of Newburyport.

From the reports of Prof. F. L. Vinton, made September 28, 1876, Dr. R. P. Stevens's, made April 13, 1877, and the superintendent of the mine, Edgar Shaw, I glean the following points of interest. Facts about the history of its working, change of proprietorship, etc., are irrelevant to our purpose, and will not be mentioned. The country rock is our Exeter sienite. The ores occur in a vertical fissure-lode fully 200 feet wide, traced two miles in a north-east-south-west course, but not of uniform thickness or value over this distance. The lode mass is compact trap with quartz, seams of indurated calcareous clay and selvages of softer clay, especially on the north-west wall. The ore band wrought lies near this north-west or foot-wall, and consists of argentiferous galena, accompanied by gray copper or tetrahedrite, with a gangue of quartz.

Heavy spar, fluor, pyrites, copper pyrites, and blende occur in small amount. For the depth of 60 feet, the galena constitutes a sheet averaging 12 inches wide. Below this level the ore is more crystalline; and the lode clearly discernible to the depth of 220 feet. There are five levels in the mine, and two shafts; and Prof. Vinton estimated that 40,000 gross tons of ore were actually in sight, which may be concentrated to 4,000 tons of dressed ore worth $94 per ton. The ore in sight on the first level was 1,500 cubic yards, and 10,000 upon the fifth or lowest. Underground, the vein has been explored a distance of 400 feet. The best part of the ore is situated in a chimney, nearly vertical, but inclined south-west, and averaging a width of 100 feet on the several levels.

Dr. Stevens mentions a mass of auriferous quartz parallel to the lead seam on the south-east side, varying in width from one yard at the 60-feet level to 5 feet at the 150-feet level and lower down. Working tests of the value of the quartz gave $11 of silver and $9 of gold to the ton. He also refers to the probable existence of a narrow seam of tetrahedrite continuous with the main galena belt. This mineral is exceedingly rich in silver, the maximum being $4,610.62 to the ton. The galenas average about $60 to the ton, and have been the principal resource from which bullion has been obtained.

The mine is well equipped with the necessary appliances for working, and smelting or reducing works are nearly or quite ready for use. The community have differed in opinion respecting the value of the property. It is obvious that heretofore the aim of the managers has been speculative. Most of the openings in the neighboring towns are of little value. We have the same rock in New Hampshire; and whenever indications are found similar to those manifested at Newburyport, exploration may lead to remunerative mining.

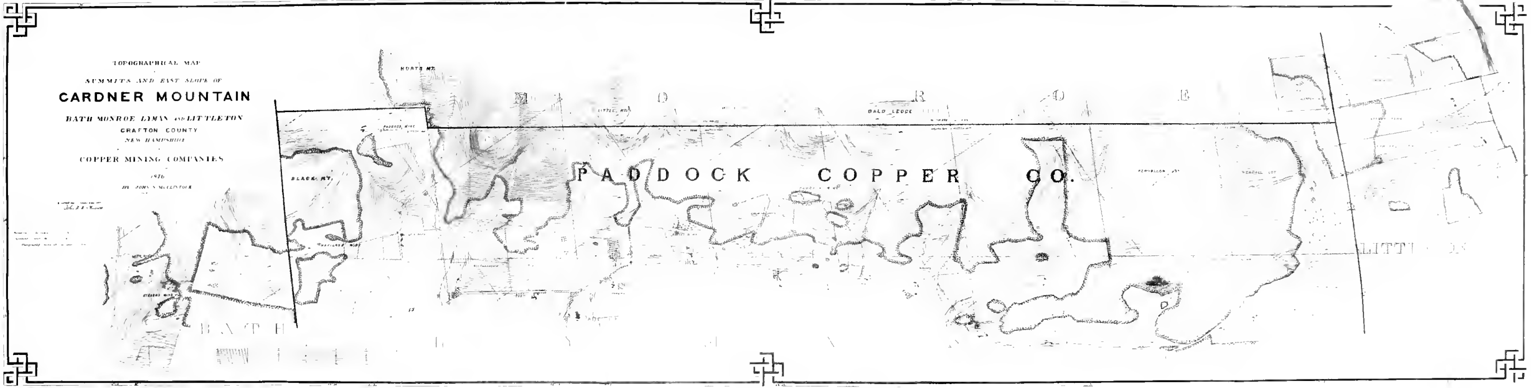
Maps of the Mining Region.

Before beginning a description of the copper mines, I will call attention to two maps. The first is a geological delineation of the Ammonoosuc mining district, and is placed for convenience in the atlas, and referred to upon page 280 in Volume II. It is designed to embrace the final results of all our topographical, geological, and economic studies, prepared for the engraver and colored at the latest possible date. The scale is about three fourths of a mile to the inch, and it is sufficiently large to show all important features. All the material at our command has been made use of, supplemented by a special survey made by Major John N. McClintock for us of the territory west of the Ammonoosuc river. The geological coloring is much the same as that on the general map, save that the representations of the auriferous conglomerate and copper belts have been added. When Volume II was written, it was not known that this band occurred east of Lisbon village. The modified drift is not distinguished.

The other map is a special survey of the Gardner Mountain copper district, prepared by J. N. McClintock. An error in the boundary line between Monroe and Lyman is my own. Contours for every ten feet are represented, and the outer edge of the wooded areas. It is designed to show the mineral proprietorship of the several tracts of land, both those valuable for ores contained, and the intervening farms. The colors show the shapes of the several tracts better than the lines alone. The following is a list of them, beginning at the north end, with their dimensions, and the nature of the minerals present:

Name.	Acres.	Mineral.
Gardner Mountain Company	250	Copper.
Kinney farm	250	Copper.
Carter farm—scattered lots	250	Copper.
Carter mine	100	Copper.
Gregory Company	160	Copper.
Wendall lot	100	Not explored.
Penhallow lot	300	Not explored.
Paddock Company	1200	Copper, lead, and silver.
Titus	250	
Richardson	250	
Abram Smith	450	
Paddock Silver Lead	300	Lead and silver.
Haviland Company	160	Copper.
Dow lot	120	Copper.
Stevens Company	160	Copper.

The map delineates the original lots of Lyman township. Farther to the south, in Bath, are three or four additional openings for copper, the


TOPOGRAPHICAL MAP
SUMMITS AND EAST SLOPE OF
GARDNER MOUNTAIN
BATH MONROE LYMAN and LITTLETON
GRAFTON COUNTY
NEW HAMPSHIRE
COPPER MINING COMPANIES
1876
BY JOHN N McCLINTOCK
HURTS MT.
LITTLE MT.
BALD LEDGE
MONROE
PADDOCK MINE
BLACK MT.
PADDOCK COPPER CO.
BATH
LITTLETON

last known as the Forsaith mine. The site of Paddock's mill is also shown.*

COPPER.

The region covered by these maps will first be considered. There are at least four belts of cupreous rocks situated upon and adjacent to Gardner mountain. Including some exposures in Waterford, the distance of the remotest openings from each other is 12 miles. The richest veins follow the mountain, and have been exploited principally upon the east side. The rocks have been described heretofore as the Lisbon and Lyman divisions of the Upper Huronian, believed to correspond with the lower copper belt of Lake Superior in age. The former of these divisions consists mainly of our "greenstones" or chlorite schists, metamorphic diorites, and diabases, with dolomites. The latter or Lyman series consists mainly of argillitic schists and slates passing into quartzites. Both these formations carry copper. I do not feel confident that the distinctions between these formations are well shown through Lyman and Monroe. The principal portion of the mountain range consists of the argillitic schist, agreeing in mineral composition with the *kellas* of Cornwall. They are altered clays, containing more or less silica, sometimes passing into quartzites. The range to the east, represented by the Quint mine in Littleton, and that in Monroe, are connected with the chloritic schists and diabases. The same series, with inferior copper seams, crops out in Lisbon, underlying the village.

The same formations are developed in Quebec province about Sherbrooke, Ascot, Lennoxville, etc., where they are filled with copper veins. More openings have been made in this formation in Quebec than in Lyman. A few of the mines there have turned out well, having been operated profitably for the past twelve years. Logan referred these rocks to the altered Quebec group, a view adopted by us in our first annual report, but abandoned soon after.

The ore of copper is chalcopyrite,—the common yellow sulphuret of iron and copper,—consisting of sulphur, 34.6; copper, 34.6; iron, 30.5=

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* The positions of all the known pits and openings for copper are indicated by a bright color. Upon some of the lots it is possible to observe six or seven of these openings upon veins parallel to one another. The accurate tracing out of these subordinate lines is a matter of great difficulty, and can hardly be stated with precision at present. Of the general arrangement and direction of the whole series, the map speaks plainly.

100. Excepting occasional blue and green carbonates and the black oxide, any other ores of copper are scarce in this region. The associated ores are argentiferous galena, zinc blende, and an abundance of pyrrhotite, the last named frequently forming beds by itself with slight percentages of copper. All these ores may be auriferous, but to how great an extent remains to be proved.

The veins are usually situated in broad belts of intermingled pyritiferous and siliceous layers, separated by elvans or diorites. The immediate veins may be one, two, or more feet wide, often so close together as to be practically from six to ten feet broad. The ore is in massive, not crystalline bunches, most abundant immediately contiguous to nodules of quartz. Several cases of small veins crossing the strata will be described in connection with individual mines. Our theory as to the origin of the deposits has been that they were originally beds, not fissure veins; and that in later periods the copper has been segregated from the general metalliferous belt into the several strings and veins making up the richest portions. These are found intersected by small cross veins of ore with scarcely any gangue, so that, as the country is exploited more and more, the evidences of the presence of the copper in so-called fissure-lodes increase.

I have thought the continuity of the vein is to be seen in the presence of a series of lenticular patches or bonanzas, not succeeding each other on absolutely the same plane, but overlapping. On this view, what seems to be the same vein in adjacent lots is rather a series of flattened bunches, working more and more to one side. I have not yet discovered irregularities in the veins on Gardner mountain corresponding in magnitude with those of the auriferous conglomerate in the southeast part of the town, though only exploration is needed to develop them.

I will now describe the features of the several mines in detail.

Gardner Mountain Copper Company. This property consists of 250 acres of land held in fee simple, a farm-house with the usual outbuildings, and the improvements effected for mining purposes. Much of the land has been cleared, a part remaining wooded. It has been known heretofore as the Albee mine, from its former owner, J. A. Albee. The principal outcrops are on a hill several hundred feet above the Connecticut, sloping northerly. The eastern slope is precipitous. The veins are hence well situated for exploration by cross-cuts, or through a drift following the course of the metalliferous rock. The rocks are mainly argillitic schists carrying bands of cupreous ores. There are three distinct metalliferous belts, divided by two greenstones (or sandstone, as called by the miners). Their character is indicated at the surface by yellowish-brown ferruginous stains. When these are dug into, iron or copper pyrites invariably show themselves. The most western of these belts is 178 feet wide, measuring from a point close by the shaft-house. A small opening upon this belt, several hundred feet to the south-west, shows copper. The middle belt is 87 feet wide. A shaft 78 feet deep is on its west side. It was not practicable to descend this opening at the time of my visit (October 5, 1877); but the piles of rock about the shaft-house reveal the nature of the materials brought up from the lowest depth. The vein matter is a mixture of slate and quartz, with bright yellow copper sulphuret conspicuously disseminated through it, in company with pyrites, or mundic, and a few crystals of ankerite. The ore pile contains over 100 tons, showing well in copper. It was said that the whole width of the vein had not been disclosed at the bottom of the shaft. Near the copper ore are piles of compact pyrrhotite, somewhat cupreous and perhaps auriferous, which came from the upper part of the opening. My report for 1869 made the following statement respecting this property, based upon observations upon this opening: "On Albee's land several openings have been made, in one case 20 feet deep. There seems to be a sprinkling of copper in the schist for a width of 30 feet; and near the lower edge of the cupreous rock is a solid mass of iron and copper pyrites three feet wide, the former mineral preponderating. These features are promising for a good mine. The Cornish miners prefer to see the iron pyrites or "mundic" very abundant at the surface, knowing by experience that the copper pyrites gradually takes its place according to the depth of the excavations. Our observation satisfies us that this rule holds as good in North America as in Cornwall." A gentleman who descended the shaft recently told me that the copper-bearing vein varies in width from six inches to eight feet, and the ore differs in quality from 1⅞ per cent. at the surface to 28½ per cent. at the depth of 60 feet. To the south-east of the shaft are 150 feet of metalliferous schists, belonging to the eastern belt, extending from the eastern sandstone to the edge of a precipice. Two openings showing copper ore have been made in it,—the first, 25 feet across it, and 5 or 6 in depth; the second, 6 or 7 feet long, 40 feet nearer the precipice. If these openings were connected, the whole distance would probably present the same cupreous color. These beds dip from 70°–75° S. 60°–70° E.

Since my visit, the shaft has been sunk to 70 feet depth, and a new one commenced farther east and excavated 50 feet. The company consist of energetic capitalists from Portland, Me., and they propose to sink 150 feet further in the new locality.

The Gregory Mine. This is situated in the eastern copper belt, upon a ridge 4,000 feet easterly from the Gardner Mountain mine, and separated from the former by a valley 250–300 feet deep. In 1869 I made the following statements respecting it:

"The only copper opening on the eastern belt in Littleton is at Mr. Little's, near the town line. A shaft 18½ feet deep has been sunk in the centre of a mass of copper-bearing schist 40 feet wide. The richest portion of this mass is a vein six or seven inches wide, which at the bottom of the shaft has expanded to nearly three feet in average width. The general appearance of this property reminds one of the rock worked near Lennoxville, P. Q., on what is known as the Clark mine. On the Little estate the vein must extend for 150 rods, and the surface descends rapidly to the Connecticut river, so that a fine opportunity is here presented for the excavation of an adit along the course of the vein, which will both drain the shaft above and prove the value of the rock for a considerable distance."

In September, 1877, I found the mine in possession of gentlemen from Maine, who were at work sinking the same shaft I saw in 1869. It had then reached the depth of 60 feet. Another shaft, 78 feet distant, has been sunk in the barn to the depth of 53 feet: and a drift has been started to connect them together, the space not excavated being only 16 feet. In the south shaft there is a drift northerly 25 feet at the depth of 30 feet, and 18 feet to the south at the 25-feet level. At the bottom of this shaft a breadth of two feet contains much copper associated with quartz bunches. The rest of the space in the shaft has more or less of the ore scattered throughout. Neither wall was seen, the sinking having been prosecuted with the idea of reaching as great a depth as possible, without reference to its bounds. The large pieces brought out of the south shaft make the most brilliant specimens of any seen in the range, there being very little iron pyrites to lessen the bright yellow color. Large piles of ore are found in the barn and yard. One lot of twelve tons of seven per cent. ore has been sold from the barn shaft, and much remains there dressed to about the same proportion. There is no shaft-house except the barn, but a very good boarding-house for the miners. We traced the vein northerly upon the crest of the hill, the manifestation of it there consisting of pyritiferous schists. The width of the best part of this vein is thought to be six feet; and the two walls, when seen, consist of the homogeneous "sandstone" of the country. The hoisting is done by horse-power; and there is considerable water in the mine.

During the past winter, work has been continued. A drift has been driven 30 feet into the hanging wall, in order to determine the width of the vein. Ore was found sprinkled through the whole distance.

Haviland Mine. This mine is situated on the Bath line, on the road from Lisbon to McIndoes Falls over Gardner mountain. It embraces a tract of land amounting to 160 acres, partly wooded and partly suitable for pasturage. The shaft-house is half a mile back from the highway. The argillitic schists usually dip about 70° S. 40° E. Narrow bands of diorite rock or "sandstone" are interspersed with pyritiferous schists. At the time of my visit, September 27, 1877, the shaft had been sunk 169 feet, sloping with the vein, steeper at the top than at the bottom. It is in a pyritiferous belt 200 feet wide at the surface. At 70 feet is a short drift, where copper ore is disseminated through the schist. At 168 feet the rock has been cut 40 feet below the lower wall, and 30 feet towards the hanging wall. Through this 70 feet of cutting, seams of cupriferous mundic and copper sulphurets are constantly met with. There is a marked improvement over the surface rock in what has been brought up from the lowest depths. Four veins cross this land,—one to the east, and two west from the shaft. Two or three other openings upon this land show more copper than at the shaft. This shaft has been sunk through the sandstone belt, which is 13 feet wide at 160 feet. The schists on the east are 100 feet wide before striking the next sandstone beyond, which is the most eastern copper belt.

During the winter of 1878 work has been continued, and the shaft is now down 200 feet. At the 60 feet level is a drift of 30 feet; and at the 100 feet level is another drift 40 feet long. The mine is named from F. P. Haviland, of Waterville, Me.

Stevens Mine. This lies near the north line of Bath, to the south of the Haviland. It contains 130 acres of tillage, pasturage, and woodland, and lies upon the southern slope of the Gardner mountain range. In coming from the Haviland mine the contour lines show a slight change in the direction of the mountain.. The mining improvements consist of a small boarding-house, shaft house with a shaft 100 feet deep (Sept. 26, 1877), cross cut 150 feet long at the bottom, and four other small openings in various places.

The shaft follows down a band of cupreous schists several feet wide, the angle of descent being greatest at the top. Three prominent bands of copper ore are seen at the surface, gradually widening in the descent, each one being twelve inches, and solid at the bottom. Prof. Bartlett's assay gives $37 worth of gold to the ton as coming from the pyrrhotite in these seams. There is a large pile of this ore outside of the shaft house. About 200 feet west is another vein showing copper ore along a breadth varying from two to eight feet, the gangue being white quartz with the mineral scattered through it, instead of cupreous argillitic schists, as in the first instance. This has been opened some ten or twelve feet in depth. There is a third vein about 150 feet east of the shaft, which can easily be reached underground from the main shaft. A fourth vein occurs 400 feet east of the shaft. Thus three veins are reached by one shaft less than 400 feet apart. In April, 1878, I learn that the cross cut 100 feet deep has reached the vein to the west, and ore is being raised from it. The "silver vein" is an opening on the southern slope to the west of the copper excavations. There is here a trench 25–30 feet in length, displaying a vein of galena 18 inches wide. Several barrels of this ore have been taken out. It is said to contain, of silver, $50 to the ton. It is of value in the future development of the country in connection with the argentiferous veins at the Paddock lead and copper mines. An unusual feature of the Stevens property is the occurrence of numerous boulders of copper and iron pyrites on the south slope. By reference to the maps it will appear that the main ridge of the Gardner mountain is bent to the east as it passes into Bath, and diminishes in size. It is on that southern slope that these boulders occur, noticed even twenty-five years ago. Such stones have not been observed on the eastern slope of the mountain all through Lyman. While it is possible they may have been derived from the veins to the north, the laws of boulder distribution imply their derivation from some locality near at hand, perhaps not north of the Bath line. Their occurrence recalls the discovery of the valuable mines about Capleton, P. Q., from similar indications. The presence of cupreous boulders on a similar south slope led to a search for their source, and the vein was discovered quite near at hand, and proved to be richer than any others in the district.

Paddock Company. This is the largest of all the copper companies, embracing partly in fee simple the entire land and partly the mineral rights upon four of the original lots of the town of Lyman, and therefore supposed to contain 1200 acres. The course of the veins is more than three miles in length, reaching from the Titus farm upon the south to an unoccupied tract called on our map the Penhallow lot. J. H. Paddock, Esq., of St. Johnsbury, Vt., is the principal proprietor, and the manager of the mine and mill. He has brought together several of the tracts known ten years ago as the Oro, Osgood, Osborn, New Hampshire Silver Lead Co., etc. What were formerly the Oro and Osgood openings are now the No. 1 and No. 2 shafts of the Paddock mine. Concerning these two mines, I wrote as follows in 1869:

"The next is called the Osgood mine, embracing about 700 acres of the land on the east slope of Gardner's mountain. I examined four or five openings. The first, near the south line, was ten feet deep, exhibiting five feet width of copper schists. The second shows a width of ten feet of copper schists. The third is a shaft thirty-five feet deep. Eighty feet below is a short tunnel eighty feet long, and designed to cut the vein. A large pile of good specimens of this copper may be seen near the shaft.

"The next north is the Oro mine. Here is a shaft sixty-five feet deep, a shaft house, easily seen from a great distance on account of its conspicuous position, two drifts fourteen and sixteen feet long, and a vein from four to seven feet wide, carrying more ore near the hanging than the foot wall. Sixty tons, part yielding 10.80, and part 9.+ per cent. of copper, have been shipped from the mine to Boston. There are one hundred and seventy-five acres of land connected with this property, and the vein is eighty-eight rods long."

I have visited the No. 1 shaft several times during the past nine years, watching with interest the progress indicated. Work has not been done continuously. It may be sufficient to mention the present [April, 1878] aspect of the excavation. All the laborers have been transferred to the No. 1 shaft for the purpose of developing that one more rapidly than if two were being exploited at the same time. Seven miners are at work under the superintendence of Capt. Francis Bennett, recently of the copper mines about Lenoxville, P. Q. The depth of the shaft is 170 feet. It follows the vein very nearly in its course. Extensive levels are situated at ten and twenty fathoms depth. Ore has been taken from one or both of these for a distance of 80 feet lengthwise of the vein. It has been proved that the vein is continuous for the distance of 80 feet, though not perfectly straight. There are two well-marked bendings exhibited, the arc of the curve pointing easterly, and these were seen to correspond with eastward thrusts of a dolomite band at the surface. These irregularities recall the similar varied courses of the auriferous conglomerate in the east part of the town (see map, page 296, Vol. II), though much less extensive. Without doubt the careful exploitation of Gardner's mountain in years to come will reveal bends and fractures corresponding with those in the east part of the town. There are other cross cuts in the No. 1 mine confirming the truth of the continuity oft he vein, and, by inference, its probable extent indefinitely in both directions. At present a large body of ore is in sight near the twenty fathoms level, and it is being rapidly brought to the surface. The good ore occupies a width of from four to six feet. Quite recently Capt. Bennett has discovered along the foot wall a vein of silver-lead, referred to above. This is more extensive and persistent at the twenty than at the ten fathoms level, being often ten inches in width, with the quartz gangue included. Zinc blende or black jack had been noticed before as an occasional product, but it is now found to accompany the galena, the latter increasing with the depth. The discovery is of great importance, as it may lead to the development of silver mining along the mountain. The copper vein is composed of grayish-white quartz, much harder than the greenish schists adjacent. Similar veins occur in the other mining properties on the range, some of which may be the continuation of this. The map shows at least six parallel veins upon this property. One is characterized by the grayish-white quartz present; another exhibits more of a slaty aspect, as at No. 2; a third is a mass of pyrrhotite. The others are intermediate in character between the first two mentioned. The third is known as the mundic vein, and has been followed for more than a mile along the east foot of the mountains. It is slightly cupreous, and may prove to be richly so at a considerable depth, if it resembles similar veins in other metalliferous districts. The amount of ore produced from the No. 1 shaft previous to 1874 is thought to have amounted to 300 tons. Much more than that has been taken out since; but I understand the aim has been to develop the mine, to learn the extent of the veins, rather than to raise a large amount of ore. A road has been built to connect both the shafts with the mill, a mile and a half distant.

At the No. 2 shaft the adit is now 90 feet long, and the veins at the surface overhead have been extensively uncovered. A most interesting feature is the existence of a small cross vein, cutting the strata two feet wide where thickest, and uncovered for eighty feet up the mountain. It contains more copper than the regular vein. Possibly it may extend to join a vein about 170 feet further up the mountain, and but slightly exploited. This and the galena vein on top of the mountain are the only cross veins yet discovered, but as time progresses others will be discovered much larger and more important than these. From these, we may conclude that these copper beds are properly fissure lodes, though so commonly conformable to the stratification, and therefore more highly esteemed. At one visit I saw about 150 tons of dressed ore near the mouth of the adit thought to average 6 per cent. of copper present. It was found that this ore would roast much more quickly than that occurring in the Vermont mines, as at Vershire and Strafford. They differ also in containing an excess of silica rather than iron. For similar reasons, one accustomed to estimate the percentage of copper in the Vermont ores will be inclined to undervalue the worth of the New Hampshire product.

Concentration of Ores. It may be well to anticipate the proper order of description, and mention the contrivances employed by Mr. Paddock to reduce the bulk of the copper ores while increasing their value. It is of no use to send to market lean ores, because of the expense of transporting worthless rock. Hence various methods are in use to concentrate them. The oldest method is to pick out the best pieces and throw away the poorer ones. In this way these ores may be easily brought to 8 or 10 per cent. valuation. When the metal is very abundant, another process reduces the ores in a furnace by smelting to a matt of 40 or 60 per cent. copper, and thus saves a great deal in transportation. Another method, well adapted to the New Hampshire ore, is to remove the copper by a wet process of extraction. This will be mentioned soon in detail. Still another plan has been adopted by Mr. Paddock. The ore is pulverized, and the copper ore separated from the lighter worthless rock by virtue of its greater weight. Wet and dry jigs are used for this purpose, and the results appear to be satisfactory. The ores are concentrated to 15 or 20 per cent. in this way, very cheaply, and are in excellent condition for smelting.

To carry on this business a mill is required, estimated to cost, with all the apparatus, if set up new, about $17,000. There must be an engine, a crusher, apparatus for elevating the crushed rock to an upper chamber where sieves may classify the material into several sizes, and the dry and wet jigs. I will briefly describe the process as it is being carried on at the mill in Lyman. An engine is at work driving a rock-crusher, elevating the powdered rock, shaking both jigs, drying the wet products, and for other purposes. It requires the services of one person to keep the engine in order, and a second to furnish rock for the crusher. In the upper chamber are sieves separating the pulverized rock into five parts; first, the coarser pieces, which are made automatically to descend to the wet jig in the basement; second, three grades of coarseness, suitable for the Chubb concentrator, or dry jig; lastly, the slums or dust, which is too fine to be separated by either of the jigs. No attendance is required to separate these different grades and carry them to their proper places; the business is attended to by machinery. The Chubb separator is a patented contrivance, making use of intermittent air puffs to classify the material into three parts; first, the ore concentrated to its utmost extent; second, the worthless material fit only to be thrown away; and third, the middlings, a mixture of the other two kinds, which is made to go through the machine a second time. Without technical description, this apparatus may be styled a trough about 4 by 2 feet, placed over a bellows blowing 300 to 500 times a minute, according to circumstances. The air is forced through a perforated metallic plate, and the box is at the same time skaken. By these means the pulverized ore is separated into the three kinds of powder mentioned, according to relative weight, and gradually slides to the lower part of the boxes, the separation being facilitated by a slight inclination and the presence of diagonal partitions of metal strips. An attendant watches the delivery of the product into boxes, properly separating the three kinds with the assistance of movable partitions. One person can easily attend to the three machines employed in the mill, and perhaps as many as five. It is his business also to remove the boxes receiving the finished products as often as necessary, put the ore into the barrels provided for it, the refuse into its place, and the middlings back into hoppers. Meanwhile, another person in the basement watches the wet jig, where large sieves filled with the coarser rock are jigged underneath water, and the heavier parts sink to the bottom. In a short time the worthless material is thrown away, the heaviest put upon a steam-heated table and dried, preliminary to package in barrels for transportation, and the middlings saved for another washing. I have examined the tailings left from both kinds of jigs, and observe that scarcely any ore escapes. Both processes separate the ore very carefully, and the waste is only slight. One grade of the ore remains,—the dust or slums. At present this is preserved for experiment, as the best method of saving the copper ore in it has not been perfected. Tossing in water is recommended, and will perhaps be the most convenient method of separation. It seems to me that a wet chemical process might be used to good advantage, such as will be described presently.

I have been greatly pleased with the results obtained practically by this mill, and think that the processes employed will enable our mining companies to utilize their poorer ores to better advantage than before. I understand that the Chubb patent embodies peculiarities not existing in any other separator, and is better adapted than any other machine for this class of ore. It has been in use many months in Lyman, and has successfully treated as much as 100 or 200 tons of ore, so that its value has been well tested. In case it should be taken for new localities, it is recommended that it be placed at the mouth of the mine, and thus save any unnecessary transportation of the ore before concentration, and the steam-power could also be utilized for hoisting purposes.

Quint Mine. A mile or two east of the Gregory is the Quint or White Mountain copper mine, in Littleton. No copper property in this region had been so thoroughly explored as this in 1869; several buildings have been erected for shaft-house, whim, dressing-sheds, etc., and the main shaft has been sunk to the depth of one hundred feet. It was impossible for me to examine the character of the rock below the surface, as all the excavations were filled with water; but, judging from external appearances, the vein must be from six to eight feet wide, composed of white quartz with copper sulphuret, iron pyrites, chlorite, and ankerite disseminated abundantly through it. On account of the contrast in colors, very beautiful hand specimens may be obtained here. The location is a poor one, so far as drainage is concerned.

Other Properties. There are many other farms where copper has been found, and, in some cases, extensively opened. There were three examined north of the No. 1 shaft of the Paddock company in 1869, known as the Stevens and Nason, Locke, Swan and Garland, and now belonging to Mr. Paddock. All of them showed excavations a few feet in depth, a mixture of the usual iron and copper pyrites in the schists several feet wide.

Dr. Jackson examined copper upon Lang's property in Bath, adjoining the Stevens mine. From his reports I condense the following facts: Two veins occur crossing at right angles, north-east and north-west courses. One of them is from one foot to eighteen inches wide, the other thicker. A detached block of pure ore, two and a half feet in diameter, was found in the meadow. A single blast afforded 100 pounds of 20 per cent. ore.

Farther south, as shown on the map, are three other copper locations. The most southern on the crest of the mountain is called the Forsaith mine, containing 140 acres, showing quite a number of small openings, all of them showing copper ore.

There are several openings in Monroe, on the west side of Gardner's mountain. I have presumed the copper belt is repeated here, and the cupreous schists occur in many places, though comparatively little work has been done. The largest opening is upon the Bald ledge, operated several years since by Mr. Paddock. The best part of the copper schist is six feet wide, containing, in addition to the usual minerals, zinc blende and obliquely crossing veins of quartz. The shaft-house is very high up, so that the vein could be well drained to a considerable depth. The shaft was sunk to the depth of 80 feet. Ten tons of 10 per cent. ore were the result of this exploitation. Farther west, down the hill, is another vein, possibly connected synclinally with the ore high up.

In Littleton and Dalton are two openings, showing the purple and gray ores of copper. One is on Wheeler hill, and the other is known as the Dalton mine, where work has been performed under the direction of J. B. Sumner, Esq. The rock of the country is clay slate, but the gangue of the vein is a species of talcose schist, containing a little yellow copper and minute particles of magnetic iron. The walls of the Dalton mine are very distinct, about sixteen feet apart. The gangue is traversed by cross veins of quartz, often carrying fine specimens of the purple ore, or *Bornite.* A shaft has been sunk about twenty-five feet deep upon the vein, and a few openings have been made as far as 200 or 300 feet north of the shaft-house, sufficiently to prove the continuation of the vein. Similar proof exists of the presence of copper, perhaps the same vein, half a mile in the other direction. This property is upon the top of a hill. It is conveniently situated with reference to water-power, being near the Connecticut and one of its tributaries, so that the ore taken from the mine could very easily be concentrated at slight expense. An average sample of the whole vein sent by Mr. Sumner gave to Prof. Seely 5.4 per cent. of metallic copper.

Copper in Milan. Similar ores to those of Gardner mountain have been discovered lately in Milan. The formation is the same. I have examined several openings. First is that of Nathan Fogg, a short distance east of the Grand Trunk Railway. The vein dips 70° N. W. A pit has been sunk in it about fifteen feet, close by a small brook, and the ore shows well for a width of thirteen feet. It is a massive mixture of copper and iron pyrites, with galena and blende, without much gangue. A fair average gave C. W. Kempton 5.3 per cent. of copper. Immediately adjacent to the foot wall is a pretty string of argentiferous galena, half an inch wide. The upper part of the vein also shows much galena and bright bunches of copper. An assay of the average under my supervision yielded a trace of gold and 2.65 ounces of silver to the ton. Excavations prove the continuation of the vein for at least 200 feet, and in one place there is a width of 40 feet of pyritiferous schists connected with the vein. The situation is very convenient to railroad transportation.

On the hill west, Mr. Nay has opened a seam running north-west, though tending to take the north-east course of the strata, which contains argentiferous galena. Mr. Nay has uncovered the rock in several places, but had not proved the value of the property at the time of my visit in August, 1877.

On Hodgdon's land, to the north, is the Twitchell and Mason mine.

They have cut into pyritiferous schists, sinking upon a vein six feet wide, richer than the usual mass of 40 feet thickness. Many bunches of copper were taken out, and I understand from F. L. Bartlett, of Portland, that nickel is present in the ore.

On Cate's hill, in Berlin, is a vein showing the minerals pyrite, chalcopyrite, bornite, magnetite, hornblende, and tremolite. The ores are sparsely disseminated.

This region promises well to the explorer, and it will doubtless be heard from in the future. Our map shows that the rocks continue here from the Ammonoosuc district, though interrupted by intrusive porphyries.

THE WARREN MINE.

In the gneiss of Warren there is a bed of tremolite more than fifty feet wide, in connection with which is a vein of copper and zinc. Mica schist, dipping 45° N. 50° E., encloses the bed. Veins of pure copper ore with reticulations of quartz abound in the hanging wall, and a bed of the same material occurs along the line of the junction of the tremolite and schist. Veins of the copper, bunches of iron pyrites, and a resplendent black blende occur also in the midst of the tremolite, as well as a little rutile. Most of the tremolite carries copper pyrites, and the rock must be stamped and washed to allow of separation. The annexed plan shows the mutual relations of the three trap dykes, veins of quartz, and the ore vein. It was prepared by Mr. Huntington, and is not drawn to a scale.

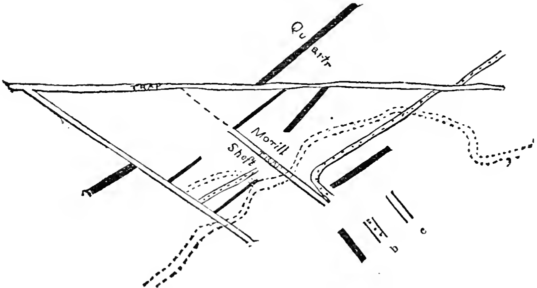

Fig. 7.—PLAN OF THE WARREN MINE.

a, Quartz ; b, Ore vein ; c, Trap.

Considerable work has been done upon this property since 1840. The tremolite does not occur with the copper at great depths. Latterly the zinc predominates, and there is a little galena. At the time of my visit the mine was full of water, and I could learn little in addition to what has been presented. I made the following statements respecting it in 1869:

> The Warren zinc mine is now under the management of Capt. Edgar. It has been known for twenty years as a copper mine, but as the vein has been followed downwards the zinc has to a considerable extent increased at the expense of the copper, and it is for the zinc chiefly that the mine is now wrought. The principal vein is of quartz, ten feet wide, crossed by a mass of the mineral tremolite. The hanging wall is a sandstone, the foot wall micaceous slate. To the depth of twenty-five feet, copper ore and galena predominated. Below that point, to the bottom of the excavation, one hundred and fifty feet, the zinc is the most abundant, amounting to one half. At the bottom the vein is twenty feet wide, and there is a drift one hundred and eighty feet in length. There seems to be a "pipe" or "chimney" of pure ore in the vein, sometimes fifteen feet thick and twenty broad, which is the most valuable part of the metallic sheet. It does not proceed on the direct line of the dip, but passes down about ten degrees from it.
>
> At present (1869) the ore is first sent to the Lowell Bleachery Company, Mass., where the sulphur is removed and converted into sulphuric acid. The residue then goes to Bethlehem, Pa., where it is smelted into spelter.

Since 1870 the mine has not been worked. It is owned by Horace Brooks, of Franconia.

COPPER MINES IN SOUTHERN NEW HAMPSHIRE.

Within a few years a new impulse has been given to mining for pyrites, on account of the sulphur contained in it, for the manufacture of sulphuric acid. This is used in bleaching, fabrication of artificial fertilizers, and a hundred other ways. Quite recently, chemical works for the utilization of sulphur have been established about the principal cities, and there is a great call for the ores containing sulphur. By the burning of the ore,—a sulphuret of iron,—the sulphur takes oxygen from the air, becoming sulphurous acid. This is condensed in water in leaden chambers, where an additional atom of oxygen is added, and the resulting compound is sulphuric acid. One of the principal sources of this pyrites is Strafford, Vt., where copperas has been manufactured for the past fifty years. From that single locality on Copperas hill, thousands of tons of ore have been sent to market. The species is pyrrhotite, containing 39.5 per cent. of sulphur, and is therefore less valuable than common pyrites, which has 53.3 per cent. of sulphur.

There are several veins of pyrites in New Hampshire that can be successfully mined for the manufacturing establishments, especially as copper is usually associated with them. These veins are also nearer the market than those of Vermont, which are now mined so largely. Perhaps the most important of these is in the south-west part of Croydon. This has been visited twice,—in June, 1869, and May, 1870. The results of our examination are briefly these: The rock is micaceous and gneissic, one of the sub-divisions of the White Mountain series probably. It is elevated two or three hundred feet, on the south-east flank of Croydon mountain. Higher up is the quartzite, dipping at a high angle to N. 65° W. It probably overlies the sulphuret schist unconformably, as it certainly does three miles farther north, the latter dipping 80° W. 10° S. One or two hundred feet east of the vein is a white gneissic rock, carrying an unusual amount of mica. This is parallel with it, and may be used as a guide in tracing it through the country. In this way the vein was followed for three fourths of a mile to the north, and from what was said to us, it is judged to extend equally far to the south. The vein has been opened to the depth of twenty-five feet. It was full of water at our first visit, but was drained at the second visit by means of a syphon. The vein mass is uniform in its width and composition. Next the hanging wall is six inches width of slaty layers, holding both copper and iron pyrites. Next succeeds two feet thickness of magnetic pyrites, or pyrrhotite, very compact, solid, and nearly pure. There is no foreign mineral present except small nodules of quartz. Next follows one foot ten inches of the same, less compact. Fourthly, is two feet thickness of gangue of quartz, or a micaceous mass carrying a large proportion of copper pyrites and zincblende. Below all this is a slaty mass three or four feet in thickness, similar to the upper layer, carrying considerable pyrites, which possibly may be utilized. The second, third, and fourth of these layers are valuable, and united amount to six feet in thickness. By Prof. Seely's determination, the sulphur in No. 2 amounts to 37.68

per cent.; in No. 3, to 38.10 per cent.; and in No. 4, to 19.35 per cent. No. 4 also contains 3.17 of copper and 16.62 per cent. of zinc.

On examining the veins to the north the sulphurets are found cropping out on the surface for one or two hundred feet, and the vein itself can be traced on the property nearly to a house eighty rods distant. Further tracing was not attempted in that direction. It is common for this vein to be cut by irregular veins of white quartz.

The outcrops are on a steep hill, perhaps three hundred feet above a comparatively level tract. Thus the vein could be easily drained, whether an adit be driven into the hill at right angles to the vein, or from the north and driven in on the vein itself. This site is less than three miles in a gently ascending country from Northville (Newport), on the Concord & Claremont Railroad.

Neal Mine. Next in value is the Neal mine in Unity. This has been visited three times. It is owned by the Neal family, and is about four miles from North Charlestown. The vein has been described in Dr. Jackson's report. It is a mixture of iron and copper pyrites, nearly three feet wide, and has been traced fully 2,200 feet in length. Drainage can be effected to the depth of seventy feet. The vein dips 78° W. 10° N. It has the same geological position with the Croydon mine, lying near the western border of the gneiss, and if the ores were mixed it would be difficult to distinguish many of the varieties from each other. It is probable that the ore would all become copper pyrites at 100 feet or more below the surface.

There are other interesting veins on this property, but it is only sufficient for our present purpose to say that the pyrites can be as profitably mined for sulphur here as at Croydon, and if copper or other valuable metals should be ultimately discovered in abundance, it might be wrought for them also.

Other veins carrying considerable amounts of pyrites, which are all worthy of exploration with the hope of successful results, are the King property, upon C. Houston's land, in the south-east part of Hanover; the land of J. W. Cleaveland, of East Lebanon, in the north-west part of Enfield; in the south-west part of Lebanon; Dr. Hubbard's mine on the Jackson farm, in the south part of Claremont. On account of the great value of this ore in the manufacture of fertilizers, it is to be hoped that these veins will be thoroughly explored, the market well supplied with sulphuric acid, and thus both the mining district be benefited and the prices of the phosphates be reduced, and the whole community reap the advantages of lower prices of fertilizers.

THE HUNT AND DOUGLASS PROCESS.

Other localities of copper are numerous, especially in the Connecticut valley, as in Haverhill, Orford, and Lyme. These and others are mentioned in the catalogue of mineral localities in Part IV. Some of them may prove valuable as mines after exploitation, especially one on the west flank of the hill between Mts. Cuba and Smart.

Copper is reduced at West Fairlee, Vt., by smelting. The ores of eastern Vermont and those in New Hampshire south of Woodsville, belong to a different formation from those mentioned in the Ammonoosuc district,—the Coös instead of the Huronian. Some authors, especially the managers of mining companies, inform the public of their identity. But an examination of the rocks associated with the two will show that our copper veins belong to at least three distinct periods. Our ores are usually low grade, and hence can be easily reduced by a wet process cheaper than by smelting. Having investigated the merits of the Hunt and Douglass process, I think it one well fitted to reduce our ores, and herewith present a brief notice of it, compiled from an authoritative sketch in the *Mineral Resources west of the Rocky Mountains*, for 1876:

This is what is technically called a wet method, because the copper is removed from its ores in a dissolved state, the solvent employed in the present process being a watery solution of neutral proto-chloride of iron and common salt. Most oxidized compounds of copper,—whether obtained artificially by roasting sulphuretted ores, or found in nature in the form of carbonates and oxides,—when digested with such a solution are converted into a mixture of proto-chloride of copper, which are dissolved, while the iron of the solvent separates in the form of insoluble hydrous peroxide of iron. When the solution of chlorides of copper thus obtained is brought in contact with metallic iron, the copper is separated in a metallic crystalline state, while the iron passes into solution, reproducing the proto-chloride of iron, thus restoring its solvent powers to the liquid, which we shall call " the bath," and fitting it for the treatment of a fresh portion of copper ore. This process of solution and precipitation can, under proper conditions, be repeated indefinitely with the same bath, the only reagent consumed being the metallic iron.

The chief advantages which wet processes possess over smelting lies in the economy of fuel. To extract copper from a low grade ore by smelting, five or six furnace operations are necessary, and about one ton of coal is consumed for each ton of ore treated; while for the various wet processes, a single calcination, in which not more than 300 weight of coal is consumed for each ton of ore, is the only furnace operation required to obtain the metallic copper in a precipitated form known as *cement copper*. An important item of cost in wet processes is the metallic iron employed to separate the metallic copper from its solutions. The same amount of iron is required to precipitate a ton of copper, whether extracted from a poor or a rich ore; but as for the smelting of the latter much less fuel is required, it follows that rich ores are generally treated by smelting rather than in the wet way, any saving of fuel in the latter being more than compensated for by the cost of iron. No general rule, however, can be laid down to determine what grade of ore can be more profitably treated by one method or the other, inasmuch as circumstances of locality, affecting the cost of fuel and the price of iron, must in each case be taken into account.

The various other wet methods of copper extraction may be divided into two classes: those in which the previously oxidized ore is treated with hydrochloric or sulphuric acid to dissolve the oxide of copper, and those in which sulphuretted ore, generally after a preliminary roasting, is calcined with an admixture of sea-salt or sulphate of soda, by which the copper is converted into chloride or into sulphate. All of these methods, when properly applied, effect a pretty thorough extraction of the copper; but the cost of the reagents which have to be added to every charge of ore precludes altogether the use of some of these methods, except in certain favored localities, and renders them in almost all cases, it is believed, less economical than the present one with the Hunt and Douglass bath, for which the following advantages are claimed:

I. It is a general method adapted to all compounds of copper, while that by calcination with salt is only applicable to sulphuretted ores.

II. It does not require the addition of reagents, such as acids, salt, or sulphate of soda, to each charge of ore, since in the regular course of the operation the solvent required for the treatment of the ore is constantly reproduced.

III. The bath employed being neutral, certain impurities of the ores, such as arsenic, which passes into solution and contaminates the product in the wet processes, remain undissolved, so that a purer copper is obtained.

IV. There is no unnecessary waste or consumption of metallic iron.

Ores reached by this process. First, may be included the various sulphuretted ores, as copper pyrites (often mixed with iron pyrites) and the variegated and vitreous sulphurets, all of which are readily oxidized by calcination. Second, are the oxidized compounds of copper, such as the red and black oxides, the green and blue carbonates, and salts, like the oxy-chloride and silicates like chrysocolla. Third, are the deposits of native or metallic copper, which in almost all instances are most advantageously treated by mechanical means. The presence of carbonate of lime or magnesia is objectionable, since it decomposes the proto-chloride of copper, and thus indirectly precipitates the iron from the bath. The action of oxides of lead and zinc, which come from the roasting of blende and galena when these are present in the ore, produces a similar effect. When not too abundant, the effect of all these substances may be corrected by careful roasting.

Practical workings. This process was first worked continuously for a year at the Davidson mine in North Carolina. The ore, a pyritous copper in a slaty gangue, was dressed up to 5 or 6 per cent., crushed, roasted so as to contain about one fourth of its copper as sulphate, and treated in stirring-vats in charges of 3,000 pounds. The loss of copper was from .3 to .5 per cent.; and the bath maintained its strength in chloride of iron without the use of copperas or sulphurous acid. The amount of iron consumed was equal to 70 per cent., and the salt to 25 per cent., of the copper produced. The entire cost of producing cement copper from the dressed ore of 5½ per cent. was estimated at 3⅔ cents per pound.

Next, six calcining furnaces for the treatment of twelve tons of pryitous ore daily were erected by the same proprietors at the Ore Knob mine in the same state. Up to January 1, 1875, over 200 tons of copper had been made there by this process. The cost of mining, making the copper, and all expenses, amounted to 8 cents per pound. These works were soon after enlarged to nearly three times their former capacity; but, in sinking below the water-line in the mine, the ore, hitherto free from lime, was found to contain 30 per cent. of carbonate of lime. This rendered it necessary to concentrate the ore by crushing and washing,—works for which have been erected.

At Phenixville, Penn., two sorts of copper ores are being treated by this process,—the one a magnetic iron containing about 3 per cent. of copper, the other a hydrated silicate. One ton of the first and four fifths of a ton of the second are now daily successfully treated at this locality.

The cost of the *plant*, or buildings and machinery required for the working of the process, is from $12,000 to $15,000. The details are given in the annexed letter from Dr. Hunt:

LETTER FROM DR. HUNT.

As you desired, I write you some notes as to our copper process, its cost and its advantages, compared with smelting or shipping ores, considered from the point of view of New Hampshire copper mines. I give, first, the cost of treating in a small work 12 tons of 2,000 pounds daily, and suppose the ore to yield 8 per cent. of copper, labor to be $1.25 a day, and wood $4 a cord:

For grinding (steam power), 1½ cords,	$6.00
Labor of 3 men, at $1.25,	3.75
For roasting, 4 cords,	16.00
Labor of 12 men,	15.00
Tank-house, 2 men,	2.50
Superintendent and chemist,	5.00
Scrap-iron, 1,300 pounds, at 1½ cents,	19.60
Three hundred pounds salt, and sundries,	4.25
	$72.00=$6 for 2,000 lbs. ore.

The cost of plant for the above, including a 32-horse-power engine, 4 furnaces, 21 tanks, and 2 pairs of rolls and buildings, has been, at Phenixville, $12,000.

To compare the above with shipping ore from Strafford to Boston. Let us suppose hauling and handling to station, $2; freight on railroad, $4.40=$6.40 per ton (the smelter's ton is 2,352 pounds). The wet assay of the ore is 8 3-10 per cent. copper, from which he deducts, according to custom, 1 3-10 cents, leaving 7 per cent. to be paid for at the present rates of $3.75 per unit.

10 gross or smelters' tons (23,520 pounds) of 7 per cent. ore at the above price will bring	$262.50	
Deduct for freight at $6.40 per ton, ...	64.00*	
		$198.50

The above amount of ore equals 11¾ net tons of ore at 8 3-10 per cent., in treating which in the moist way the loss will not be over 5-10 per cent., leaving 7 8-10 per cent. of copper to be accounted for, or 1,833 pounds. This, as cement copper, will sell for 21 cents when ore brings $3.75 per unit, equal to $384.93. But the treatment of the ore, as we have seen above, costs $6 the ton=$70.50, to which, for packages and freight to Boston, we may add $7=$77.50.

Deducting this from $384.93, we have for net return from the ore treated by the Hunt & Douglass process, ...	$307.45	
For the ore shipped as above, ...	198.40	
		$109.50*

To this we must add the consideration that the selection of ores of 8 3-10 per cent. for shipment involves a considerable loss, and that with rocks on the spot it would be advantageous to treat ores of much lower grade got with less labor in dressing. Deducting from the estimate above the cost of iron, which varies with the richness of the ore, we have for 12 tons $52.50=$4.38 the ton.

Suppose, then, we treat 20 tons of 5½ per cent. ore, to yield 1 ton (2,000 pounds) of copper, we have ($4.38 × 20) . .	$87.60	
Two thirds ton scrap-iron, at 1½ cents a pound, ...	20.00	
		$107.60

Thus the cost of producing 1 ton of copper from these low grade ores is only $107.60, while such ore would perhaps hardly pay the cost of shipping.

I have stated the principal points of interest to you, but have not referred to the use of tin plate scrap, which in most localities can be got for little or nothing, and thus save the cost of the scrap-iron, and materially reduce the cost of making copper. Our works here are not yet in full operation, but will be in the course of ten days. I shall

---

* I am told that the railways count but 2,000 pounds to the ton, so that the ten gross tons of ore would pay freight as 11⅓ tons, making freight $75.20, or $11.20 more than above, which sum must be deducted from $198.20 and added to $109, making the daily balance in favor of the Hunt & Douglass process $120.

be glad to hear from you further in this matter, and shall spend here the rest of the month.

Very truly yours, T. STERRY HUNT.

Phenixville, Pa., June 12, 1875.

Iron.

There are several localities where an abundant supply of this ore exists. At Franconia the ore was smelted for sixty years; and the iron manufactured is more highly prized than that made in other states. The remoteness of our state from the coal fields, and the decimation of our forests whereby the yield of charcoal has fallen off, have led to the abandonment of iron mining at Franconia.

The vein is of magnetic iron, associated with hornblende, epidote, garnet, mispickel, and other minerals. It is stated by Jackson to be from 3½ to 4 feet wide. It has been opened for several hundred feet on the steep south slope of Ore hill in Lisbon, and hence is unnecessarily exposed to accumulate rain-water. A shaft is situated low down, said to be 150 feet deep. At the upper end of the cut there is a curve in the vein, amounting practically to a bonanza, beyond which the direction taken by the vein is uncertain. A short adit on the west side of the hill beyond did not discover the vein, as was expected. The vein dips 70° S. 40° E. The rock on the west side of the vein is hornblende schist and gneiss.

Furnaces were erected for the manufacture of iron here in 1811, and continued in blast till 1870. Charcoal was the fuel employed. Dr. Jackson has given a full account of the special process of the manufacture of the iron, to which those interested are referred. It seems that the annual yield varied from 250 to 500 tons of pig iron, of which a part was reduced to wrought iron in a forge. The following figures expressed the cost of manufacture:

> The proportions used in charging the blast furnace were 15 bushels of charcoal, 5 boxes each containing 56 pounds of magnetic ore, one box of limestone for flux. The average daily product was 2½ tons of pig. From 200,000 to 300,000 bushels of charcoal were annually consumed, taking 160 bushels for each ton of iron made. Hard wood charcoal cost $4 per hundred bushels, spruce or soft-wood charcoal, $2.50 per hundred. The limestone cost $1 per ton. The ore cost $6 per ton at the furnace at Franconia village, two or three miles distant from the mine. The items were these: mining, $5;

hauling, $0.50; breaking, $0.50. The average product of cast-iron was 60 per cent. on the ore smelted, being a loss of 9 per cent. Jackson's assay was the following: magnetic oxide, 96.20, silica, 2.30, titanic acid, 1.50=100. Metallic iron, 69.04. Ten miners were employed at the rate of $15 per month. The pig sold in 1840 at the furnace for 2 cts. per lb., castings at 5 cts. per lb., and bar iron at 5½ cts. At the furnace 100 laborers were employed for six months, and half of them for the balance of the year. The furnace buildings and the miners' houses are still standing. From a detailed statement of the superintendent, the operations for 1838 showed an expenditure of $14,128.63; sale of pig and scrap, $14,594.98; sale of castings $7,309.12,—total, $21,904.10. Excess of receipts over expenditures, $7,775.47.

At the present day the mining could be effected more cheaply than in 1840. A miner living at Sugar Hill assured me of his ability to contract for the delivery of ore at the surface for $2 per ton, provided means were taken to drain the excavation. His plan was to open the vein so low down that the water would make no trouble.

Dr. Jackson mentions two other places in the state where the natural facilities for the manufacture of iron are as good as those at Lisbon, viz., at Bartlett and Piermont. The following sketch of the Bartlett locality is furnished by Mr. Huntington. The other statement is by a friend, who is well qualified to judge of the value of ore deposits.

IRON ORE IN BARTLETT.

A little south of west from the village of Jackson there is a high mountain ridge, the eastern extremity of which is known as Baldface. This ridge extends to the western slope of Mt. Crawford, but it is cut by the valley of Rocky Branch, and also by a stream, Razor Branch, in the western part of Bartlett. This ridge, for the most part, is a coarse granite, composed chiefly of feldspar and quartz, but it contains some mica, and generally manganese. In this granitic rock, in the northern part of the town of Bartlett and east of Rocky Branch, occurs the most extensive deposit of workable iron ore ever found in New Hampshire.

In the ridges that project south from the ridge just mentioned the granite is of a different texture, being more compact, and the feldspar, instead of being a light flesh-color, is a dull gray, and more distinctly crystalline. This rock forms the precipitous cliffs north of the road running from Jackson to Upper Bartlett. North of the granite containing the iron and forming the mountain south of the settlement in Jackson known as Green hill, the rock is a mica schist which passes into a quartzite. The schist dips N. 40° W. at an angle of 25°, and hence it rests upon the granite. On the eastern slope of the mountain is a schist entirely different from that which forms the mass of the mountains; and besides, it has an easterly dip, and it seems probable that it is the remnant of a synclinal axis that once filled the valley of Ellis river.

This deposit of iron has been known for many years, and was first noticed by Mr. Meserve. It was visited by Dr. Jackson, and is thus described by him:

"One of the veins at the upper opening measures thirty-seven feet in width in an east and west, and sixteen in a north and south direction. The second opening, two hundred feet lower down the slope of the hill, exposes the ore, maintaining the same width. Three hundred feet lower down the vein is observed to narrow, and is but ten feet wide, and four hundred feet farther down the width increases to fifty-five feet. Five hundred and forty-six feet lower still there is a small opening or cave twenty feet deep, where the ore narrows again. On searching to the westward of this great vein, at a distance of two hundred and fifty feet, we soon discovered a new one, which appears to be of the largest dimensions. * * * Forty-nine feet farther westward the soil is full of angular fragments of the ore, indicating another vein. It is evident that this mountain is intersected by a great number of veins of excellent iron ore, and will furnish an inexhaustible supply. It is proper here to remark, that it is composed chiefly of the peroxide of iron, combined with a small proportion of the protoxide, and it contains a little oxide of manganese. From the composition of the ore we know that it will make excellent iron and the best kind of steel."

Fifty tons of the ore were sent to Sampson & Co., celebrated English iron and steel manufacturers, who have reported favorably upon its good qualities. In my examination of this ore deposit, the measurements for mapping the property were made by Daniel Barker, Esq., of Bangor, Me. Starting from the most westerly outcrop on the slope towards Rocky Branch, we found the principal outcrops to lie in a direct line running N. 42° E., and the entire distance one hundred and seventy-five rods. The last outcrop on the east is six feet in width. Measurements of the openings on the west slope towards Rocky Branch were made by Dr. Jackson when the mine was first opened, and could be done much more exact than now. In several places, particularly north of the line followed, there are indications of iron, which may prove as extensive as the beds already opened.

An analysis of the iron ore by Mr. Williams is as follows:

Peroxide of iron,	69.4
Quartz and feldspar,	25.2
Oxide of manganese,	2.7

69.4 of peroxide, containing 48.117 per cent. of metallic iron.

Another specimen yielded,—

Peroxide and protoxide of iron,	77.25
Quartz and feldspar,	21.40
Alumina,	.15
Manganese,	1.20

Or 53 per cent. of metallic iron.

The masses of ore seem to be in vertical segregations. Consequently there is more uncertainty as to their extending to a great depth, than if the ore occurred in lodes in a stratified rock; but this uncertainty is in a measure counterbalanced by the large masses in which the ore here occurs.

Until recently this ore has been far from any means of transportation by railway; but now the Portland & Ogdensburg Railroad, which extends through Bartlett, will pass within three miles of the mine, and a branch road can be easily built up Rocky Branch to a point where a tramway can be constructed to the shaft, and thus the ore can be moved altogether by steam.

The following may be considered a fair estimate as to cost of mining and profits:

200 tons of ore per day, at $2.64 per ton, ...	$528.00
General expense, ...	50.00
Freight to Portland, ...	300.00
Entire cost, ...	$878.00
Value of ore at $6 per ton, ...	$1,200.00

which leaves a margin of $322 per day as profit on a capital not exceeding $160,000.

The following is an estimate for a day, provided the ore is smelted in the valley of Rocky Branch near the mine:

200 tons of ore, at $2.64 per ton, ...	$528.00
16,000 bushels of charcoal, at 8 cents per bushel, ...	1,280.00
30 furnace men, at $3.50 per day, ...	70.00
160 laborers, at $1.50 per day, ...	240.00
Limestone for flux, ...	100.00
Repairs, etc., ...	40.00
General expenses, ...	250.00
Freight on 100 tons of iron to Portland, ...	170.00
	$2,678.00

These figures, at the present (1871) price of pig iron, would leave a very large margin for profit, although the necessary outlay for the construction of furnaces, etc., would greatly increase the capital stock to be employed in carrying on the operations. The ore could probably be extracted, especially if it is done by open mining, at a much less cost than we have given in the above estimate, the location being favorable for this kind of excavation. The mine is owned by E. S. Coe & Co., of Bangor, Me.

The other statement is as follows, in a letter penned after two days of examination, dated November, 1873.

There is really iron upon Iron mountain, and some of the ore of excellent percentage; but it occurs the most capriciously of any iron I have ever come across, and the workings have not as yet revealed any reliable body of ore. In one of the little drifts, out of which apparently the greatest part of the rich ore has been taken, the rock seems barren on the right hand, and on the left, before you, and, strangest of all, under your feet. There is no vein; and yet, while the ore occurred pocket-like, it does not lie segregated in any wise from the containing rock, but passes into it on every side by imperceptible gradations. Appearances at some spots suggested the idea that the common rock of the mountain had been impregnated by the vapor of metallic iron rising from below at points where fissures and seams in the country rock permitted it. If this theory be correct, while there must be a large body of iron somewhere down below, all the ore anywhere near the surface would be in chimneys of entirely capricious distribution.

Piermont. On the road from Haverhill to Piermont, running due south-east from Haverhill Corner, a mile and a half from the village, a ledge of mica schist crosses the road, whose strike is N. 25° E., and the dip 45° N. N. W. Three miles out, a second ledge of the same rock crosses, having the same strike and dip, but here becomes more quartzose. This ledge shows striæ running 10° west of north. Three and three quarters miles out, a third ledge crosses, of the same rock, in which are quarries of flagstones and whetstones, the latter known as "Pike's quarry." The excavation here on the south side of the road shows the rock striking due north, and dipping 45° W.

Four and a half miles from Haverhill, in the north-eastern part of Piermont, Eastman's brook passes through the depression between Iron Ore mountain and the northern extension of Piermont mountain. At the falls in this passage is a saw-mill. That part of the ridge north of the stream, in which alone mining has been done, is likewise known by the name of Cross's hill. The first of the old workings, made thirty years ago, is in the open pasture, a few rods below the saw-mill and about thirty feet above the road, from which it is visible. A small outcrop of the ledge has been entered here to the depth of a couple of feet. About 70 feet above this in the edge of the woods is a second working, the most extensive, apparently, which was made. Here the ledge dips 25° S. S. W., with an outcrop of 12 feet perpendicular, in which the working was made laterally some 8 or 10 feet. The mountain, following the same general strike as this ledge, is on its north-west side seamed with numerous parallel outcrops, most of which lie above the one which has been worked. The summit is 250 feet above working No. 2; and from this point the ledge can be seen seaming Piermont mountain in the same manner on the south side of the stream, a quarter of a mile distant. Following the ridge north-easterly, about 50 rods from the end summit and some little distance below the ridge line, in the woods, is working No. 3. Half a mile north-east of the summit, in the edge of the open pasture, near the northern end of a small pond, is working No. 4. Here a cut has been made into the ledge transversely from a point five or six feet below the outcrop on the hillside. All these workings have been upon the same ledge, which runs persistently the whole distance, and indefinitely further with the extension of the mountain.

The rock of the mountain is quartzite, whose numerous outcrops have all the same general strike and dip given above. It is in layers, varying from half a dozen inches to as many feet in thickness, and is generally gray, though in some layers brown in color. At working No. 2, a few feet west of the layer principally worked, is a band one foot wide of pure white quartz, which would serve as an excellent guide in tracing this ore-bearing ledge. Very many of the layers have disseminated through them, in intimate commixture with the quartz, the peroxide of iron in its micaceous form. In the most highly impregnated layers the amount is sufficient to give the cleavage face of the rock the specular lustre and a black color; but its transverse face is a dull gray, from the superabundance of quartz. Most of the ore seems to have been taken out from a layer three feet wide; but this is not specially richer than its neighbors, and its impregnation varies in different places. Nowhere is there a true metallic vein.

The ore, while mingled with quartz beyond the possibility of washing, has none of those impurities which deteriorate the metal. The richest portions might yield as much as 60 per cent. of iron; but the vast mass of the rock would not average 30 per cent. Of the ore, such as it is, there is any amount, for the iron-bearing ledge could doubtless be entered anywhere in its course with substantially the same results as where it has been worked. The ore could not, under the most favorable circumstances, bear transportation.

At Winchester a magnetic ore, carrying 24.26 per cent. of metallic iron, occurs in three beds situated upon the opposite sides of a gneissic anticlinal, whence it is probable that six beds outcrop. The thickest is somewhat less than 40 feet, dipping 40° E., exposed for 200 feet. The smaller beds are five or six feet thick, opened about eight feet deep for 200 feet, and dipping 30°–50° W. These beds were wrought and abandoned before 1800, the ore having been smelted at Furnace village in Winchester.

Of other localities, Thorn mountain in Jackson shows several veins of magnetic ore in granite, from a few inches to two and a half feet wide, running N. 25° W. on the top, and N. 55° W. on the west side of the mountain. Dykes of basalt cut the veins, which afford 37.99 per cent. of metallic iron. The magnetic iron of Unity contains 62.6 per cent. of metallic iron; and the hematite of Lebanon 65.17 per cent. The hematite of Black hill, Benton, yielding 62.4 per cent. of metallic iron, is from six inches to three feet in width, and quite irregular, contained in a granular quartz. Bog ores of considerable amount, containing from 36 to 55 per cent. of metallic iron, are mentioned in the towns of Eaton, Barnstead, Charlestown, Haverhill, Lebanon, Milford, Lancaster, and Pelham. Additional localities of like account, of all three kinds, are in the towns of Warren, Haverhill, Bath, Landaff, Franconia (east part), Lyman, Dalton, Gorham, Berlin, Gilmanton, Moultonborough, Jackson, Pittsfield, Barnstead, Merrimack, Bedford, Amherst, Lyndeborough, Peterborough, Swanzey, Gilford, Freedom, Grafton, Eaton, Enfield, Canaan, and Orford.

The following table gives the results of Dr. Jackson's analyses of iron ores from various parts of the state, some of them said to be of considerable importance:

	Peroxide of iron.	Silica.	Titanic acid.	Vegetable matter.	Manganese.	Sulphuric acid.	Loss, and water.	Metallic iron.
Thorn mountain, Jackson	54.8	43.6	......	......	......	......	1.6	37.
Unity—magnetic	90.4	4	6.8	......	......	......	......	62.6
Winchester—magnetic	34	66.6	......	......	......	......	......	24.26
Lebanon—hematite	94	6	......	......	......	......	......	65.17
Benton—hematite	90	8	......	......	......	......	2	62.4
Eaton—bog ore	72	12	......	12	......	......	4	49.92
Barnstead—bog ore	71.6	9.4	......	9.8	......	......	9.2	49.71
Barnstead—nodular	52.8	2.8	......	10.8	2.4	......	30	36.5
Charlestown—bog ore	69.4	4.6	......	18.6	Trace	.48	6.92	48.12
Haverhill—bog ore	72.6	4.6	......	12.8	......	......	10	50.31
Lebanon—bog ore	70.6	7.6	......	15	......	......	5.8	48.65
Milford—bog ore	80	8	......	8.8	......	......	3.2	55.67
Lancaster—bog ore	71.2	2.6	......	12	......	......	14.2	46.56

LEAD.

Lead is very widely disseminated. In nearly every town of the state you will find a tradition to this effect: "A few years since, my uncle, 88 years old, died. He knew of a valuable vein of lead upon the mountain. Was told of it by an Indian, who used to take an axe, chop off a lump of the ore, melt it, and run it into bullets. Uncle never told me exactly where it was, but there must be a magnificent vein of lead on the mountain." Without doubt this is a correct statement, as lead is very common; and those who have patience to explore the mountain over may be rewarded for their pains. With the little space left, I can only briefly mention the most important of our known lead openings. I will commence with a description of the Madison mine, written by me in 1870. Jackson has described this more fully in his report.

Madison Lead Mine. The rock is a quartzite, near an immense sandy plain, where rock exposures are almost unknown. An egg-shaped excavation has been made into this rock not less than forty feet wide, and perhaps sixty feet long by seventy-five deep. The wall rocks have a high westerly dip, and the vein is six feet wide. The ores are galenite and blende, of which only the former is utilized at present. There is a force of twenty-five men employed to mine, raise, sort, and crush the ore, which is sent to New York to be smelted and to be resolved into lead and silver. Prof. Seely's assay of the galenite shows that it contains of silver to the ton of 2000 lbs., ninety-four ounces, eleven pennyweights, and five grains, or nearly eight pounds.

This mine was first worked in 1826. It has been occasionally worked, but never so energetically as at present (1870). There is machinery on the ground worth $50,000, including one steam-engine of eighty horse-power, a second of fifteen, a twenty-four stamp mill and Cornish crushing rolls, capable of crushing a ton of rock in ten minutes. During the past winter the amount of ore dressed to seventy per cent. of lead has averaged one barrel per day. In the spring, and at present, this rate of production has been doubled. The actual selling price is $113 per ton, or $55 for the silver and $58 for the lead.

This mine has also supplied zinc-blende in abundance. No use could be made of it, as, until recently, there were no furnaces in the country capable of reducing it. Not long since 100 barrels of this zinc ore were sold to parties in New Jersey for $6 each, whereas they should have brought as much as $20. Those who have zinc-blende in abundance would do well to save it, and watch the market prices given for it.

A mile east of Madison station, on the Portsmouth, Great Falls & Conway Railroad, not far from the north-east corner of Silver lake, galena has been exploited at several points upon the same mineral belt. This has been proved for as much as three eighths of a mile, within which distance three openings have been made upon it by as many different parties. At the northernmost, known as the "Burke property," the most work has been done, two shafts having been sunk to the depths of 30 and 90 feet respectively. The next opening, going southward, is known as the "Banks shaft," and is 45 feet deep. The next, called the "Hoyt shaft," is down 27 feet. The ground occupied by these three companies is no more than should have been consolidated into one mining property. The vein, so called, is a mineralized band in the ferruginous gneiss of the country, evidently persistent in its occurrence, and believed by some to be the extension of that at the well-known Madison lead mine, which lies four miles to the south-west. The vein strikes N. 15° E., and, like most bedded veins, has a variable dip, ranging in this from 45° to 90° W., at most points nearer the latter. Its substance is quartz, white and gray, spotted frequently with a soft greenish-yellow magnesian mineral. The ores are galenite, blende, and pyrites, preponderating apparently in the order given. In such of the rock thrown out as was visible, they do not occur any of them in large nodules, but scattered in specks through the gangue, and in such form that much would be unavoidably lost in the necessary process of mechanical concentration. A fair average sample, taken from the accessible output of the "Banks shaft," of such rock as would have to be worked, crushed without any separation of ore from gangue, showed,—in the hands of a professional assayer,—gold, 0.01 oz., silver, 3 oz., to the ton of 2000 lbs.

Shelburne Lead Mine. About 1⅓ miles west of Shelburne station, on the Grand Trunk Railway, Lead Mine brook empties into the Androscoggin on the north side. Following up this brook 1⅓ miles, a branch comes in from the west through a narrow gorge on the eastern declivity of Mt. Hayes. At the junction of the two brooks are the ruins of ore-separating works, run by water-power, and of three log-cabins. We are here at an elevation of 130 feet above the Androscoggin. Taking the western branch, a further walk of about forty rods brings us to an abrupt turn in the brook at a right angle, the stream coming down over the cliff, which forms the northern wall of the gorge, in a cascade thirty feet high. The mineral vein runs along the bottom of the gorge, much of its course in the very bed of the stream. At the abrupt turn above mentioned the first opportunity to attack it above water-level has been availed of to drive an adit westerly into the mountain upon the vein itself. The adit is 5 feet by 4, and extends about 30 feet. Within a distance of fifteen rods from the adit three shafts have been sunk in the bottom of the narrow gorge, so close to the brook, and their mouths so little above its level, that the most ordinary rise would flood the entire workings. This metalliferous deposit has been worked at several different periods by different companies, and the adit was an after-thought of a later company. One of the shafts is stated to be 80 feet in depth, and another 275, and to have proved the vein eight feet wide at the lowest point reached, carrying in places six inches solid ore. If this be so, the vein at the surface is evidently "a pinch," and the adit could have given no practical vantage without the sinking in it of a winze. At the present not only are the shafts flooded,—they were this probably twenty-four hours after the pumps stopped,—but the floor of the adit is under water, so that it is impossible to learn much of the deposit without a considerable amount of actual work being done. The vein, which is one of segregation, has a strike N. 75° E., and a dip 70° N. 15° W. At its surface its width ranges from two to six inches. The gangue is quartz, which on the hanging-wall is quite pure, while on the foot wall, which is ill defined, it grades into a micaceous gneiss. The chief ore carried is galenite, associated with a very dark blende, and a notable amount of pyrites. The galenite seems to be invariably mixed with these ores, while on the other hand the pyrites occurs in some places unassociated. A sample of galenite with pyrites, gave, in the hands of a professional assayer,—gold, none; silver, 15.06 oz. to the ton of 2000 lbs. This ore was almost free from gangue, and may be considered a favorable sample. From the fact that so many parties have worked this,—one of the historical mines of New Hampshire,—always with the result of abandonment, it would seem a fair inference that however wide the vein may have become in depth, and however rich the ore, the ratio of ore to gangue must have been too small.

Galena has also been exploited during recent years at a point a few miles farther west on Mt. Hayes. The results were unsatisfactory, and the workings unextensive, compared with those just described.

Silverdale Mine. In the south part of Pittsfield, on the Suncook river and the Suncook Valley Railroad, is the hamlet known upon the maps as "Webster's Mills," called more recently upon the neighboring guide-boards, "Silverdale." The exploitation for silver-lead has been on the east side of the river, about one fourth of a mile north of the bridge, upon the first bench above the immediate river-bottom. The southernmost shaft is that at which the most work has been done, and from which the specimens in the state cabinet were taken. A few feet north of this is an untimbered cut, ten feet deep, which simply serves, being dry, to show the vein for that slight depth. Several rods further north is a third opening, known as the "Couch shaft," apparently off the vein. The two shafts are full of water; but a resident of Silverdale, familiar with the workings, states that the first is about 35 and the second about 30 feet deep. The vein is a "bedded" one, and, along with the synchronous country rock, has a general strike N. 34° E., and a dip 85° N. 56° W. It averages two feet wide, the gangue of quartz carrying the ore in perpendicular seams running parallel to the vein walls. The foot-wall on the east is of white gneiss, reticulated with little quartz veins, and its plane of demarcation from the vein is very definitely marked. The hanging-wall is indistinctly defined, the vein-rock grading into a quartz characterized by greenish-yellow and brown patches of softer mineral, sometimes nodular, and sometimes angular in outline. Blende runs through the vein in sheets one half inch thick persistently, occasionally widening into bulges one half foot thick, blotched with large-crystalled galenite. On the border of the vein the rock carries considerable pyrites in minute sprinkled crystals, and occasionally chalcopyrite in small blotches.

A furnace has been erected at the bridge for smelting the galenite under a new patent, said to contain original and valuable features. The furnace-house being locked and the key temporarily out of town the day the locality was examined, no description of it can be given. An assay of the Silverdale ore gave 1.6 ounces of silver to the ton.

London. In the central part of the township of Loudon galena has been exploited at the locality called "Buswell's Mine." The opening is on elevated land, the aneroid showing a height of 300 feet above Pittsfield station on the Suncook Valley Railroad. The shaft was not only full of water, but planked over at the time the spot was visited, so that little idea could be formed of the mine. There is plainly no vein, the opening having been made in what is apparently the rock of the country, though it might, on more extended examination, prove to be an exceedingly wide trappean dyke. This rock has a general strike N. 40° E. and dip 80° N. W. It is porphyritic, the included crystals, most commonly one half inch long and one sixteenth wide, showing very distinctly on surfaces slightly weathered. There is likewise considerable included quartz. The galenite occurs in small blotches, showing a tendency to form in the centre of quartz nodules. It is unusually dark-colored and splendent, plentifully sprinkled with minute crystals of pyrites. The entire quantity of ore is slight.

Rumney. Upon porphyritic gneiss in the north-east part of the town is a vein owned by George L. Merrill. The metalliferous mass is 12 feet wide, exposed in an excavation 14 feet deep. The walls dip 80° N. 70° W., enclosing a soft feldspathic rock with some quartz. Two kinds of trap rocks are situated in the vein, dark- and light-colored. The galena and blende follow reticulating veins of quartz, inter-penetrating the general mass. The galena contains a trace of gold, and 1.95 oz. of silver to the ton.

North Woodstock. Handsome specimens of galena, blende, and pyrites have been shown us from Horner's farm. Some work has been done in the way of opening the vein. The galena shows a trace of gold, and 7.84 oz. of silver to the ton.

Hooksett. Upon the quartz ridge south-west from the Pinnacle is a small lead vein. The best part of it shows three inches width of galena. This is hardly sufficient for mining.

Other localities are in Bath, Haverhill, Epsom, Nashua, Lyndeborough, Dunbarton, Tamworth, Sandwich, Lyme, and elsewhere.

TIN.

Tin ore has been discovered in Jackson in such quantity and so related that miners have thought a good vein of it might be developed by diligent exploitation. From time to time prospectors have searched the neighborhood, particularly in Maine, where greater success has been met with than in our state. Dr. Jackson was greatly interested in the subject, particularly as this was the first discovery of the ore in so great quantity in the country. From investigations made about 1840, the following conclusions have been derived:

The rock of the country is a mica schist dipping 30° N. E. by E., with veins or elvans of granite crossing it. The ore is cassiterite, occurring in four veins, making a triangular space of 200 to 300 square feet by their intersection. No. 1 is mostly compact ore, eight inches in the widest part, yielding 30 per cent. of tin, associated with chalcopyrite and mispickel, and the course is N. 7° E. No. 2 contains crystalline ore with mispickel, half an inch wide, running N. 80° E. in granite. This ore crosses the others, like the horizontal line in a figure 4. No. 3 is a compact ore in mica schist, from half to three quarters of an inch wide, running N. 56° E. No. 4 is nearly parallel to the last, from a half to an inch and a quarter wide. No. 1 is cut by a dyke of trap. The rock near the veins contains from two to ten per cent. of tin. The other minerals found with the cassiterite are mispickel, pharmacosiderite, chalcopyrite, native copper, wolfram, fluor, and molybdenite. In 1843, eleven and a half ounces of ingot tin were obtained from the Jackson ore; but the mine never seems to have been worked steadily, though it was being mined at the time of my visit in 1864.

The following notes in regard to the working of the tin mine were furnished by Mr. George N. Merrill, as also a view of the tin locality, and a profile (Fig. 8) showing the situation of the schist and shafts.

"The American Tin Company was chartered by the legislature of New Hampshire July 15, 1864, and they issued sixty thousand shares at $5 per share. The company actually expended and paid out $4,371.69. The last work done at the mine was in August, 1865. The company sunk two shafts, one twenty-five the other forty-five feet, and made an adit ninety feet. To have reached the main shaft would have required an adit 400 feet in length." The rock excavated from the adit is composed mainly of a uralitic sienite not found elsewhere. This may furnish a clue to the kind of rocks carrying tin.

Considerable time has been devoted to exploring the country between Madison and Milan, where it was supposed, from the character of the rocks, that tin might be found. In many places there are indications of metallic deposits, but for the most part they are iron sulphides, at least on the surface, while a few blasts might reveal something more valuable. Every new mine that is discovered has characteristics peculiar to itself, and these have to be carefully studied before any one can form a correct judgment in regard to it. Minerals present themselves, too, under so many different phases, and when exposed to the atmosphere are often so changed as scarcely to be recognized, that no one, unless he has made explorations, can form any estimate as to the time required or the labor necessary to be performed. Hence, explorations for tin in New Hampshire require the expenditure of considerable means in costeaning and sinking shafts before it will be possible to pronounce definitely that the metal cannot be found. In going from

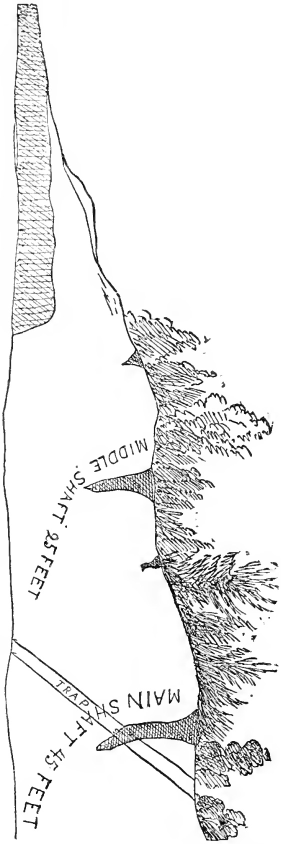

Fig. 8.—Section of Workings at Tin Mine, Jackson.

Adit, 90 feet. Distance from entrance of adit to main shaft, 400 feet.

Robertson's Corner to Madison Corner, just after passing the height of land south of the road. we find the schist in many places pyritiferous, and often much decomposed. There are also numerous beds of granite, or possibly they may be nothing more than immense veins. The schist, where it does not contain pyrites, is similar to that in Jackson where tin has been found, and here it belongs to the Montalban series. In Jackson, every locality where it was thought there could be any show for tin was examined, and an analysis of many of the specimens collected has been made by Prof. Seely, and very rarely has there been found even a trace of tin. The most promising localities away from the old opening are in the valley immediately north of Thorn mountain and on the west slope of the Black mountain, and the tin rocks here underlie the andalusite schists, at least on south end of Black mountain, and apparently uncomformably. On the west side of Tin mountain, near the Dundee road, the schist is pyritiferous, and there are numerous beds of granite; the rocks seem to be quite similar to those on the opposite side where tin has been found. Going north, the entire western slope of Black mountain, from its base half way up, seems to be composed of pyritiferous schists, beds of granite, and gneiss. There is a promising locality near Mr. J. R. Harriman's; also, near the place formerly occupied by Mr. J. Y. Perkins.

Bismuth, Manganese, Arsenic, and Molybdenum.

Native bismuth has been found upon Sunapee mountain, near Newbury. Nothing further than the fact of its existence is known. Manganese is not common in large amount. Bog manganese is reported in Gilmanton, Grafton, Lisbon, Haverhill, Laconia, Rindge, and Nelson.

In Winchester and Hinsdale is a bed of impure rhodonite 8 feet thick, according to Jackson, enclosed in gneiss, dipping 70° S. 60° E. in the first, and 84° easterly in the second locality. When this mineral is pure, it is highly prized for ornamental purposes.

The arsenical pyrites—mispickel or arsenopyrite—is very common in our state. It is most abundant along the Connecticut valley, both massive and crystallized. Localities of note are Jackson, Francestown, Haverhill, Lebanon, Weare, Groton, Lisbon, Lyman, Middleton, Dunbarton, Epsom, and Alton. Should the manufacture of arsenic ever be called for, New Hampshire can afford a plentiful supply. This mineral is worth studying as a possible source for gold, silver, cobalt, and nickel.

Molybdenum occurs quite abundantly at Westmoreland. Dr. Jackson examined the locality with care, and thinks the mineral is plentiful. It is the sulphuret, associated with blue compact feldspar and quartz containing apatite. Experiments have not been made to satisfy us whether the compounds of this metal can be used successfully as a mordant in the dyeing of cloths. The blue color of the compounds is one of great beauty. The papers have occasionally stated that parties have proposed to reopen the mine and extract the ore, but our visits have never found evidences of recent work there. I annex a careful description of the locality by a friend who visited the place at my request:

The old workings on Lincoln's hill, Westmoreland, in a gneissic rock, which is characterized by a predominance of mica and quartz, the latter having in many spots a bright red color, so that the outcrop is suggestive of ferruginous quartzite. The general course of the ledge is N. 40° E., with a dip of 50° N. W. The outcrop in which the surface work was done is on the side of a slight depression in the hill; and here the rock has been blasted to a depth, on the upper side, of 5 or 6 feet. From this point the ledge can be traced down the hill 270 paces to where it is intersected by a dry water-course, the outlet of the above mentioned depression, beyond which, on the opposite swell, it is not seen. Above the pit outcrops are visible to a yet greater distance on the rising hill. About 50 paces below the pit an adit has been carried into the knoll from the bed of the water-course, which here is parallel with it. The adit bends a little to the east in its further part, but its general course is straight, and may be set down as E. 20° S. It is 4 feet wide, about 6 feet high, and 35 feet long. The precise height it is impossible to give, for the reason that, at the time of its being visited, it was filled with water and ooze to the depth of three feet, with an unknown amount of débris beneath this. The rock is schistose, and notably micaceous at the surface, but at the distance of a dozen feet becomes massive. The walls of the adit are so covered now with the exudations and incrustations of more than thirty years, the period which has elapsed since the abandonment of the work, that it is impossible to tell, without putting in a blast, into what it has been pushed. It is pretty plain, however, from the absence of any seaming of the walls at its further extremity, that it has not entered any vein. In the pit before mentioned the vein exposed is of quartz, about two inches wide, and carries molybdenite, granular and in small scales, often in radiating clusters. In its present appearance, and the character of the loose fragments of the gangue lying in the pit, the vein gives no evidence of richness; but it would be unwarrantable, without clearing and blasting, to express any opinion upon this point.

CHAPTER II.

BUILDING MATERIALS, ETC.

IN this chapter I propose to enumerate the principal quarries whence stones used for building purposes are obtained; mention whatever facts have been obtained respecting the quantity of material sent to market; the names of the companies; number of men employed, etc. The articles used for building are properly granite, slate, flags, clays for brick, limestone, and soapstone. Other useful articles, obtained from the earth for direct use, or capable of special manufacture, are quartz and feldspar for glass; mica, plumbago, precious stones, whetstones, copperas, alum, titanium, polishing powder, moulding sand; and ochre for paint. These all occur abundantly within our limits.

GRANITE.

So common is this rock that New Hampshire is usually known as the *Granite State*. In every-day life this term is applied to rocks which are not properly granite in the technical sense, as sienite and gneiss, but all of them useful for building. In the stratigraphical and mineralogical parts of our report, different classifications are employed. In the first instance are the Concord, Conway, Albany, Chocorua, and other geographical terms, used for convenience. In the second instance, the names of the peculiar constituent minerals are employed to distinguish them,—as the biotite, muscovite biotite, and hornblende granites. It will be unnecessary in this connection to make extensive use of either of these classifications, though they will be referred to many times.

In every part of the state the common gneiss rocks are used for stone walls and the underpinning of buildings. No mention can be made of such material, but only of those that are of superior quality, or what, on account of convenient situation, have been extensively employed in the villages. I will first mention all the facts in my possession respecting the quarries, their locations, proprietorship, capabilities, etc., reserving any generalizations to subsequent pages. The economic facts have been chiefly collected in the spring of 1878.

A very large number of our quarriers operate upon a stone like that obtained in Concord, and hence familiarly known as the Concord granite, or the muscovite-biotite variety. Those of this character are known in Concord, Hooksett, Salem, Pelham, Nashua, Milford, Fitzwilliam, Troy, Marlborough, Roxbury, Swanzey, Plymouth, Manchester, Farmington, Sunapee, and Mason.

Concord. The granite quarries of Concord are situated one to two miles north-west from the city, on the easterly slopes of Rattlesnake hill. The Concord & Claremont Railroad runs at the north-east foot of this hill, and the granite is loaded upon its cars at points one fourth mile to one mile south-east from West Concord station. Two of the quarries nearest to this station are beside the railroad; the distance teamed from others varies from one eighth to three fourths of a mile.

The largest of these quarries are those of the Concord Granite Company and the Granite Railway Company. Nine other quarries are worked at the present time. The number was somewhat greater in 1873, which was the last of several years marked by unusual business prosperity; and the number of men employed and the value of granite sold by the larger proprietors, all of whom still continue operations, were during these years two or three to ten times as great as now.

Brief notes respecting the Concord quarries are as follows:

Concord Granite Company: Alfred Sampson, president; E. C. Sargent, treasurer and agent. This quarry was first opened about twenty-five years ago; owned as now, with a large business, since 1860. In 1873, about 25 men were employed in quarrying, and 200 in cutting, the annual sales amounting to about $200,000; in 1877 this company have employed about 8 quarrymen and 30 cutters, with sales of $20,000. Largest block quarried, 20 tons; it is claimed that a solid block 100 by 25 by 10 feet could be got at this quarry. Buildings from it are that of the Presbyterian Board of Education, in Philadelphia; Booth's theatre, in New York; the Advertiser and Herald buildings, in Boston; and the Custom House in Portland.

Granite Railway Company: Henry E. Sheldon, agent. Quarry opened in 1861. In

1873, about 20 quarrymen and 80 cutters were employed, with sales amounting to $200,000; there are now 4 quarrymen and 25 cutters, with a yearly product of $20,000. Largest block, 18 tons; could supply one 40 by 20 by 6 feet in dimension. Buildings from this quarry are the Equitable Life Insurance Co. (above the basement), Staats Zeitung building, and Germania Savings Bank, in New York; the Charter Oak Life Insurance Co. (above the basement), in Hartford; and the City hall and Horticultural hall, in Boston.

Norton & Holmes (formerly, till 1878, P. E. Blanchard's quarry): opened in 1865. In 1873, 20 men were employed in quarrying and 60 in cutting, the yearly sales being about $45,000; they are now $8,000. This quarry supplied the basement and trimmings for the first three stories of the Tribune building, New York; the Washington and Eddy street fronts of the City hall in Providence; Bemis block, near the Transcript building, in Boston; and the Soldiers' monument in Georgetown, Mass.

Donagan & Davis: quarry opened in 1872. In 1873, 15 quarrymen and 4 cutters were employed; sales, $75,000. No quarrying has been done for two years. Some 10 cutters are now employed, the sales being about $10,000. The largest block of granite ever taken from Concord was supplied by this quarry, being the base of the Soldiers' monument at Marlborough, Mass., 8½ feet square by 3½ feet thick, weighing 22¼ tons. Shafts could be got 18 feet long and 4 feet square. The building of the New England Life Insurance Co., in Boston, was from this quarry.

Fuller & Pressy: quarry opened in 1865. In 1873 about 25 men were employed in quarrying, the sales amounting to $20,000; now 15 men are employed, the sales being about $7,000, all unhammered stone. The largest blocks supplied have weighed 15 to 20 tons; shafts could be got 18 feet long and 3 feet square. Jordan & Marsh's building in Boston is from this quarry; also, the Manchester, N. H., Soldiers' monument.

Abijah Hollis: quarry opened in 1865. In 1873, 12 men were employed in quarrying; at present about 8 are at work. All the stone is sold rough. Largest blocks ever sent away, 18¾ tons; could get a block measuring 100 by 30 by 12 feet. Examples of the stone from this quarry are the Ether monument, Boston public garden; the Cadet monument, Mount Auburn cemetery; and the Soldiers' monument at Concord, Mass.

Gay Brothers: quarry opened in 1865; purchased by present owners in 1876. Men employed in 1873 and now, about 6,—all in quarrying.

Crowley & Quinn: quarry opened in 1864. In 1873, 10 men, all at quarrying, with sales amounting to $5,000; in 1877, 3 in quarrying and 4 in cutting, with sales of about $3,000. Largest block, 10½ by 5 by 3½ feet; could supply shaft 20 feet long and 3 feet square.

Putney & Nutting: quarry opened about 1850. In 1873, 6 men were employed, all in quarrying, with $5,000 sales; now, very little is done. The Masonic Temple in Boston is from this quarry.

G. W. Emerton: quarry opened in 1875; 5 quarrymen and 5 cutters; yearly sales, about $8,000.

Charles A. Bond: quarry opened in 1877, employing 5 men.

The principal dealers in hammered granite in Concord, not owning quarries, are P. E. Blanchard, who employs 15 men at stone-cutting; Hunton & Perry, 18 men; John H. Flood, 15 men; Blanchard & McAlpine, 10 men; and Flanders & Gannon, 12 men.

Hooksett. In Hooksett two granite quarries are worked. They are near together on the east side of the Merrimack, two miles south of the village and about half a mile from the Concord Railroad. The upper quarry, which yields the finer stock, was opened as much as fifty years ago. For several years past it has been worked by Oliver Gay, by whom the lower quarry, used principally for bridge masonry and rough work, was opened in 1873. At that time 30 men were employed in quarrying and 10 in cutting. In 1877 both these quarries were purchased by A. L. Waite, who employed last year about 15 men, principally in quarrying. Proprietors in 1878, Bonney & Waite.

Salem. A quarry in Salem, opened about forty years ago, owned since 1870 by David Nevins, of Methuen, is situated one third mile west-south-west from Salem depot. Ten quarrymen were employed here several years ago, but very little is done now.

A visit to the Nevins quarry, in 1875, showed that the rock is strictly gneiss, dipping 50° N. 70° W., with prominent vertical joints running N. 65° W. There was a cap of poor rock overlying the workable stone, requiring removal before good material could be obtained. This was 25 feet thick in some places. Both the horizontal and vertical joints exist here. The opening is shaped like the letter L, 300 feet long, measuring both arms, and 100 feet wide. The ground is low, so that pumping is required to remove the water.

Pelham. In Pelham, the greater part of the quarries are on Gage's hill, two miles east-north-east from the village. The nearest railroad stations are Salem and Messer's, on the Manchester & Lawrence Railroad, four and a half miles distant. A proposed railroad from Nashua to Plaistow would pass at the north foot of this hill. The distance to be teamed from the different quarries would then vary from one eighth of a mile to one mile.

The largest business here is that of Bodwell & Webster, for whom Samuel Kelley is agent. This quarry was opened about 1850. It has been under the present owners since 1873. In 1874 and 1875 about 6 men were employed in quarrying and 4 in cutting, the annual sales being about $8,000. Last year the sales were about $3,000. Largest blocks quarried, about 4 tons; could supply shafts 15 feet long and 3 feet square. The granite is bedded in sheets varying from 6 inches to 3½ feet in thickness. This company owns a tract of 80 acres.

Other quarries on this hill are those of Benjamin D. Kittredge, employing about 5 men; Abner Kittredge, 3 or 4 men; D. H. Webster & Son, 4 men; Gage & Woodbury, 4 men; J. N. Woodman, 5 men; John Roney and Moses Johnson, each 2 men.

This granite finds a market principally in Lawrence, Haverhill, and vicinity. Lawrence dam is built of it; and most of the stone caps and sills used in these cities are supplied from Gage's hill. The stone is of fine quality, well suited for cemetery and building purposes. The earliest quarrying upon this hill was in 1782, by Abel Gage. Two other quarries are situated in Pelham, 1¼ and 1½ miles south-east from the village. The former is owned by Oscar F. Carlton, who employed 5 men in 1873, but does very little work now. The latter is owned by Calvin Coburn, who, in 1873, had about 15 quarrymen and 5 cutters. This quarry supplied the stone for the Lowell water-works. The granite of both quarries goes principally to Lowell, being teamed 5 miles. It is mostly used for rough masonry and edge-stones. The proposed Windham & Lowell Railroad will run near these quarries.

Nashua. A quarry, half a mile south-west from the city, on land of the Nashua Manufacturing Company, and opened by them in 1823, has been leased and operated by C. W. Stevens since 1872. About 6 men are employed in quarrying and 3 in cutting. The sales in 1873 were about $10,000; last year, $6,000. Used mostly for bridge masonry, edge-stones, and foundations. Largest blocks, 6½ feet square by 1½ feet thick; and slabs, for cemetery borders or for underpinning, 20 feet long.

Milford. This town has numerous granite quarries, several having been recently opened. Brief notes of them are as follows:

Luther M. Burns, 2 miles south-south-west from the village: qurrry opened 75 years ago, being the oldest in Milford; owned as now since 1862. In 1873, 12 men were employed, the annual sales amounting to about $15,000. Last year the sales were only $2,000. Largest blocks sold have been 28 feet long, for borders of cemetery lots; shafts, 15 feet long and 2 feet square, could be supplied. The town-house in Wakefield, Mass., is trimmed from this quarry.

Nathan Merrill: quarry near the foregoing, opened in 1873. Workmen, 3; annual sales, about $1,500. Blocks 20 feet long and 2 to 3 feet square can be supplied. The basement and steps of the Baptist church in Milford, N. H., and one of the buildings of the Bigelow Carpet Company, of Clinton, Mass., are from this quarry. The proposed Manchester & Fitchburg Railroad would go near these quarries.

Thomas M. King: quarry half a mile south-east from the village, and about an eighth of a mile from the railroad; opened in 1870; owned as now since 1874. Workmen, 7; yearly sales, about $2,500,—one half being dimension stone, the rest being used for cellar walls and similar work. This granite is finer grained than most of the quarries in this town. Much of it lies in straight sheets, 6 inches to 1 foot thick, from which heavy flagstones, of any size up to 20 feet square, can be obtained. In another part of the quarry the beds are thicker, and can supply monumental shafts 3 or 4 feet square. The fire engine building in Lowell, and Merchants' Exchange in Nashua, are trimmed with this stone.

William Jones: quarry on south side of Souhegan river, 4 miles west of the village; opened in 1875. Yearly sales, about $1,000.

The following are on the north side of Souhegan river:

Everett Hutchinson: quarry 1 mile north-west of the village; opened about 1870; 5 workmen; yearly sales, about $2,000.

Daniel A. Bates: quarry about 2 miles north-west of village; opened in 1866, being the first quarry north of the river; owned as now since 1874; workmen, about 5; sales yearly, $3,000, formerly (in 1874) $8,000.

George F. Parker: quarry near the last; opened in 1869; annual product, formerly, $4,000, now $1,200.

Albert Carlton: near the foregoing; opened in 1876; workmen, 2; annual sales, about $1,500.

Kittredge & Palmer: same locality; opened in 1874; annual sales, about $1,500.

Parker Fletcher: same locality; annual sales, about $1,000.

Newton Perham: quarry in edge of Amherst, teaming to Milford; yearly product, about $1,000.

Granite dealers in Milford, who dress the stone but do not own quarries, are Isaac H. Carlton, Charles S. Barnes, Marvell & Weaver, Pierce Perham, and Frank Frost.

Fitzwilliam. The granite quarries in Fitzwilliam are principally situated beside or near the railroad in the vicinity of the depot. Brief notes respecting them are as follows:

Daniel H. Reed: quarries one half mile south of the depot; opened in 1816; owned and worked as now since 1864, on a tract of 300 acres, mostly of granite suitable for quarrying. Five openings are now worked, two of them supplying large amounts. Quarrymen, 10 to 30; average number of cutters, 5. Sales in 1869, $40,000; now, about $15,000 yearly. A part of this granite lies in straight sheets, varying in thickness from a few inches to a foot, from which flagstones of any desired extent can be obtained. Largest block sold, 12 feet long by 4 feet square, weighing 16 tons; largest sheet, 16 by 9 by 1 foot. The statues on Horticultural hall in Boston, and St. Paul's church in Worcester, are from this granite.

Albert Hayden: quarry one fourth mile north of the depot; opened in 1872; 6 workmen; yearly sales, about $5,000. Kruff's block, Pearl street, Boston, was from this quarry.

A. D. Stone & Company: quarry about 1½ miles north of Fitzwilliam village, teaming to Troy depot, 2 miles. Workmen, formerly, 20; no work done last year.

The following quarries are beside the railroad, one mile west of Fitzwilliam depot:

Ethan Blodgett & Company: quarry opened in 1867. Average number of quarrymen, 16; of cutters, 9. Sales in 1873, about $20,000; last year, $12,000. Largest block, 10 by 7 by 2⅔ feet, weighing 15½ tons. Shafts 20 feet long by 3½ feet square can be supplied. Specialty, monumental and cemetery work. T. K. Earle's house in Worcester, the court house in Fitchburg, and the trimmings of Morse Institute in Natick, Mass., are from this quarry.

R. L. Angier: quarry opened in 1865. Average number of quarrymen, 8; of cutters, 8. Value of product in 1873, $10,000; in 1877, $6,000. Largest block, 16 feet long by 2½ feet square, weighing 15 tons; could supply 20 feet long by 3 feet square; has sold blocks 6 feet square and 2 feet thick; could supply 10 feet square and 3 feet thick. Trimmings of Murdock block, and of the National Bank, in Winchendon, Mass., and the Soldiers' monument in Granville, N. Y., are from this quarry.

The Flint quarry, Thomas Hale, agent: not worked last year. Formerly, 15 workmen; yearly sales amounting to about $12,000.

Mr. J. H. Bigelow, freight clerk at Fitzwilliam depot, states the total amount of granite freighted from this town during the last five years to be as follows: in 1873, 13,083 tons; in 1874, 8,103 tons; in 1875, 5,952 tons; in 1876, 6,867 tons; in 1877, 5,923 tons.

Mr. Reed and Mr. Angier can supply a dark variety of granite, containing a large proportion of black mica. This is chiefly used for trimmings. Polishing is done by Mr. Hayden and by Mr. Angier. All the quarrymen of this town sell their granite rough or dressed, as purchasers wish. J. E. Fisher & Co., at Fitzwilliam depot, are also dealers in hammered granite, employing 5 cutters.

Troy. Two quarries have been worked in Troy. One, owned by D. M. Woodward, of Worcester, Mass., is situated three fourths of a mile east of the village; opened in 1871; formerly 5 men, all in quarrying; no work done last year. The Bank block in Fitchburg, Mass., was from this quarry. The other, owned by Luther Whittemore, is half a mile south-east of the village. Average number of quarrymen, 3; not much done last year.

Marlborough. This town has one granite quarry, 1¼ miles north-east from the depot. It is owned by A. G. Mann, of Worcester, Mass. This quarry was opened as early as 1812; under present owners since 1868. The number of quarrymen has varied from 10 to 40; the cutting is mostly done at Worcester. This granite lies in sheets which vary from 3 inches to 3 or 4 feet in thickness. Largest blocks sold, 12 tons; sheets have been split out 70 feet long and 6 feet wide. A considerable part of the sales here has been of paving-blocks, 7 inches square and 4 inches thick. The Union depot at Worcester (except trimmings, which were from Fitzwilliam), and the Stone mill at Harrisville, came from this quarry.

Roxbury. The south-west corner of Roxbury has valuable granite quarries. The largest is that of the Keene Granite Company, H. A. Bodwell, president, E. S. Bodwell, treasurer. This quarry is 2½ miles north-east from South Keene station, where the company's stone-sheds are located. The proposed Manchester & Keene Railroad will run three fourths of a mile distant. Quarry opened about 1850; owned as now, and business greatly increased, since 1872. This company own 227 acres of land, with a right to quarry on 150 acres more. They employed formerly 150 quarrymen and 200 cutters, their sales in 1873 being about $350,000. Largest blocks sold, 12 tons; a sheet now split out would yield a block 30 by 15 by 6 feet in dimensions. Most of the granite quarried by this company has been used in building the new state house at Albany, N. Y. At present, very little work is done here.

The Cheshire Granite Company, S. G. Griffin, president, has a quarry a third of a mile west of the last; only a small amount of work done.

Another quarry, opened about 1840, now owned by John L. Randall, of Albany, N. Y., is situated one mile north-east from these, being about four miles from Keene. It has been worked since 1873 by Nourse & Dean, of Keene, who several years ago employed 6 quarrymen and about 10 cutters. No quarrying of importance done last year. This granite lies in sheets which vary from 6 inches to 8 feet in thickness. Largest blocks moved from the quarry, 12½ feet long by 2½ feet square; shafts 30 to 40 feet long and 4 to 6 feet square could be got. The Episcopal and Baptist churches, and the depot in Keene, are trimmed with stone from this quarry.

Swanzey. Nourse & Dean also lease a quarry, opened in 1863, near Westport station in Swanzey. It is one half mile from the railroad. About 6 men were employed here last year. The Episcopal church in Keene is built from this quarry. R. Stewart, superintendent of Cheshire Railroad, sent the following statement about the granite business along his railroad for the year ending April 30, 1871:

* * * "The largest proportion of the Fitzwilliam stone is sent to Boston, Worcester, and Lowell; while considerable from that point, as well as Marlborough, is seeking a market at Springfield, Hartford, New Haven, and other points reached by Connecticut River Railroad. The stone from Troy is sent principally to Fitchburg for building purposes. The tonnage for the year is as follows: Fitzwilliam, 9,458 tons; Troy, 1,717 tons; Marlborough, 3,292 tons; Keene, 1,040 tons; Westport, 652 tons; total, 16,139 tons. There are occasional shipments to local stations that would, I think, on actual figures of everything, show from 18,000 to 20,000 tons sent."

Plymouth. Four miles north-west from Plymouth are valuable granite quarries, first opened by H. W. Blair, in 1870. They are one half mile north of the Boston, Concord & Montreal Railroad, from which a branch track runs to the quarries. Since 1872 they have been owned and worked by Sanborn & Blair, employing from 5 to 20 men, with average yearly sales of about $4,500. The greater part of this granite is used for bridge masonry. It is also employed in cemetery work, and in building. It lies in sheets 2 to 10 feet in thickness, and slabs of fine stock 20 feet long can be supplied.

Manchester. Two quarries are being worked in a bunch of granite upon the company hill,—one, the Amoskeag quarry, and the other, Bodwell's. The latter's excavation was about 25 feet long, 150 wide, and from 10 to 50 feet deep, three years since. The company's quarry was not so large. Both were being worked energetically, as there is a great demand for stone in the largest city of the state. The stone is inferior to the Concord, though resembling it, being coarser, breaks more readily, and shows a slight tendency to crumble. Other quarries are about Rock Rimmon, on the west side of the Merrimack river, and in the very twisted ancient gneiss between Hallsville and Massabesic lake. The foundations of the city hall, and much of the curbstone in the streets, are of this latter material. The Rimmon stone is granite of rather inferior quality, containing bits of pyrites.

Mason. An extensive business is carried on at the Glen quarry in Mason, owned by A. Macdonald, of Mt. Auburn, Mass. It is situated close to the Peterborough & Shirley Railroad, in the east part of the town. There are two principal openings. The one I saw is the more southerly, estimated to be 300 feet long, 150 wide, and 40 deep. The surface shows slightly the breakage by ice in the glacial period, like that observed in Manchester. From 25 to 30 workmen were employed in 1877. Steam is used extensively. To the east is a larger opening, capable of furnishing obelisks 60 feet long. A large monument has been erected of this granite at Greenville, Penn. There are many of various sizes at Mt. Auburn. A very pretty building, belonging to the Delta Psi Society, is being built of this stone at Hartford, Conn. The joints in this quarry are somewhat irregular. Seams of kaolin clay occasionally occur in them. There are other quarries farther north along the railroad, doing less business than the one described.

Sunapee. There is considerable quarrying done at Sunapee Harbor, very near the lake, on Keyser hill. A variety nearly black is found here, which is properly mica schist, not granite, in connection with a variety very like that of Concord. (See Vol. II, p. 510.) It is marked on the county map as the Bailey quarry.

Farmington. There is plenty of excellent granite in Farmington, hardly distinguishable from the Concord stone. The area, as shown by the atlas map, is not large, but it is sufficiently so for all practical purposes. The quarries are about a mile and a half north-west from the depot, and were being successfully worked at the time of my visit in 1875.

MISCELLANEOUS GRANITES.

Several different kinds of granite are quarried in various parts of the state, the most important of which will be mentioned. One not very different in external appearance from the Concord is that of Haverhill.

Haverhill. In the edge of Piermont, two miles south of Haverhill, are two granite quarries, known as the Catamount and Black Hill quarries, owned by James Barstow and W. H. Page. These quarries have been worked more or less for nearly 100 years. They have been for several years leased to Daniel J. Winn & Co., of Haverhill, who employed 4 men in quarrying and cutting in 1873, with sales amounting to $2,000; last year 7 men were employed, the sales being about $3,000. The Catamount stone is used principally for bridge masonry and similar purposes. The Black Hill stone is adapted for the finer kinds of cemetery and ornamental work. Blocks 30 feet long and 5 feet square could be got from the latter quarry.

Another granite quarry is worked by Hubert Eastman near North Haverhill. It has been worked more or less since 1840, and the sales for some seasons have amounted to $400. The stones have been used principally for buildings and bridge masonry. The largest block split out measured 60 by 4 by 4, tapering to a point. Has been used at Lisbon, Bath, and the adjoining Vermont towns. Has never been used for cemetery monuments.

Columbia Granite. Near Colebrook, just in the edge of Columbia, is a small area of hornblende sienite, wrought as granite by George Parsons, of Colebrook. Its mineral character has been described by Mr. Hawes. The peculiarities are the presence of calcite and liquid carbonic acid. It is easily worked and handsome, coarsely crystalline like the Quincy granite of Massachusetts. It would make an excellent stone for ornamental pillars, especially for inside work. Most of the blocks quarried are used at Colebrook for buildings, not for cemeteries, the stone from Brunswick, Vt., along the Grand Trunk Railway, supplying that want. A few years since Mr. Parsons employed from 6 to 8 hands constantly; now only half that number is needed. Blocks of any size that can be conveniently handled can be quarried here. There have been as yet no orders for this stone from any distant locality requiring railroad transportation. The Brunswick granite is related to that from Concord, and, being favorably situated as regards transportation, is used extensively in northern New England.

St. Johnsbury Granite Company. This concern uses granite from several localities, making a specialty of monumental work. They use most extensively a biotite granite from Blue mountain, Ryegate (one that cuts the Calciferous mica schist); and, on account of the strong contrast between the white feldspar and the black mica, it has a very clean aspect. By leaving the letters and ornamental work raised and polished, an interesting effect is produced, as it makes a strong contrast with the main body of the stone. It receives and retains a high polish. Their gray granite comes from Brunswick, Vt. They are also beginning to use a red biotite granite from Stark, the same with one that has been described in the other parts of this report. It resembles somewhat the red Scotch granite, but is superior to the imported article, because it is finer, and is not permeated with the "pin-holes" constantly occurring in the other. This company is doing a large business. They have a mill for polishing granite close by the St. Johnsbury depot, using steam, and employ a large number of workmen. The use of the "Conway granite" from Stark is the only known instance of the extensive employment of this variety of stone from a New Hampshire locality. There is a good mass of it at Biddeford, Me., that is extensively used.

I have the following additional statements respecting the St. Johnsbury Granite Co., from R. W. Laird, treasurer. The Blue mountain granite requires 2½ miles of transportation to the railroad. It is entirely free from iron, and blocks may be quarried 300 to 400 feet long and ten feet square. Monuments made of the three granites were exhibited at the Centennial exhibition at Philadelphia, and the red Stark stone received a medal and diploma, with the following award: "For the good quality of the material, the originality of design, and the workmanship of the articles exhibited." 80 workmen are employed in April, to be increased in the summer to 100. Monuments are sent to every part of the country, especially the Middle states. The red granite is wrought from boulders.

Lebanon Granite. This may be taken to represent a type of granite very unlike any others that have been mentioned, and it is worked at Walling's quarry in Lebanon; at Freeman's, one less extensively opened, further north in the same town; on Corey hill, and other places in Hanover and Enfield. It is properly a protogene gneiss. It is a heavy, massive stone, better capable of sustaining weight than the Concord variety. S. H. Walling & Son do a large business, and supply the wants of Lebanon, mainly, for building purposes. Stone of very large size can be obtained here. The rock is free from iron pyrites. This cannot be said of the Hanover stone, which was used for the basement of Culver Hall.

One thing should be said of this impurity in the Hanover rock. There is a building on Corey hill containing pieces of the pyrrhotite as large as beechnuts, and though the house has been standing nearly seventy years, there are scarcely any iron stains upon it. This species of pyrites sustains itself so well that oftentimes its presence need not be feared. A more remarkable instance of the ability of this pyrites to resist decomposition may be seen in the Francestown soapstone. I have examined many of the stoves manufactured from this stone, and noticed that bright particles of this pyrites were thickly sprinkled through it. I have also looked at pieces of this steatite that had been subjected to great heat for a long time without much change. It would appear, therefore, that this mineral may not be injurious to granites, as it seems to withstand successfully the vicissitudes of both heat and cold.

Porphyritic Gneiss. This is only employed locally. I have been greatly pleased with the appearance of curbs and foundation stones of this granite, as seen commonly at Lake Village and Meredith. The large rectangular white feldspar crystals render the stone attractive. There is a gray Scotch granite with these reddish-white crystals scattered through it, which is like our porphyritic gneiss. Those who desire a new variety may be pleased with this. The town of New Hampton abounds with handsome ledges of this rock; but any of the areas thus designated upon the map will furnish to a careful search very attractive blocks.

The White Mountain Granites. By these I mean the Conway, Albany, Chocorua, and sienite groups, of which whole mountains stand ready to be quarried, and thus be made serviceable to civilization. Of these, certain portions of the first are unsuitable for building purposes or monuments, because they disintegrate so readily. This has been explained (Part iv, p. 195) by the presence of innumerable pores in the feldspar which admit water charged with carbonic acid, and thus gradually impair the integrity of the stone. But all the Conway granite mountains are not of this character. The other varieties are also capable of furnishing peculiar grades of building stone, and perhaps the time is not far distant when their beauties will be discovered and utilized. Railroads now thread among the mountains, so that new quarries of stone can be easily transported to market. There are fine-grained varieties of the Conway species near the Portland & Ogdensburgh Railroad in the Notch, which are durable. A very handsome stone of this sort has been used by Dr. S. A. Bemis for his dwelling, though more care might have been taken to secure a material free from pyrites.

It was my intention to have presented statements respecting the points to be observed in selecting a good granite for quarrying, the application of microscopic study, and a comparison of our stone with the Scotch, Massachusetts, and other kinds of building material, particularly with reference to strength and ability to resist decomposition. The reader may consult Part IV for a part of this intended sketch, and the rest in general treatises upon building materials, since the size of this volume is already too great.

SLATE.

The only formation likely to furnish quarries of roofing-slate is the Cambrian range along Connecticut river. The Vermont portion has quarries upon it in Guilford and Thetford. There have been several quarries upon this belt in our state, at Littleton, Hanover, and Lebanon, but no work has been done upon any of them for several years. The stone is not quite so good as that in western Vermont or Maine, but certain portions might be utilized in several localities for home purposes, especially for curbs, platforms, tables, flags, etc. In Littleton are two openings in the north part of the town, upon the adjacent farms of Richard Smith and Mr. Bachelder. The band of rock suitable for working is nearly an eighth of a mile wide, and the principal opening has been excavated to the depth of 20 or 25 feet. Bachelder's quarry is the farthest from the road, and has had the most work done upon it. The strata are vertical, and, as the outcrops are on a hill, the facilities for drainage are good, and working surfaces can be obtained 100 feet in depth. The rock seemed to be free from pyrites, was soft, but does not cleave so thin as the slate from Maine. About two miles westerly from Littleton village is a large excavation on the west side of the Blueberry mountain range, high up, and well situated for mining. The opening is about 200 feet long and 50 deep, presenting a face of these dimensions. There is a cross cut into this opening through which the slates are transported over a tramway. Several houses have been erected for the accommodation of the workmen, and a large amount of rock has already been removed. The samples of slate stored for shipment appear to be of excellent quality. The color is a bright dark blue, and the stone soft, and apparently durable. The face corresponds with the front of the hill, so that the position is a favorable one for mining, the slate standing about perpendicular. Thirteen years since, an attempt was made to form a company to work the quarry, but for some reason it failed. Many of the layers are filled with cubical crystals of pyrites, and it is likely that the abundance of this mineral discouraged the proprietors, preventing the carrying on of a large business.

In East Lebanon a company has expended $25,000 upon opening a quarry and erecting a mill, but the work is now abandoned. The property consists of 100 acres of land, about 100 rods in length, along the course of the slate, with a fine water-power,—the Mascomy river,—and situated by the track of the Northern Railroad. Over $4,000 has been spent in opening the quarry, under the superintendence of E. L. Cleaveland, presenting a vertical face about 55 feet broad and deep. I saw slabs 15 feet square, and others, larger, can be obtained. The valuable part of the bed is 30 feet in width. The mill on the Mascomy is 44 feet wide, 65 feet long, and three stories high. It contains machinery driven by water-power, put in at an expense of $8,000, requiring the services of 20 workmen when fully equipped. The slate is not used for roofing, as it does not split sufficiently thin, but may be used for the manufacture of chimney pieces, table-tops, shelves, etc., and marbleized like the slate of western Vermont, where this business has been successfully conducted for many years. The other uses of the stone are for sinks, cisterns, burial cases, flooring, tiling, etc.; and the waste is ground and bolted into slate flour, of which the company sold 150 tons in 1868. In continuing the quarrying, some difficulties arose requiring a further outlay of capital, insomuch that the company became discouraged and suspended operations, the superintendent having accepted a position at the Copperas Hill establishment at Strafford, Vt.

Other openings have been made upon Moose mountain, Hanover, and Croydon mountain in Cornish.

Flags. Such slates and schists as are suitable for flagstones are chiefly what have been described under the Cambrian and Coös schists of the Connecticut valley. They are all comparatively soft, and will not compare for durability with the blue stone from Hudson river, which is used so commonly in the larger towns of lower New England. All stones of this sort that have been quarried in our state are only used locally.

LIMESTONE.

Haverhill. In the east part of Haverhill is a large bed of grayish-white limestone situated in gneiss. It is about a mile and a half from the East Haverhill station, on the Boston, Concord & Montreal Railroad. There are several openings in the bed. The rock is partly bluish-gray, resembling that wrought at Thomaston, Maine, and partly white and coarsely crystalline. It has been seen for 800 feet in length and 400 in width. Dr. Hayes's analysis of it is the following: Carbonate of lime, 94.04; carbonate of magnesia, 1.36; carbonate of iron, .58; phosphate of lime, .22; quartz, silica and mica, 3.80=100. "This sample was variegated gray in color, and contained the quartz, silica and mica as rock mixture. It will afford 53.7 per cent. of lime, to which will be added four parts only of earthy matter. Much of the lime in the market contains 27 per cent. of earthy and foreign matter. Some samples I saw of the limestone contained less earthy matter than the sample analyzed."

In 1864 a pamphlet was prepared by Nicholas Mason, descriptive of the properties and capabilities of this stone, from which it appears that the entire cost of making the lime was 30 cents per cask. At Rockland, Maine, the corresponding expense is given by Alden Ulmer, inspector, at 80 cents per cask.

Lisbon Limestone. In Lisbon lime is also manufactured by Orren Bronson to the amount of 2,200 casks annually. The bed is shown on the several maps to extend several miles through the eastern part of the town, and to crop out on different stratigraphical lines. The thickness is not so great as in Haverhill, but great enough to supply a kiln for many years. Some parts of it were thought to approach 100 feet in thickness. Four different quarries were wrought forty years since, consisting of Mr. Bronson's, Thomas Priest's, David Priest's, and Uriah Oakes's,—the others to the north-east of the first, and within four miles' distance. The T. Priest bed is 13 feet wide; it has been explored for 300 feet in length, and can be wrought to the depth of 60 feet without the necessity of pumping. There is a slight curvature to the bed. As shown on the map, the range continues to the furnace in Franconia, broken twice. The opening north of Sugar hill supplied the furnace with material for fluxing the iron ore. There is another range of limestone parallel with the Bronson-Oakes belt, about two miles to the north-west, following a back road from Salmon Hole brook to the South Branch. Quartzite is associated with it.

Orford and Lyme. In Orford and Lyme is another development of limestone identical in character and geological position with those of Haverhill and Lisbon, and it is essentially continuous for 10 miles near the west edge of the gneiss. On the west side of Cuba mountain a bed has been wrought at intervals for fifty years. Some of the beds are 20 feet thick, and several run close together, as at Tillotson's quarry, where the aggregate thickness of the limestone is 38 feet. I suppose there must be beds of limestone upon Lime hill, though none are marked there upon the map. On the Charles Scott place, in Lyme, are beds 6 feet in thickness. Massive garnet and crystals of hornblende occur in connection with the enclosing beds. Dr. Jackson describes a mixture of limestone and granular quartz on the same farm 120 feet in thickness. Analysis shows it to be quartz mixed with silicate and carbonate of lime. It consists of silica, 80.40; lime, 14.72; magnesia, 1.12; oxide of iron, 0.88; carbonic acid, 2.88=100. It was recommended for the manufacture of glass. On Holt's hill is a bed of limestone one foot thick, in company with iron pyrites. The limestone crops out conspicuously in East Lyme where the road branches to Dorchester and Canaan. The region of these limestone beds in Orford and Lyme is now very sparsely inhabited, insomuch that the road at the west base of Smart mountain is almost impassable.

Littleton. Lime has been burnt in the Helderberg limestones of Littleton in at least two places. One is about three miles to the north of the village on Burnham's hill. Two extensive openings occur here, showing a breadth of stone from 10 to 60 feet thick. The other locality is on Parker brook, about a mile west from the depot. Both these kilns were in action some thirty years since, and produced an excellent quality of lime. It was brown after burning, but slacked white. The amount of the stone is abundant, as has been mentioned in the discussion of the Helderberg formation. The stone near Parker river is unusually white. Another mass of stone, seemingly 40 feet wide and of better quality than the last, occurs on Fitch hill, a mile south-west from the brook locality. This rock forms a knob in a pasture beyond the best fossil outcrop. Still another opening occurs back of J. K. Corey's house, in the south part of the town, near the Ammonoosuc river. By examining the geological map, one will see that the Helderberg group extends southerly upon both flanks of Blueberry hill; and good outcrops of limestone may be looked for in almost any part of the blue-colored areas. That for a mile along the river in North Lisbon is largely composed of a white limestone, but it is not free from silica and rock, and would not answer so well for the manufacture of quicklime.

It is our belief that nearly all the beds mentioned are capable of furnishing a good quality of lime. It is equally strong with that furnished from Maine, but usually makes a brown mortar like that from Weathersfield, Vt., which, by the way, is exactly the same material as the Haverhill and Lisbon stones. Because the mortar is not a pure white it has fallen into disuse, and the Maine or Vermont limes employed instead for finishing. Our stone would furnish good material for three fourths of the plastering needed for houses, or it may be used for agricultural purposes. As it is inexhaustible, there is no reason why the farmers should not order it in large quantities.

At Lime pond, in Columbia, the marl has been used to some extent for the manufacture of quick lime. This article is fully equal to the best imported variety; but the supply is not inexhaustible.

Limestone occurs in many other towns in New Hampshire, but in a comparatively impure condition. It occurs in Plainfield, Cornish, Claremont, Clarkesville, Stewartstown, Amherst, Warner, Wakefield. I append a few analyses of some of these rocks, by Dr. Jackson:

	Silica, mica, etc.	Carbonate of lime.	Carbonate of magnesia.	Iron oxide and alumina.	Carb. iron and manganese.	Carbon.	Magnesia.	Percentage of lime.	
Haverhill—first quality	.5	99.3	......	......	0.2	....	....	55.7	=100
Haverhill—second quality	3.80	90.66	......	......	5.54	....	....	51.03	=100
Thomas Priest, Lisbon	8.2	90 18	.....	......	1	....	....		=100
David Priest, Lisbon	15.6	81.6	......	......	2.8	....	....	45.6	
Uriah Oakes, Lisbon—flux	20	80	......	......	2	...	....	43.9	=100
Lyme	25.7	71.7	......	......	2.60	....	....	40.35	=100
Lyme—dark colored	15	83.6	......	......	1.2	2	....	47.04	=100
Orford	64	90	......	4	.... .	....	....	50.66	=110.4
Amherst	21	75.2	......	2.4	......	...	....	42.32	=98.6
Warner—white crystalline	33	56.4	......	......	......	....	10.8	31.74	=100.2
Warner—gray siliceous	72	10	13	3.2	......	....	....	5.62	=98.2
Cornish—Judge Jackson	31	58.6	1.6	7.8	......	....	....	32.98	=99.2
Lunenburg, Vt	40.6	47 6		11	......	....	....		=99.2
Plainfield	25	23.8	46.6	2.8	......	....	....	13.39	=98.3
Cornish—Johnson's quarry	59.6	22.6	13.8	3.8	......	....	....	15.72	=99.8

BRICK CLAY.

A few facts have been acquired relative to the manufacture of bricks in the state. They relate to the largest establishments.

The extensive deposit of clay in Pembroke, Allenstown, and Hooksett, has been described on page 94 of Part III. The brick-makers find a slight difference between the gray and blue clays,—the latter requiring more sand to be mixed with it, and shrinking more in burning. Brief notes respecting the manufacture of brick in these towns are as follows:

Natt & William F. Head, Hooksett, make about five millions of brick yearly, employing 60 men. Their market value, loaded on cars, has ranged from $6 to $10 per thousand. They are sold largely in Manchester, Nashua, Lowell, Lawrence, and Worcester.

Jesse Gault, Hooksett, manufactures three to four millions yearly, employing 40 men.

Other brick-yards are those of William G. Andrews, Hooksett, employing 5 men; Jabez Green, Suncook, 5 men; Charles Bailey, Suncook, 5 men; Philip & Warren Sargent, Suncook, 20 men; Edmund Elliott, Pembroke, 5 men; Henry T. Simpson, Pembroke, 20 men. These yards will average about 80,000 brick yearly to each man employed.

Brick-yards formerly worked, but idle for the last two or three years, are owned by Cochran & Russ, Suncook, and by James Thompson, Hooksett.

The brick-makers in Plaistow are as follows: Moses Goodchild, manufacturing about 1,000,000 brick yearly, employing 15 men; J. S. Lamprey, about 1,500,000, with 15 men; Isaac H. Pollard, 800,000, with 8 men; H. H. Cheney, 700,000, with 7 men; Isaac Hall, 500,000, with 5 men; George Denoncour, 1,000,000, with 10 men; D. Gauselain, 500,000, with 5 men; J. W. Porter, 500,000, with 5 men; Alack Janell, 1,000,000, with 10 men; Joseph Kimball, 500,000, with 5 men.

Bricks are made also at Dover Point, Rochester, Lebanon, Keene, Bedford, Boscawen, Bristol, Bartlett, Claremont, Haverhill, Concord, Durham, Epping, East Kingston, Francestown, Franklin, Greenville, Hampton, Hancock, Hillsborough, Jaffrey, Lancaster, Littleton, Merrimack, Moultonborough, Newport, Northumberland, Ossipee, Plymouth, Rindge, Rumney, Great Falls, Unity, Warren, Winchester, and Wolfeborough.

SOAPSTONE.

The Francestown Soapstone Company, with a capital of $300,000, has its mills for sawing at Nashua, and commenced operations, on a larger scale than had been employed hitherto, in May, 1866. The bed had been discovered originally by Mr. Daniel Fuller, in 1794, while engaged in ploughing. It was first wrought in 1802; and stone was transported to Boston for sale as early as 1812. Previous to 1866, about 2,000 tons of stone had been sold; 1,500 tons were sold in 1866, and 2,020 in 1867. The company made 3,700 stoves in 1867. I have no statistics of the extent of manufacture since this date; but the business is known to have been conducted upon a similar large scale ever since 1866. The refuse fragments and dust are also utilized, being ground and sold for packing.

I have visited this locality several times. The bed is regular, not nodular like the steatite and serpentine beds in Vermont. The opening is 80 feet long, 40 wide, and 80 deep, a little wider at the bottom than at the top. The bed has been followed for 400 feet in length. The peculiarity of the stone consists in the uniform distribution through it of spherical radiated aggregations of crystalline plates of talc. These make the stone uniformly strong in all directions, unlike most of the Vermont rock, which is apt to split along seams of original structure. The Francestown stone has largely superseded that from Vermont for the manufacture of stoves. I have already alluded to the dissemination of minute crystalline bits of pyrrhotite disseminated through the soapstone without seemingly injuring it.

The presence of radiated spherules marks this bed in its stratigraphical distribution. Other beds of it are found in Weare, Warner, Canterbury, and Richmond. The first named is near the top of Mt. Misery, and has been quite extensively opened by Hon. M. A. Hodgdon. I saw it first in 1869, and judged the bed to be 15 feet wide and quite hard. The stone had the same lithological features with that in Francestown, and occupies the same stratigraphical position. The excavation was about 10 feet deep. Two or three years later, the bed had been better defined by additional excavation. The hole in 1874 was seen to be 71 feet long and 60 feet wide, representing the width of the soapstone. Two or three large bunches of hard rock—horses—occur in it, one of them estimated to be 35 feet long. In going down there was seen, first, the common country rock, underlaid by a coarse-grained ledge with long hornblende crystals capping the soapstone. The latter rock is at the top inferior to that found lower down. Small bunches of granitic rock occurred occasionally; and the pyrrhotite showed itself in a vein three inches wide. The work was prosecuted far enough to determine the nature of the stone underneath the principal horse. The material was soft, but somewhat shelly. The great improvement in the appearance of the stone over what it was on the surface leads us to believe that good material will eventually be quarried here.

Mr. Hodgdon has also opened the ledge in the south-east corner of Warner, in the same bed, or its repetition by a fold. The bed is over 20 feet in width, and deserves to be opened more fully.

In Canterbury, this rock has been quarried near the Boston, Concord, & Montreal Railroad, a mile and a half south of the station. A hasty run over the ground showed the presence of two beds, each about 25 feet wide, separated by hornblendic rocks. One bed has been opened in two places. I have been unable to learn anything about the history of the work done here, and do not know why the quarry has been abandoned. It is very near a railroad, and conveniently situated for working. The stone is only partially like that from Francestown, occurring more like those in Vermont.

Circumstances have prevented such exploration of the country between Francestown and Canterbury as was anticipated. I have one impression of the relations of rocks to the soapstone that may be of value to others. The Canterbury bed lies just above a prominent belt of white feldspathic or granitic material. This may therefore be the guide to the occurrence of the soapstone. I have observed it in the west part of New Boston, and in Hopkinton. (See Vol. II, pp. 589, 159.)

Other localities of soapstone, of greater or less interest, are in Richmond, on land of Lorenzo Harris; boulders in Hampstead, Pelham, and Dracut, Mass.; and 1½ miles east of E. Hill's in Swanzey. This last named bed has not been mentioned heretofore, and is not located upon the map. I have no facts in regard to it to present.

Orford. Five beds of soapstone occur in this town, one in the Huronian, the others in the Coös mica schists. They are all of good quality. Some facts about them are found on pp. 382-4, in Volume II.

Haverhill. The soapstone quarry in Haverhill, now controlled by David Page, is situated about three miles north-east of North Haverhill station. It was first opened in 1855, and was worked up to the middle of the winter of 1857. About 150 tons were taken out and sent to market. The stone was pronounced to be of a fine quality for the first opening. The quarry then changed owners, and was not worked again until 1874, when some 50 or 60 tons of the stone were taken to market, and found to be of very good quality for all purposes for which soapstone is used. It is claimed that it can be brought to a finer edge than that from any other locality in the United States. It can be quarried in large quantities, and of almost any dimensions. The Boston, Concord & Montreal Railroad is 1½ miles distant.

Manufacture of Glass and Pottery.

Excellent materials for the manufacture of glass and pottery are abundant. The feldspar occurs in the coarse granite veins carrying merchantable mica. This range has been described in Volume II, page 514, extending from Easton to Surry, being of a fibrolite mica schist, and is admirably shown upon the map. At almost any part of this range these coarse granite veins are liable to occur. Masses of it a foot square are common wherever the veins have been opened. It is now thrown away because it cannot be utilized. Our feldspar has been successfully used in the manufacture of artificial teeth by several dentists. The time is coming when our immense supplies of feldspar will be utilized. We have no beds of kaolin or porcelain clay that are of value. Quartz, valuable for the manufacture of glass, is exceedingly common. The ranges of it which I have represented upon the map, and fully described in Volume II, are nearly all sufficiently pure for this purpose. These occur, first, through Hillsborough, Rockingham, and Strafford counties on the east, and from Cheshire to Grafton on the west side of the state. Very frequently there are large hills, hundreds of feet high and broad. In Lyndeborough there is an establishment fitted up for the manufacture of glass, based upon the presence of one of these beds of quartz. Although milky white, the quartz contains a small percentage of iron, and is therefore apt to impart a green color to the bottles manufactured. The iron is removed by first burning the stone in a kiln, so as to magnetize the hematite and limonite present; secondly, the brittle calcined rock is pulverized; thirdly and lastly, the powder is caused to fall over revolving cylinders bristling with magnets. These attract the iron, and thus purify the pulverized material, which is now ready to be put into crucibles. A very large business is done at Lyndeborough.

Mica.

Our state is celebrated for its mica. It occurs in enormous quantities, suitable for commercial use, in immense, coarse granite veins, where the three mineral constituents are found in large pieces. The mica I have seen in plates a yard long, but 10 or 12 inches is a more common size. On account of the great value of this mineral, we have taken special pains to learn where it is distributed, as it does not occur at hap-hazard any more than veins of the metals. Upon the map we have distinguished a mica schist with fibrolite, one of the supposed divisions of the Montalban group. It is usually about two miles wide, and reaches from Easton to Surry, with occasional interruptions. It is extraordinarily developed about Rumney and Hebron, spreading out to fill the space between the two great areas of porphyritic gneiss. Those who search for this mineral will find that the valuable deposits of mica are to be found chiefly within this fibrolite area as delineated upon the map, corresponding with that of the feldspar.

Quarries for mining mica have been opened in the following localities: In Grafton, the oldest and best known establishment is that of the Ruggles company, upon Isinglass hill. About 1840 they obtained some 600 or 700 pounds annually, valued at $1,500. In 1869 they marketed 75 boxes of 350 pounds each, worth from $2.15 to $2.50 per pound. This makes a total of 26,250 pounds, worth perhaps $60,000. In January, 1877, the Ruggles mine is said to have shipped 3,600 pounds of mica, selling for $2 per pound. They employed, in 1869, 12 men for seven months of the year. Within two or three years the price of mica has increased, and hence the business has been much stimulated. Grafton now has six openings, which are all worked. Mellen's quarry is about 700 feet above the valley, to the north of the Ruggles mine. There are six or eight places where excavations have been made. Martin & Page are at work energetically, near the top of Alger or Beryl hill. This is the locality where the largest known beryl was once on exhibition. These parties have worked here for two years. Another place is opened by Kilton & Sargent. On Hoyt hill in Orange is the Worcester mine. The vein shows for 400 or 500 feet near the hill-top, and its maximum width is 100 feet. Five men were employed here at the time of my visit. The largest plate of mica obtained here is 8 inches square. There are two other mines on the east side of the railroad in Grafton. There are others, in Alexandria, New Hampton, Wilmot, Marlborough, Acworth, Alstead, Groton, and Springfield. The Alstead quarry has been worked intermittently the past thirty years by Mr. James Bowers, who sold in 1840 one thousand dollars' worth to the Boston market. His quarry is on Beryl hill, a famous locality for the latter mineral. On Hall's farm in Groton are unusually large plates of mica, where no mining has been done. The Springfield locality has furnished beautiful and large tourmalines.

Those who drive about Springfield, Grafton, Orange, etc., cannot fail to see these veins on the hill-tops, whitening their crests and sides. The vein on Hoyt hill, Orange, is quite conspicuous on the right-hand side, as the cars near the summit from the south. Aaron's ledge in Springfield is a landmark 15 to 20 miles away. The range seems to terminate with the Colonel Sanborn hill in Springfield; but I have found limited patches of it, not shown upon the map, near George's mills. The mica of New Hampshire is extremely abundant, and there is no danger that the supply will be exhausted for many generations.

PLUMBAGO.

This mineral is found in Goshen, Antrim, Bristol, Nelson, Hancock, Chester, Mt. Monadnock, Sutton, Barrington, Bedford, Troy, Walpole, Washington, Hillsborough, Keene, Wentworth, Orford, and elsewhere. It is not equal in quality to that obtained at Ticonderoga and other Laurentian districts, but sells readily for a second quality article, and is useful for the manufacture of crucibles. The most extensive mine is at Goshen, formerly owned by President Pierce. It is on the flank of Sunapee mountain, included in pyritiferous mica schist, and accompanied by radiated black tourmaline. The bed is small, and traversed by a better quality of the same mineral in cross veins. The amount raised and sold annually has varied greatly. In 1840 the yield was 20 tons. A few years later the product was greater; and the locality is capable of furnishing a larger supply, should it be called for.

The Antrim bed is irregular in thickness, varying from a few inches to two feet. The material is said to be soft and pure.

Few minerals are talked of more than plumbago by the farmers, as they often find it in an impure condition. A good article is free from grit, and can be readily cut with the knife without coming into contact with hard bunches. To those searching for it, I would recommend exploitation where the rocks are most crystalline. All our mica schists show the mineral, but it is apt to be impure.

PRECIOUS STONES.

These are not abundant; but very beautiful specimens of beryl, garnet, cinnamon stone, amethyst, rose quartz, iolite, and other minerals are often found, which are suitable for being cut as gems. I refer the reader to Part IV for a description of the minerals and localities.

Polishing Powder.

Chapter XIV, Volume I, is devoted to a description of the organisms, which by their decay give rise to the white, light earth sometimes called infusorial silica. It is liable to occur beneath any bog in the state. The few deposits we have are of excellent quality, and the quantity is sufficient for commercial use. The largest deposits are at Umbagog lake, Fitzwilliam, Stark, Tamworth, and on Stamp Act island, Wolfeborough. Others are known to exist at Bemis lake in Livermore, Littleton, Laconia, Bristol, Chalk pond in Newbury, Epsom, Bow, in a pond north-west from the Crawford house, White Mountains, Concord, Manchester, Durham, Grafton, and Exeter. The Fitzwilliam deposit is sold extensively for a polishing material. The principal use made of this article at the present day is in the manufacture of dynamite, and it commands a price of from $15 to $18 per ton. The most northern locality is in Cambridge, upon Umbagog lake, near W. M. Thurston's, where it occupies, in the lake, on the islands, and on projecting points of land, an area of fifty acres or more. It varies in depth from a few inches to two feet, although, as our observations were limited, the depth may be in places much greater. It is covered in the lake by a lacustrine deposit, and on the islands by an accumulation of soil.

In the town of Stark we find it in Pike's pond. It is here known to be three feet in depth, and it is probably much more. It seems to be distributed over the entire bottom of the pond.

Whetstones.

These are quarried in Piermont and Haverhill by Mr. Pike. I have not his figures for the number of stones produced; but the business is a large one, and the material is inexhaustible. Other towns along the Connecticut river contain the same rock.

Two localities of novaculite or oil-stone are capable of supplying plenty of oil-stones. One is upon Fitch hill in Littleton, near the Helderberg fossils; and the other is at the north base of the Ossipee mountains. The place may be known by the fact that certain dark streaks in the stone have been mistaken for the rocks accompanying coal. Parties interested in selling the "mine" procured bits of bituminous coal from a convenient blacksmiths' shop, and strewed them in the soil near this opening.

OCHRES.

Bog-iron ores of the nature of ochre occur at Bow, Lancaster, Bedford, Amherst, Merrimack, Bath, Madison, Grafton, Lebanon, Barrington, Gilmanton, Mason, Lyndeborough, New Boston, Chesterfield, Nottingham, Orange, Pembroke, Salisbury, Jaffrey, Moultonborough, Orford, Surry, and Plainfield. One of the most extensive is upon the land of David Colby, in the west edge of Hooksett, where I saw a few hundred pounds of red and yellow paints that had been washed free from impurities and prepared for the market. The material seemed to be sufficiently abundant to be utilized. I have not seen the ochre manufactured into paint elsewhere in the state.

The other articles enumerated at the outset, viz., copperas, alum, titanium, and moulding-sand, can be obtained from various localities. The first could be manufactured at several localities in the Connecticut valley, though not so as to be able to compete successfully with the works upon Copperas hill.

CHAPTER III.

NATURAL FERTILIZERS.

THE rocks of New Hampshire are largely granitic or feldspathic. In decomposition an abundance of potash is liberated, together with variable quantities of soda and lime. But our soils invariably show a small percentage of phosphates universally distributed. As crystals of apatite are uncommon, the question has often arisen in my mind, Whence is this salt derived? We cannot believe that enough animals have left their skeletons during the later periods, when the present soil was in the process of formation, to explain the commonness of this essential ingredient. If not of animal, it must have been of mineral origin.

The statement has been made by prominent agriculturists, that our rocks generally contain phosphate of lime. One of the points aimed at in the microscopic study of our rocks has been a search for apatite, under the impression that the soil phosphate must exist in minute crystals, invisible to the naked eye. Our researches have shown the presence of this mineral in rocks from every part of the state. This fact gives us confidence in the ability of our underlying formations to furnish from age to age a plentiful supply of this salt, so essential to the growth of crops.

Part IV contains numerous incidental references to the localities of microscopic apatite. I will enumerate the instances there mentioned, presuming that they are much more abundant than are here indicated. It occurs in the porphyritic gneiss of Antrim, the ancient gneisses of

Westmoreland, Grafton, and Swanzey, various mica schists, the quartz schists of Portsmouth, the Huronian of Norwich and Hanover, the gabbro of the White Mountains, the diabases of Bemis brook and Rye, the augite sienite of Jackson, the sienites of Chatham and Red hill, the diorites of Campton, Stewartstown, and Dixville, and the granite of Rye, Concord, Colebrook, Lightning mountain, Jackson falls, and the coarse veins carrying the valuable masses of mica and feldspar. It is found, also, in the porphyry of Waterville and Albany, and in the town of Piermont.

The other natural fertilizers of importance are limestones and the various forms of peat. The first have been described already in the preceding chapter. It is astonishing that our farmers so entirely neglect the abundant supplies of limestone occurring in our midst, and either fail to procure this mineral, when required for their soil, or else purchase that which has been brought hundreds of miles.

Only two beds of calcareous marl are known in the state,—at Hollis and Columbia. Both are limited in amount, while the substance itself is of excellent quality.

Two and a half miles south-east of Colebrook village, in the north part of Columbia, is Lime pond. This pond is nearly a hundred rods long, and probably half as wide. Its bottom is covered with white calcareous marl, which has a depth in some places of 15 feet. On the east side of the pond there is also a buff-colored sedimentary deposit.

The marl is formed by the accumulation of myriads of shells of the Cyclas and Planorbis, an abundance of which was everywhere found where the marl was covered with water, for the pond has been partially drained. Dr. Jackson supposed the neighboring peat swamp to be the most active agent in supplying the shell-fish with calcareous salts, from which they secrete the carbonate of lime of their shells. "On testing the water, it was found to be charged with crenate, apocrenate, and humate of lime, and it contains, also, a notable proportion of ammonia. In evaporating a portion of the water, a buff-colored precipitate subsides, which contains the above-mentioned organic acids, combined with lime and an excess of carbonate of lime, which was originally held in solution by carbonic acid as a bicarbonate."

Peat is the vegetable soil of bogs and swamps, and consists of the dèbris of decomposed aquatic or marsh plants. That formed from moss is of the best quality, and it is very abundant in the granitic regions of the northern United States. Muck is peaty matter mixed with soil, and is consequently less valuable than the pure article. Peat ripens with age or advancement in decomposition, and is thus comparatively heavy and dense, and appears pitchy. Its value increases with age. This substance may make a good fuel; but especially it is susceptible, under proper treatment, of becoming a valuable fertilizer. It absorbs and retains water and ammonia, promotes the disintegration of the rocks, renders light soils more productive by its application, and acts as a direct fertilizer.

Those who have experimented with this material, and compared its properties with those of ordinary stable manures, find that it usually carries, in a given amount, one third more organic matter, an equal amount of lime and nitrogen, but is deficient in potash, magnesia, phosphoric and sulphuric acids. These deficiencies may be remedied by adding to 100 pounds of fresh peat one pound of commercial potash, or five pounds of unleached wood ashes, one pound of good superphosphate, or one pound each of bone-dust and plaster of Paris. In view of the small amount and the cheapness of the materials to be added to peat to make it equal to stable manure, it seems as if the farms of New Hampshire might be greatly enriched at a very small expense. The peat of various localities requires different degrees of amendment; and therefore only the general rule given above can be stated to show what ought to be done. Samples should be sent to a chemist for special analysis by those who wish to utilize the article.

Without speaking exhaustively, we have a few notes about peat in different localities, which may be of service in giving some idea of the great abundance of the deposit in every section of the state. The facts from the extreme north were furnished by Mr. Huntington, and others are copied from Mr. Upham's note-book.

Bogs and peat swamps are very numerous in northern New Hampshire. They are found in every town, and are often of great extent. Sometimes they present a broad area, without the vestige of a tree or shrub, except along their borders, and this area is covered with a luxuriant growth of grass (*Calamagrostis Canadensis*). One of the largest of this kind is a mile and a half west of Second lake, at the head of Bay brook, and it has an area of fifteen or twenty acres. West of Perry Stream, on the same line going west, there is another extensive bog; and also northward, near the head of the same stream, there are several. These are more or less occupied by shrubs and trees. The laurel, *Kalmia glauca*, labrador tea, and the *Ledum palustris*, are common, while here and there, from the sphagnous bed, rises a hackmatack or larch. Northward of Second lake, towards Mt. Carmel, there is a very extensive swamp, but there are no open bogs. Here, besides the laurel, the labrador tea, and the larch, we frequently find the cedar and the alder. Half a mile south of the south bay of Connecticut lake there are two small open bogs; and on these cranberries are abundant. These bogs, like those north, seem to have been formed almost entirely from a species of moss (sphagnum). The peat here is not more than six feet in depth, and for the most part it seems to be composed of partially decomposed fragments of the moss.

Organic acid produced by the vegetable matter, when long saturated in water, removes from the subsoil of the bogs the oxides of iron and manganese, as well as lime and other alkaline earths: hence the subsoil of bogs usually consists of bleached whitish sand and clay of a very unproductive character. There are few exceptions to this, in localities where the soil contains a very large proportion of lime. On the other hand, when the underlying rocks contain an iron sulphide, the sulphuric acid produced from this mineral gives a still greater degree of acidity to the bog, while the iron is sometimes in too great quantity to be entirely removed. "The iron and manganese, removed in the manner above mentioned, are deposited, usually, in rounded kernels at the outlet of such bogs, or in the soils through which the water soaks, and become partially exposed to the air. In this way small quantities of bog-iron ore and bog manganese ore are formed in the vicinity of many swamps. All these facts respecting bogs have their analogies on a large scale in our ancient rocks." "The bogs, when drained and their surfaces dressed with sand or sand and lime, to supply the siliceous and calcareous matter in which they are deficient, are excellent soils, second only to dyke marshes in their productiveness in hay and oats." There are many bogs in northern New Hampshire that might in this way be reclaimed, as it is not improbable that in time the peat from the swamps will be used as fuel and as a fertilizer. One of the most extensive swamps in the state is in the south-east part of the Dartmouth College grant. The distance across this bog on the state line is 290 rods, and the distance east and west, including the bogs on both sides of the Magalloway, is much greater. Along the Androscoggin there are several interesting peat deposits. One in Milan, just north of the mouth of the Chickwolnepy, has in it many trunks of fallen trees, principally tamarack (larch), nearly all of which are well preserved. In Shelburne, on the farm of Mr. Burbank, is a peat swamp that has been partially reclaimed.

The peat lands of Rochester, probably more than 150 acres in total amount, are well seen from the Portsmouth, Great Falls & Conway Railroad. The deepest soundings in these bogs, found by the railroad survey, were a little more than 20 feet. Between the village and the first crossing north is the most extensive single area. Here 50 to 60 acres, upon which the peat is 5 to 15 feet deep, situated on the east side of the railroad, are owned by the Strafford County Improved Peat Company. This company was incorporated during the civil war, when the price of coal was greatly advanced. After the war, coal was again cheap, so that it was thought impossible to prepare peat for the market at a profit, and no work was ever done by the company. Mr. E. J. Mathes has used this peat two or three years as fuel for his house. It is cut with a spade shaped like the Irish slane. The pieces are spread to dry, for which they need to be turned over after two or three days. In this way the water, to the extent of 75 per cent. of their original weight, is evaporated, and they shrink one third in size. Thus prepared, the peat is very spongy. A better process, also employed by Mr. Mathes, is to grind the peat and break up its vegetable fibers, in the manner that clay and sand are mixed for brick-making. Thus ground and moulded like bricks, pieces 4 by 6 by 8 inches in dimension shrink in drying to 2 by 4 by 6 inches, or to one fourth their original size. The peat thus prepared is compact and hard, requiring a hammer to break it. It yields a considerable amount of ashes, which are very light and dusty. They are found useful for polishing.

Several peat-bogs occur in Stratham. The largest is the Temple meadow in the south-east part of the town, covering 60 acres, the depth of peat averaging about 4 feet; its greatest depth is 6 feet. This peat has never been used. Another peat-swamp, occupying about 10 acres, lies one mile north of the village. This was used for fuel to some extent about fifty years ago. Its only use now is as a manure, for which about 100 cords are dug yearly. About half a mile east from the last is the Heath swamp, containing about 100 acres of peat. This was never used for fuel. About 50 cords are employed yearly for manure. The depth of peat in these swamps exceeds 20 feet.

Other localities, where peat is conspicuously abundant, are South Lancaster, Springfield, Grantham, Enfield, Lebanon, and many others in Rockingham, Strafford, Hillsborough, and Merrimack counties.

INDEX.

INDEX TO PART V.

ERRATA.

PART III.

On page 167, line 6 from the bottom, for "Plate IV," read *Plate VII.*

On page 184, line 5, for "Bronson hill," read *Bronson's kiln.*

On page 184, line 13, for "S. 28° E," read *S. 28° W.*

The same upon page 212, line 20.

On page 187, line 16, "Mrs. M. Gale's" should be placed under *Belmont.*

On page 187, line 35, "K. Hall's" should be placed under *Gilford.*

On page 187, lines 4 and 5 from the bottom, for "south corner," read *Strafford Corner.*

On page 188, last line, for "Newbury," read *Sutton.*

On page 189, line 15 from the bottom, "E. C. Sanborn's" should be placed under *Hampton Falls.*

On page 194, lines 6 and 7 from the bottom, "Lufkin's and Howe's" should be placed under *Rumford.*

On page 202, last line, insert "not" before distinguishable.

On page 203, line 11, for "south-east," read *south-west.*

On page 302, first line, for "rounds," read *mounds.*

PART IV.

On page 8, line 8 from the bottom, for "clacite," read *calcite.*

On page 80, line 7 from the bottom, for "Fig. 2 on Pl. 9," read *Fig.* 9 *on Pl.* 2.

On page 102, in the formula, for "Al," read Al^2.

On page 15, and elsewhere in the first chapter, for "pinnacoid," read *pinacoid.*

PART V.

On page 44, line 7 from the bottom, and page 45, line 26, for "slums," read *slimes.*