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PROFESSORS JOSIAH P. COOKE, GEORGE L. GOODALE  
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PROFESSORS H. A. NEWTON AND A. E. VERRILL, OF  
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THE

# AMERICAN JOURNAL OF SCIENCE

[THIRD SERIES.]

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ART. I.—*Theory of an Interglacial Submergence in England*;  
by G. FREDERICK WRIGHT.

UP to a very recent date English geologists were very generally agreed that the British Isles have been visited by at least two distinct glacial epochs since Tertiary times, and that during the supposed interglacial period there was a subsidence in the northern part of England, amounting to from 1,400 to 2,000 feet. The evidence most relied upon in proof of this theory is the occurrence of interglacial stratified beds of sand and gravel containing sea shells at Moel Tryfaen, near Mount Snowdon, about 1,400 feet above sea-level, and at Macclesfield, near Manchester, about 1,200 feet above the sea. At other places, also, similar interstratified beds occur at lower levels; as at Wellington, in Shropshire, about 500 feet above tide; upon the east coast, near Flamborough Head, from 300 to 400 feet; and throughout Holderness, at lower levels. North of Flamborough, also, the glacial deposits pretty continuously show a threefold division, consisting of two strata of till separated by stratified material, but the deposits here nowhere rise more than 400 or 500 feet above the sea.

But in view of accumulating facts concerning the stratification that takes place about the margin of a great glacier whose front is subject to temporary oscillations, interglacial stratified beds cease in themselves to be evidence either of absolutely distinct glacial epochs or of subsidence. The occurrence of unbroken salt-water shells in some of these deposits appears more nearly like positive proof. It would seem, however, that even this must now be regarded not only as questionable

in itself, but as connected with a theory which creates greater difficulties than it explains.

As long ago as 1874 Mr. Belt\* and Mr. Goodchild† suggested that the sea shells in question may have been pushed up from the bottom of the sea, like other pebbles, by the advance of the glacial current. In 1881 Mr. Clement Reid‡ also favored the suggestion, while a little later Prof. H. Carvill Lewis took up the theory and advocated it with great vigor.§ Prof. Lewis's advocacy is the more significant, in view of the fact that, in the light of his experience in conducting with me the survey of the glacial boundary in Pennsylvania, he had just devoted two years to a survey of the glacial boundary in Ireland, Wales, and England. But his sudden death interrupted both the further field work which he was proposing and the complete digestion and publication of the extensive field notes already taken.

Investigation, however, has not flagged since Prof. Lewis's death, and the opportunities for collecting additional information in a visit which I made to England for that purpose last summer, have been largely due to the interest aroused by his work. For the facts now presented I am indebted not only to the papers enumerated below,|| but in special degree to the

\* *Nature*, May 14, 1874. † *Geological Magazine*, 1874, p. 496.

‡ *Geological Magazine*, 1881, p. 235.

§ *Proceedings of the British Association for 1886 and 1887*.

|| Dugald Bell, *Phenomena of the Glacial Epoch* (*Transactions of the Geological Society of Glasgow*, 1889); J. H. Blake, *On the Age and Relation of the so-called "Forest-Bed" of the Norfolk and Suffolk Coast* (address at the Anniversary Meeting of the Norwich Geological Society, Nov. 2, 1880); H. W. Crosskey and David Robertson, *The Post-Tertiary Fossiliferous Beds of Scotland: XV—Jordanhill Brickworks, and XX—Kyles of Bute* (*Transactions of the Geological Society of Glasgow*, vols. iv and v); H. W. Crosskey, *On a Section of Glacial Drift recently exposed in Icknield Street, Birmingham, and Notes on the Glacial Geology of the Midlands* (*Proceedings of the Birmingham Philosophical Society*, vols. iii and vi); J. R. Dakyns, *Glacial Deposits north of Bridlington* (A Paper read before the Geological and Polytechnic Society of the West Riding of Yorkshire, 1880); C. E. DeRance, *Notes on the Vale of Clwyd Caves* (*Proceedings of the Yorkshire Geological and Polytechnic Society*, 1888); *On the Post-Glacial Deposits of Western Lancashire and Cheshire* (*Quarterly Journal of the Geological Society for February*, 1871); J. G. Goodchild, *The Glacial Phenomena of the Eden Valley and the Western part of the Yorkshire—Dale District* (*Quarterly Journal of the Geological Society for February*, 1875); Percy F. Kendall, *On the Occurrence of Nassa Serrata Brocchi in the Glacial Drift of the North Shore, Ramsey, Isle of Man* (*Proceedings of the Manx Geological Society*, 1889); *On the Pliocene Beds of St. Erth* (*Quarterly Journal of the Geological Society for May*, 1886); G. W. Lamplugh, *On Glacial Shell-Beds in British Columbia* (*Quarterly Journal of the Geological Society for August*, 1886); *On the Larger Boulders of Flamborough Head and other parts of the Yorkshire Coast, Parts II—IV*. (*Proceedings of the Yorkshire Geological and Polytechnic Society*, 1889 and 1890); *Glacial Sections near Bridlington* (*Proceedings of the Yorkshire Geological and Polytechnic Society*, 1882 and 1889); *On a Recent Exposure of the Shelly Patches in the Boulder-clay at Bridlington Quay* (*Quarterly Journal of the Geological Society*, vol. xxxvi, p. 515 and xl, pp. 312—328); *On Photograph of Cliff-Section*

personal attention of Dr. Crosskey and Mr. Martin, of Birmingham; of Mr. Kendall, of Stockport, and various members of the Northwestern Boulder Committee, of which he is president, and of Mr. Lamplugh of Bridlington,—all of whom have kindly accompanied me to the typical exposures of glacial deposits in the vicinities where they reside. The aid of Dr. Crosskey was specially important from the fact that he had just completed the editing of Professor Lewis's field notes, which are soon to be published. For Mr. Kendall's views I am further indebted to a systematic statement of the facts which he has prepared for me to be used as a chapter in a volume, on "Man and the Glacial Period," which is soon to be published in the International Scientific Series.

At the outset the theory of deep interglacial submergence to account for the shell-beds of Moel Tryfaen and Macclesfield encounters many most formidable objections: 1st. The subsidence must have been one which affected the north of Wales and central England, without affecting the region south of the Bristol Channel and the Thames; for confessedly there are no marks of subsidence or of glaciation over that area. 2d. There is in other places a remarkable absence of marks of subsidence over the northern part of the center of England, where it is supposed to have been the greatest. This is the more noteworthy, since in the glaciated region farther north kames abound, while at Glen Roy, a prominent feature in the landscape is the beaches formed during the existence of temporary glacial lakes, showing that the time which has elapsed since the glacial period has been too short to permit such features to be obliterated. But throughout all England there is a conspicuous absence both of such beach lines at high levels and of any other marks which would have been left by a sea margin had it continued for any appreciable time at the level of the shell-beds under consideration. 3d. This is still more remarkable from the fact that the Pennine Chain is not more than 25 or 30 miles wide from east to west, and east of

at Hildershorpe (Proceedings of the Yorkshire Geological and Polytechnic Society, 1887); D. Mackintosh, On High-Level Marine Drifts (Quarterly Journal of the Geological Society, 1881, pp. 351-369); Fred W. Martin, On Some Sections of the Drift between Soho and Perry Barr, near Birmingham (Proceedings of the Birmingham Philosophical Society, vol. iv, part II, pp. 364-370); First Report upon the Distribution of Boulders in South Shropshire and South Staffordshire (Proceedings of the Birmingham Philosophical Society, vol. vi, part I); Aubrey Strahan, On the Glaciation of South Lancashire, Cheshire, and the Welsh Borders (Quarterly Journal of the Geological Society, 1886); C. Reid, Geology of Holderness and of Cromer (Geol. Survey); Woodward's Geology of England and Wales is a storehouse of accurate information upon this as upon all other subjects of which it treats; R. M. Deeley, The Pleistocene Succession in the Trent Basin (Quarterly Journal of the Geological Society for November, 1886); G. W. Lamplugh, On the Drifts of Flamborough Head (Quarterly Journal of the Geological Society for August, 1891).

Macclesfield there is an entire absence upon its flanks both of glacial deposits and of beach lines. 4th. The shell-beds are strictly confined not only to the area which was demonstrably covered by glacial ice, but to those more limited areas which were reached by ice that is known to have moved in its way over shallow sea bottoms. 5th. The assemblage of shells is not such as could have occurred in one place in the ordinary course of nature. There are associated together in these deposits cold-water forms with warm-water forms, rock-haunting species with sand- or mud-loving species, and in no case has a shell been found in these beds with its valves in apposition.

An interesting illustration of this latter point is brought out in Mr. Kendall's paper "On the Occurrence of *Nassa serrata* Brocchi, in the Glacial Drift of the Northern Shore, Ramsey, Isle of Man." This mollusk is now characteristic of the Mediterranean Sea, and cannot endure even the present temperate climate of the Irish Channel, yet specimens of it are found in the glacial deposits on the Isle of Man. It is in the highest degree improbable that this mollusk could have lived where it was found under any conditions that have been supposed to exist since the close of the Tertiary period. The theory that it was transported from the remains of Pliocene beds on the shallow bottom of the Irish Sea is certainly the most natural if only one can grant that it is conceivable. Other shells found in the glacial deposits in Northwestern England and Wales almost as much out of place are *Cytherea chione* L., *Mitra* sp., and *Turritella triplicata* Brocchi. It is worthy of note, also, that Prof. Edward Forbes early called attention to the fragmentary condition of the shells in the beds of the northwest of England, and to their general distribution through the till. Speaking of the Moel Tryfaen shells he says: "I have lately examined them carefully with a view to see whether they indicate an ancient coast-line or beach, or an ancient sea-bottom. But they cannot be regarded as indicating either, being a confused mixture of fragments of species from all depths, both littoral and such as invariably live at a depth of many fathoms. . . Such deep- and shallow-water species mingled could at no time have lived together, or been thrown upon one shore."\*

During a visit this summer to Ketley, near Wellington in Shropshire, in company with Dr. Crosskey, Mr. Martin, and Prentiss Baldwin, we were fortunate enough to discover an unusually large collection of nearly perfect shells in the interstratified glacial deposits of that place. We could not indeed determine that there was till underneath the sand (which was here twenty-five or thirty feet at least in thickness), but there

\* Memoirs, Geological Survey, vol. i, p. 384; quoted by Dugald Bell.

were several feet of till overlying the sand, and a thin stratum of gravel at the junction of the two. In this gravel Mr. Baldwin discovered several slightly worn shells and on further examination forty or fifty well-preserved specimens were brought out. All these were identified by Dr. Crosskey as belonging to species now common on the English coast. The elevation above the sea would vary only a little from 500 feet. A few miles from the same locality, at an elevation above the sea of about 700 feet, Dr. Crosskey had previously discovered in the glacial deposits other shells which were of a decidedly arctic type. It is extremely improbable that both could have lived in that locality amid the conditions involved in the interglacial hypothesis, as the temperature which would be favorable to one would be destructive to the other. But on the supposition that both had lived and died in succession upon the bottom of the Irish Sea, and then had been transported by the moving ice to near their present position, where the till was subjected to temporary water action sufficient to sort out a portion of its material, everything is intelligible and consistent.

Various reports have also come from Scotland of arctic shells in glacial deposits at some distance above sea-level. Those found near Airdrie have been most written about, and were the highest reported, being 510 feet above the sea. But closer examination shows that they also may be explained in accordance with the theory of Professor Lewis. This Sir Archibald Geikie practically admits in the second edition of his "Text-book of Geology," saying that "the layer containing them may have been transported by an ice-sheet" (pp. 897, 902). Mr. Dugald Bell informs me that after carefully examining all the alleged instances of elevated shell-beds in the glacial deposits of Scotland, there is no clear proof of any glacial submergence of more than 200 or 300 feet, and the evidence for even that amount is questionable.

As to the conceivability of the transportation of shells in the till, many significant facts have recently been brought to light. The till in the vicinity of the shell-beds mentioned, and in other places where the ice has moved inland from the seabottom, contains a great number of shell fragments indiscriminately mixed with the mass. I have even seen in a mass of boulder clay the half of a bivalve, with its cavity filled with sand, which had kept its place under the shell as it was shoved along; thus serving to protect it from being crushed. As long ago as 1884, Mr. Lamplugh, in examining the dry dock which was then being excavated in Esquimault Harbor, Vancouver, discovered evidence that most of the glacial shells which were found in the drift there had "been pushed up into

the gully by ice in its passage southward across the harbor," for they were so scattered through the unstratified mass that it was impossible to draw a line between the shelly and the shell-less clay.\* In the glacial deposits surmounting the chalk cliffs near Flamborough Head, Mr. Lamplugh showed me elongated masses of sandy material containing well-preserved shells, but which were included in till, and had evidently been drawn out by the shearing movement to which the whole mass was subjected. There could be little question that in this instance the mass had in some way been pushed up from the sea bottom by the same ice-movement which had carried thither the rest of the till. Here the elevation was between 200 and 300 feet, and I see no reason why the causes operating to produce that amount of movement and elevation might not under favorable conditions have transported similar masses to the elevation of the shell-beds at Moel-Tryfaen.

In recent speculations upon the movement of ice too exclusive attention has been given to its analogies with the motion of a semi-fluid, forgetting that under a mechanical thrust ice moves like a solid, and may plough up and push along before it whatever is in its way. Indeed, as I recall the phenomena at Muir glacier, I feel confident that this is what is taking place on the bottom of the inlet. A large number of the icebergs are formed by the falling off of the precipitous ice-front, owing doubtless to the fact that in the ordinary motion of the glacier the upper strata move faster than the lower. At times I saw such masses break off in columns more than 250 feet in height, and extending below the surface of the water, but the fractures did not reach to the bottom of the ice, for occasionally an immense mass in front of the ice-wall would rise bodily out of the depths of the water, bringing up much dirt with it. This projecting foot of the ice may perhaps have been moved forward bodily at the bottom of the inlet by successive mechanical thrusts of the moving mass of ice behind. So in analogous situations where there is a concentration of lines of pressure from behind, we can conceive that material would be gradually thrust up in front of the ice without much attrition. At any rate, the fact that the material is so raised and pushed along in front of the ice I think will have to be accepted.

Returning now to the specific glacial phenomena in England, it would seem that they can be generalized under one glacial epoch, upon the following scheme, which is based upon the facts as they are now reported. The beginning of the glacial period was marked, in the seas surrounding England,

\* Quarterly Journal of the Geological Society, Aug. 1886, p. 283.

by the southerly retreat of the Pliocene fauna and the incoming of subarctic and arctic species; so that shells of diverse nature became commingled all over the bottom of the Irish and North Seas. Scandinavian glaciers advanced over the shallow North Sea till they reached the shores of England at Flamborough Head, where they were met by the glaciers that had been slowly coming down from southeastern Scotland and northeastern England. This latter movement of the ice was compelled to hug the shore by the Scandinavian glacier, and its boulders are found only as far south as Flamborough Head. The Scandinavian movement reached pretty generally to the line extending from Flamborough Head to London.

Contemporaneous with this movement over the North Sea, glaciers began to push out in all directions from the northern part of Wales, having their center in the broad elevated area of the Arenig mountains about twenty five miles southeast of Snowdon. Towards the east this movement extended across Shropshire and the southern part of Staffordshire to a line extending from Litchfield, through Birmingham, and Bromsgrove to the Severn Valley. But meanwhile a more powerful ice-movement was under way, originating in the snowfields of Eastern Ireland, Southwestern Scotland, and the Lake District in England. The glaciers from these centers, meeting in the Irish Sea, advanced to the north shore of Wales, and in divided currents passed over Anglesey on the west, and on the east through the broad Vale of Chester which separates the Welsh Mountains from the Pennine Chain by a distance of 60 or 70 miles. Immense quantities of Scotch and Lake boulders were thus transported into the valley of the Severn as far as Wolverhampton, about half way between Wellington and Birmingham. This northern ice seems to have predominated over, and pushed aside, the weaker movement from the Welsh Mountains, which had deposited the band of boulders just mentioned, extending from Litchfield to Bromsgrove. I shall be surprised if future explorations do not reveal Welsh boulders underneath the Scotch drift, so extensively developed near Wolverhampton. It is in this northern drift that the shell-bed discovered by Mr. Baldwin at Wellington occurs.

The triple stratification spoken of as characterizing the marginal deposits near Flamborough Head, and in Lancashire and Shropshire, need not necessitate anything more than a local recession of the front, followed by a subsequent corresponding advance. Indeed, it is evident that the problems of the glacial margin in England closely resemble those in the United States, and Professor Lewis's observations require the same corrections for the personal equation in England that we have had to make for him in America,—corrections which he

himself had begun to make at the time of his lamented death. When, in 1880, Professor Lewis conducted the glacial survey of Pennsylvania with me, we were laboring under the mistaken idea that the margin of the glaciated area was everywhere marked by a pronounced terminal moraine, and we did not pay sufficient attention to the so-called "fringe" of glacial deposits which nearly everywhere extends a greater or less distance in front of the moraine. In my own subsequent work west of Pennsylvania I devoted my main efforts to the determination of the boundary of this fringe, leaving the interior moraines to be filled at leisure. The correction of our determinations which has been made by Mr. Max Foshay in Western Pennsylvania, and that by Messrs. Salisbury and McGee of Professor Cook's work in New Jersey, had already been foreshadowed both by Professor Lewis and by myself,\* but, as we rightly supposed, nowhere in Pennsylvania and New Jersey does the fringe extend many miles south of our moraine.

In England Professor Lewis's moraine as reported to the British Association needs about the same correction to determine the extreme limits of the ice as is required in Pennsylvania. Almost everywhere in England there was a fringe of glacial debris in front of Lewis's moraine, but in England no more than in America does it seem to be necessary to interpret this fringe as the remnants of an earlier and distinct glacial period. The close conformity of the boundary of the fringe to that of the more pronounced glacial deposit seems to point clearly to the operation of a common cause; for it would seem in the highest degree improbable that two distinct glacial periods should so closely correspond in the marginal line of their deposits. Certainly we should not make this supposition except in the presence of facts which will not allow of a simpler explanation.

Oberlin, O., Oct. 16, 1891.

\* See *The Ice Age in North America*, pp. 135, 136.

ART. II.—*The Permian of Texas*; by RALPH S. TARR.

FROM the time of the publications of Marcou and Shumard on the Geology of the Southwest to the present, the existence of Permian in Texas has been reported by various observers. Many have doubted its existence, but Prof. C. A. White\* has brought forward conclusive evidence on this point and it is not now doubted that a large part of Texas is occupied by Permian beds. Much remains to be done in this region before the distribution of these strata through space and time is thoroughly understood. In the first and second annual reports of the Texas Geological Survey, Mr. W. F. Cummins has added many facts of interest to our knowledge of the Permian of Texas, which he estimates to have a thickness of fully five thousand feet.

A detailed study of the Carboniferous beds beneath the Permian, both in the eastern and western side of the basin, and a reconnoissance trip across the Permian deposits are the basis for the following remarks upon the Permian, the excuse for their publication being the limited information on hand in regard to this formation.

The Permian of Texas occupies a broad, gentle syncline in the Carboniferous, the western arm being a part of the Rocky Mountain uplift. Its present boundaries, and consequently its former extension, have not been ascertained. Many hundred square miles are covered by these strata in the sub-humid and arid belt of central Texas, the Pecos River forming, approximately the western boundary, while on the east the strata do not extend much farther than Abilene.

In lithologic character the strata are distinctive and, except near the contact, not to be confounded with the Carboniferous. They are chiefly beds of clay, sandstone and conglomerate, strikingly red in color. Limestone beds also occur, these usually being a pale gray, quite characteristic, though often stained on the surface by the red clay from the red beds. In addition to these strata there are beds of gypsum and of salt, and in the center of the district all the water is rendered unpalatable by the presence of these salts. Most of the beds are unfossiliferous, but Dr. White has described thirty-two species of invertebrate fossils from the Texas Permian, and Prof. Cope fifty-seven species of vertebrates. It is upon this basis that the beds have been referred to the Permian.

It is the object of this paper to indicate the sequence of events which have led to deposition of the Permian beds in

\* Am. Nat., xxiii, p. 109, Feb., 1889.

this district. The Carboniferous rocks of central Texas have been divided by the writer\* into five divisions, based upon lithological and faunal characteristics, as follows: Richland Sandstone, Milburn Shales, Brownwood Limestone, Waldrip Coal Measures, Coleman Limestone and Clays. The history here indicated is one of gradual submergence until the time of the Brownwood limestone, then an emergence continued through the time of the Coleman strata, which are infra-littoral beds. The Brownwood beds contain the typical marine fossils of the Carboniferous, the Waldrip coal measures combine with these the land flora, and these conditions continue into the Coleman beds.

The latter are the highest of the Carboniferous strata and near the Permian have less character than lower down. The series consists of alternating beds of limestone and clays and the presence of clay is everywhere evident, even in the purest limestones. Shore lines, proved by ripple-marks, reptile tracks, coal seams and other signs, show that at this time the Carboniferous beds were in part subjected to denudation. It is probable that the denudation of these rocks was in large measure the source of supply of the clays of the Coleman beds, and the unconsolidated nature of the coastal strip accounts for the general absence of conglomerates and sandstones.

The shallowness of the water and its muddy character gave rise to or permitted the extension of a new fauna into the seas. That the clear water animals which aided in the formation of the Brownwood limestone still existed in the neighborhood is well proved by their frequent recurrence in certain purer beds of limestone in the Coleman series. They were temporarily forced out by changed conditions and again and again allowed to return. This repeated alternation, both lithologic and faunal, is characteristic of the Coleman beds, but the predominant lithologic character is a muddy water deposit and the fauna a mud-loving one, including such species as *Myalina*, *Pinna*, *Allorisma*, *Bellerophon*, and the like.

On the western border of the Permian area the same general series of rocks is found in the Carboniferous of the Guadalupe mountains. The lower rocks are here shallow water deposits, followed by deeper water limestones of great thickness, and these in turn by an upper series of alternating beds. Shore lines are absent here, however, proving that this point was not the exact western coast line. Shumard has called these beds Permian, but I have shown in a manuscript report in the hands of the State Geologist of Texas for publication, that they are really Carboniferous, this being proved by palæontologic, lithologic, and stratigraphic evidence.

\* First Ann. Rep. State Geol. Survey of Texas, 1890, pp. 201-216.

The Permian occupies the basin between these two Carboniferous areas, which are several hundred miles apart, the basin being a syncline formed by the west dipping Carboniferous of the east and the east dipping rocks of the Guadalupe and other mountains of western Texas. The Permian strata are themselves folded into a very gentle, almost imperceptible, syncline, being almost, if not quite, conformable to the gently dipping Carboniferous beds on which they lie.

The line separating the Carboniferous from the Permian on the east is very indistinct, being traceable only with difficulty. Mr. Cummins reports an overlap or slight unconformity at this contact, though its exact value is not determined as yet. Where seen by the writer there seemed to be an almost imperceptible gradation from upper Coleman to Permian. Small overlaps abound in the Coleman series and it is possible that the overlap reported by Mr. Cummins has but slightly more value, though this is suggested only tentatively.

The facts stated above show in later Carboniferous times a shallow water condition at points several hundred miles apart. In the east, in particular, the conditions are those of a shallow sea skirt by newly made land of unconsolidated strata. It cannot be affirmed from the evidence at hand that this was a Mediterranean sea, but indications point to that conclusion. The great extent of similar beds, in both central and west Texas, are rather against the supposition of estuarine conditions. I conceive for this period a condition not unlike that of the present Gulf of Mexico. The Paleozoic and pre-Paleozoic core of central Texas was skirt with the recently added coastal strip of Carboniferous strata, and the connection with the Arkansas and Indian Territory mountains was complete. What formed the enclosing barrier on the south and west we have no means of knowing in the present meagre knowledge of the geology of these regions.

This is not pure unconfirmed conception, for the subsequent events of Permian time point quite conclusively to this explanation. That the Permian in its most typical development was a completely enclosed sea is proved beyond a doubt by the nature of its beds. In no other way can the numerous layers of gypsum and salt be accounted for. The redness of the clay and sandstone beds is then easily explained, though for this other explanations are possible. The peculiar sickly gray color of the limestone is that of an inland sea deposit, the remarkable absence of fossils in most of the beds points to the conclusion already drawn, and the abundance of vertebrate fossils of land and inland sea types is thus readily accounted for. The presence of extensive conglomerates with very large pebbles

derived from points as far distant as the Indian Territory, seem hardly capable of origin except in an inland sea with a tolerably arid climate, or else by glaciation.

The Permian was undoubtedly deposited in an inland sea in which salt and gypsum were also deposited. The small break, if any exists, between the Permian and Carboniferous, shows that in point of time these two formations were immediately associated, the one succeeding the other. This gradation is also proved by the fossils. One of the distinctive Permian types, *Pleurophorus*, occurs in the Coleman beds, while the same species of *Bellerophon*, *Myalina* and others, are common to the two series of beds. The Permian conditions are, therefore, foreshadowed in the Carboniferous, and probably, also, the conditions which culminated in Permian times in the completely enclosed dead sea were in Coleman times indicated by the gathering in of shore lines and the partial enclosure of a Mediterranean sea. The change of fauna from Carboniferous to Permian, and also the close resemblance of the two in many respects, as well as their wide divergence in others, may be thus explained. An enclosed sea would destroy some species and admit of the introduction of others to meet the changed conditions. A temporary destruction of some part of the barrier might admit marine types which in the lapse of time may have changed to new types.

In summary it may be said that the object of this paper is to show that the Permian of Texas is, like other areas of Permian, such as those in Europe, a deposit in large measure made in an inland sea, at certain times in its history a dead sea. This condition was foreshadowed in later Carboniferous times not only in the lithologic nature of the strata and in the fauna, but also in the topographic conditions, the later Carboniferous being in all probability deposited in a Mediterranean sea more or less completely landlocked. The Permian was the immediate successor of the Carboniferous, being separated, if at all, by a very slight break, the marked difference in the nature of the beds and the character of the fauna being due rather to changed conditions than to actual time break.

ART. III.—*The Chemical Composition of Iolite*; by O. C. FARRINGTON.

As is well known the formula of iolite has never been satisfactorily established. This is chiefly for the reason that the state of oxidation of the iron, in the analyses hitherto published, has not been determined. Stromeyer,\* Gmelin† and Schütz,‡ who made the earlier analyses, regarded the iron as protoxide. Scheerer,§ however, in 1846, in connection with analyses of iolite from Kragerö, urged that it was more probably present as sesquioxide, his reason being stated as follows:

“Das Verhältniss des Sauerstoffs der Kieselerde zu dem der Thonerde und zu dem der 1 und 1 atomigen Basen ergiebt sich hiernach wie:  $\text{Si } 26 \cdot 20 : \text{Al } 15 \cdot 26 : \text{R } 5 \cdot 48$  wenn man nämlich annimmt, dass die geringe Menge Eisen als Oxydul in Mineral vorhanden sei. Diess dürfte aber schwerlich der Fall sein, da der analysirte Cordierit fast völlig farblos war und auch nicht den geringsten Stich ins Grünliche zeigte, während es bekannt ist, dass verhältnissmässig sehr kleine Quantitäten Eisenoxydul hinreichend sind, um einen (nicht pulverförmigen) Silicate eine deutlich grüne Farbe zu ertheilen, sobald diess natürlich nicht durch andere färbende Substanzen verhindert wird. Nimmt man daher gewiss mit mehr Recht das Eisen in Zustande des Oxyds an, so wird das Sauerstoffverhältniss  $\text{Si } 26 \cdot 20 : \text{R } 15 \cdot 64 : \text{R } 5 \cdot 26$ .”

This conclusion of Scheerer has been accepted by most later writers. Rammelsberg,|| regarding the iron as sesquioxide, deduces the generally accepted formula,  $2\text{MgO}, 2\text{R}_2\text{O}_3, 5\text{SiO}_2$ , although the ratios are not very satisfactory. He also suggests  $\text{Mg}_3\text{R}_2\text{Si}_5\text{O}_{23}$  as a possible formula. Water seems to have been disregarded.

At the locality in Guilford, Conn., recently described by Dr. E. O. Hovey,¶ iolite occurs as stated by him, as a constituent of the rock mass. This locality was visited by the writer, and it was also found that veins of more coarsely crystalline material, running through the gneiss, contained the mineral in grains as large as a walnut and even in pieces of sufficient size for hand specimens. These large grains are very clear and transparent, and show none of the tendency to alteration so characteristic of the iolite from other localities.

The exceptional purity of this material led the writer to make a chemical analysis of it, and care was taken to use only those grains which were perfectly clear and showed the charac-

\* Unters., Rg. Min. Ch. † Schwgg J., xiv, 316. ‡ Pogg. Ann., liv, p. 565.

§ Pogg. Ann., lxxviii, p. 319.

|| Mineralchemie, 1875, p. 652.

¶ This Journal, III, xxxvi, 57.

teristic pleochroism of the mineral. A determination of the state of oxidation of the iron was included in the analysis, FeO being determined by decomposition of a separate portion with hydrofluoric and sulphuric acids and titration with potassium permanganate. Water was determined directly, by fusing about a gram of the mineral with dry sodium carbonate in a Gooch tubulated crucible and collecting in a chloride of calcium tube. The precaution was taken to surround the first crucible with another containing sodium carbonate, so that no products of combustion from the flame could penetrate the red hot platinum and render the result too high. The analysis gave the following results :

	I.	II.	Mean.	Ratio.		
SiO <sub>2</sub> ----	49·44	49·56	49·50	·825	·825	5.
Al <sub>2</sub> O <sub>3</sub> ---	32·97	33·04	33·01	·324	} ·326	1·98
Fe <sub>2</sub> O <sub>3</sub> ----	·35	·41	·38	·002		
FeO -----	5·11	5·13	5·12	·071	} ·335	2·03
MnO ----	·32	·27	·29	·004		
MgO ----	10·39	10·46	10·42	·260		
H <sub>2</sub> O -----	1·65	1·58	1·62	·090	·090	0·54
	<hr/> 100·23	<hr/> 100·45	<hr/> 100·34			
Sp. Gr. ....	2·607					

From this it will be seen that nearly all of the iron is present as protoxide. The analysis also shows the ratio of SiO<sub>2</sub>:R<sub>2</sub>O<sub>3</sub>:RO:H<sub>2</sub>O, to be very nearly 5:2:2:0·5.

In order to test these results by comparing different material an analysis was also made of iolite from the well known locality at Haddam, Conn., the specimens being very kindly furnished by Prof. Geo. J. Brush from his private collection.

This analysis resulted as follows :

	I.	II.	Mean.	Ratio.		
SiO <sub>2</sub> ----	49·25	49·03	49·14	·819	·819	5·
Al <sub>2</sub> O <sub>3</sub> ---	32·81	32·87	32·84	·322	} ·326	1·99
Fe <sub>2</sub> O ----	·58	·67	·63	·004		
FeO ----	5·06	5·01	5·04	·070	} ·333	2·03
MnO ----	·19	·19	·19	·003		
MgO ---	10·51	10·30	10·40	·260		
H <sub>2</sub> O -----	1·81	1·88	1·84	·102	·102	0·62
	<hr/> 100·21	<hr/> 99·95	<hr/> 100·08			
Sp. Gr. ..	2·610					

Here the percentages of Fe<sub>2</sub>O<sub>3</sub> and H<sub>2</sub>O are slightly larger than in the other analysis, but this might almost be expected

on account of the strong tendency of the Haddam mineral to alteration. The ratios, however, as will be seen, are almost exactly the same as those given by the Guilford mineral. The formula of iolite is therefore  $H_2O \cdot 4(MgFe)O, 4Al_2O_3, 10SiO_2$ , the ratio of  $MgO : FeO$  being in these two analyses very nearly 7:2. The theoretical percentages according to this formula are given below, and for comparison, the mean of each of the two analyses calculated to 100 per cent, the small quantities of  $Fe_2O_3$  and  $MnO$  being reckoned as  $Al_2O_3$  and  $MgO$  respectively.

	Theory.	Calc. to 100.	
		Guilford.	Haddam.
$10SiO_2$ .....	49·40	49·41	49·21
$4Al_2O_3$ .....	33·60	33·17	33·30
$\frac{8}{3}(4FeO)$ .....	5·27	5·40	5·24
$\frac{7}{3}(4MgO)$ .....	10·25	10·40	10·41
$H_2O$ .....	1·48	1·62	1·84
	100·	100·	100·

These results show satisfactory agreement, and the percentages, it may be said, do not differ materially from those of the hitherto published analyses except in the state of oxidation of the iron. The fact that the iron is present as  $FeO$ , in spite of the lack of green color, which caused Scheerer's conclusion to the contrary, shows how little reliance is to be placed on color. Indeed, in a recent description of colorless iolite from Brazil,\* Dr. Groth expresses the belief that the usual violet color of the mineral must be merely due to a pigment and not to any essential constituent. For the purpose of determining the nature of the water, about a gram of the Guilford mineral was subjected to increasing temperatures until constant weights were obtained at each. The results were as follows:

	100° C.	300° C.	Faint redness.	Full redness.	Total.
Loss in weight.	none	0·63	0·87	0·10	1·60

Up to full redness the mineral remained light in color but on further heating, over the blast lamp, it turned black, baked together and showed a slight increase in weight, owing doubtless to oxidation of the iron.

It will be seen that the percentage lost by heating to full redness is the same as that of water found by actual determination. Hence loss by ignition at this degree of temperature can safely be taken as representing the amount of water. In the Haddam iolite it was therefore determined in this way. It is possible that too intense heating may account for the

\* Zeitschr. Kryst., vol. vii, p. 594.

small percentage of water (0.50 per cent) found by Jackson in one of his analyses. All other analyses thus far published show amounts of water between 1 and 2.5 per cent, the average from six analyses being 1.74 per cent.

The high temperature required to drive off the water shows that it is practically all constitutional. If present as hydroxyl, it is possible that it combines with Mg to form the univalent radical (MgOH). The recent investigations by Clarke and Schneider\* seem to indicate that, if the above molecule is present in a silicate, it can be decomposed by the action of dry HCl gas, so that an equivalent of MgCl<sub>2</sub> can be dissolved out by water. An experiment, conducted to test this point, gave no satisfactory results. About a gram of the mineral was heated in a current of the dry gas for 8 hours and nearly constant weight was attained. On leaching, however, with water and a drop of nitric acid, only 0.14 per cent of MgO went into solution, so that no definite conclusion could be drawn from this result.

On digesting a sample with strong aqueous HCl for three days, on the water bath, the following results were obtained:

		Ratio to per cent in complete analysis.
Undecomposed mineral ----	23.20	
SiO <sub>2</sub> -----	36.79	.75
Al <sub>2</sub> O <sub>3</sub> with Fe <sub>2</sub> O <sub>3</sub> -----	30.50	.78
MgO with MnO -----	8.04	.77
HO <sub>2</sub> -----	1.84	
	100.37	

From the above it is seen that about 76 per cent of the mineral had dissolved and since the different constituents were about equally affected, it seemed probable that by longer treatment the mineral could be completely decomposed. Accordingly another sample was digested, on the water bath, for fifteen days. The result showed the supposition to be correct, since the insoluble residue was found to be 49.95 per cent or very nearly the percentage of SiO<sub>2</sub> in the mineral. The mineral therefore is completely decomposed by long treatment with hydrochloric acid.

In conclusion the author wishes to express his especial indebtedness to Prof. S. L. Penfield, for much valuable assistance and advice rendered during the work.

Mineralogical Laboratory, Sheffield Scientific School,  
New Haven, May, 1891.

\* This Journal, III, xl, 303, Dec., 1890.

ART. IV.—*On a Series of Caesium Trihalides*; by H. L. WELLS. *Including their Crystallography*; by S. L. PENFIELD.

IN the course of some experiments with caesium compounds, bromine was added to a concentrated solution of caesium chloride with an astonishing result. There was instantly formed a bright yellow precipitate, so dense as to nearly solidify the liquid. The substance readily dissolved on warming the liquid, and, on cooling it, large crystals of a yellowish-red color were formed which were found to be  $\text{CsClBr}_2$ .

In view of the fact that  $\text{KI}_3$  was already known,\* this discovery made it probable that a series of caesium trihalides could be obtained. An attempt was accordingly made to prepare each of the following possible members of such a series containing chlorine, bromine and iodine.

- |                            |                             |
|----------------------------|-----------------------------|
| 1. $\text{CsI}_3$          | 6. $\text{CsCl}_2\text{I}$  |
| 2. $\text{CsBrI}_2$        | 7. $\text{CsBr}_3$          |
| 3. $\text{CsBr}_2\text{I}$ | 8. $\text{CsClBr}_2$        |
| 4. $[\text{CsClI}_2]$      | 9. $\text{CsCl}_2\text{Br}$ |
| 5. $\text{CsClBrI}$        | 10. $[\text{CsCl}_3]$       |

As a result, all the members of the series except the two enclosed in brackets were isolated.

These eight trihalides are easily made, being much less soluble than the normal halides. They crystallize beautifully, have remarkably brilliant colors and some of them possess an unexpected degree of stability.

#### *Method of preparation.*

Each of these compounds can be made by dissolving, with the aid of heat, the appropriate normal caesium halide and the halogen or halogens indicated by the formula in the proper amount of water, or, in the single case of  $\text{CsBrI}_2$ , in weak alcohol, and cooling to crystallization. The caesium salt used in making the mixed trihalides is preferably the one which is not decomposed by the halogen or halogens added. In most cases the presence of an excess of the normal halide is desirable in order that the halogens, especially iodine, may readily dissolve and not separate out again on cooling, but the same result may also be obtained by the use of weak alcohol. Details of preparation will be given for each body separately.

\* Jørgensen, J. pr. Ch., II, ii, 357; Johnson, J. Chem. Soc., 1877, 249.

*Color.*

In the following list the compounds are arranged in order, from the darkest to the lightest. The colors given, unless otherwise specified, are for crystals of considerable size, for when the bodies are obtained as precipitates or when the crystals are pulverized they are lighter in color.

$\text{CsI}_3$	Brilliant black, nearly opaque; powder brown.
$\text{CsBrI}_2$	Dark reddish-brown; thin crystals transmit deep red light; powder dark red.
$\text{CsBr}_2\text{I}$	Deep cherry-red.
$\text{CsClBrI}$	} Yellowish-red each having a somewhat } yellower tint than the one preceding it.
$\text{CsBr}_3$	
$\text{CsClBr}_2$	
$\text{CsCl}_2\text{I}$	} Orthorhombic variety, deep orange. } Rhombohedral variety, pale orange.
$\text{CsCl}_3\text{Br}$	

*Stability on exposure.*

The five bodies containing iodine are much more stable than the others, and will bear long exposure to the air at ordinary temperatures with very slight superficial change. This exposure in some cases may be continued for a week or more in warm weather without producing any marked alteration of color, but they constantly give off a slight odor and finally begin to whiten. The three compounds containing no iodine usually become white in a few hours on exposure, but even these can be preserved indefinitely in tightly corked tubes. Experiments showed that  $\text{CsBrI}_2$  whitened more rapidly than  $\text{CsBr}_2\text{I}$ , also that  $\text{CsClBr}_2$  decomposed more rapidly than  $\text{CsCl}_2\text{Br}$ . This indicates that their stability does not entirely depend upon the volatility of the halogens contained in them, a point which has a bearing on the constitution of this group of bodies, and which will be considered subsequently.

*Behavior when heated.*

The following table shows the temperatures of complete decomposition as determined by the change of color to white. They are only approximate since they represent gradual changes which vary somewhat with the rapidity of heating. The melting-points are also given. In open tubes these are usually sharp, but in sealed tubes often very gradual.

	Melts in open tube. (uncorr.)	Melts in sealed tube. (uncorr.)	Becomes white in open tube. (approximate.)
CsI <sub>3</sub> .....	210°	201°-208°	330°
CsBr <sub>2</sub> I .....	246°	243°-248°	320°
CsClBrI .....	238°	225°-235°	290°
CsCl <sub>2</sub> I .....	238°	225°-230°	290°
CsBr <sub>3</sub> .....	208°	155°-190°	260°
CsBr <sub>2</sub> .....	whitens	180°	160°
CsCl <sub>2</sub> Br .....	whitens	205°	150°
CsClBr <sub>2</sub> .....	whitens	191°	150°

*Behavior with solvents.*

All these bodies except CsBrI<sub>2</sub>, which is almost completely decomposed by water, can be recrystallized by treating with warm water and cooling the solution. There is usually some decomposition during this operation, accompanied by the separation of iodine or the volatilization of this or the other halogens.

All the trihalides containing iodine can be dissolved in alcohol and recrystallized from it. There is usually a slight deposition of normal halide at the same time, which can be avoided by adding a little water to the alcohol. CsI<sub>3</sub> is much more soluble in alcohol than in water. The other iodine compounds, with the exception of CsBrI<sub>2</sub>, which decomposes with water, are apparently more soluble in water. Those bodies containing no iodine are all decomposed by alcohol, leaving a white residue. Mixtures of alcohol and water are good solvents for all the trihalides.

Ether has no immediate action on the more stable compounds, CsI<sub>3</sub>, CsBr<sub>2</sub>I, CsClBrI and CsCl<sub>2</sub>I, but it decomposes all the others with separation of normal halides. When CsBrI<sub>2</sub> is thus decomposed, pure CsBr is left.

*Crystallography.*

The crystallization of the caesium trihalides is orthorhombic. The salts form an isomorphous group, the chief features of which will first be given, followed by a brief description of the different individuals.

The forms which have been observed are :

<i>a</i> , 100, <i>i</i> $\bar{i}$	<i>g</i> , 012, $\frac{1}{2}$ $\bar{z}$
<i>b</i> , 010, <i>i</i> $\bar{z}$	<i>d</i> , 011, 1 $\bar{z}$
<i>c</i> , 001, <i>O</i>	<i>f</i> , 021, 2 $\bar{z}$
<i>m</i> , 110, <i>I</i>	<i>e</i> , 102, $\frac{1}{2}$ $\bar{i}$

Of these *m*, *d* and *e* are the most prominent and usually determine the habit of the crystals. Either *m* or *d* usually predominates to such an extent that the crystals are prismatic in the direction of the vertical or the brachy-axes. The dome

*f* is very common but is usually too small to give a characteristic habit, and is therefore omitted from most of the figures. The face *g* was observed only on  $\text{CsI}_3$ . The pinacoids are variable in their development, but commonly one and frequently all three can be found on a single crystal. Pyramidal faces are practically wanting. In the examination of a great many crystals but one was found (of  $\text{CsBr}_2\text{I}$ ) on which a single pyramidal face occurred; this replaced the edge between *m* and *d* and had the symbol  $1\bar{3}2, \frac{3}{2}-\bar{3}$ . The cleavage is perfect parallel to *c*.

An idea of the similarity of the different salts may be obtained from the following table, in which the axial ratios\* and three of the prominent angles are given. The angles which were chosen as fundamental are marked by an asterisk, the others are calculated, and in all cases the measurements showed close agreement.

		I		II	
		$a : b : c$		$a : b : c$	
Series with iodine	$\left\{ \begin{array}{l} \text{CsI}_3 \\ \text{CsBrI}_2 \\ \text{CsBr}_2\text{I} \\ \text{CsClBrI} \\ \text{CsCl}_2\text{I} \end{array} \right.$	0·6824	1 : 1·1051	1 : 1·4655	1·6196
		0·6916	1 : 1·1419	1 : 1·4460	1·6511
		0·7203	1 : 1·1667	1 : 1·3882	1·6196
		0·7230	1 : 1·1760	1 : 1·3831	1·6268
		0·7373	1 : 1·1920	1 : 1·3563	1·6167
Series without iodine	$\left\{ \begin{array}{l} \text{CsBr}_3 \\ \text{CsClBr}_2 \\ \text{CsCl}_2\text{Br} \end{array} \right.$	0·6873	1 : 1·0581	1 : 1·4550	1·5395
		0·699	1 : -----	1 : 1·430	-----
		0·7186	1 : 1·1237	1 : 1·3917	1·5638
	$m \wedge m, 110 \wedge 1\bar{1}0$	$d \wedge d, 011 \wedge 0\bar{1}1$	$e \wedge e, 102 \wedge 1\bar{0}2$		
	$\text{CsI}_3$	*68° 37'	*95° 43'	78° 0'	
	$\text{CsBrI}_2$	*69 20	97 34	*79 5	
	$\text{CsBr}_2\text{I}$	*71 32	*98 48	78 0	
	$\text{CsClBrI}$	*71 44	*99 15	78 15	
	$\text{CsCl}_2\text{I}$	72 48	*100 1	*77 54	
	$\text{CsBr}_3$	*69 0	*93 14	75 10	
	$\text{CsClBr}_2$	*69 56			
	$\text{CsCl}_2\text{Br}$	*71 24	*96 40	76 0	

$\text{CsI}_3$  and  $\text{CsBr}_3$  are almost identical in axial ratios, but it is surprising that the chemically intermediate compounds,  $\text{CsBrI}_2$  and  $\text{CsBr}_2\text{I}$ , are not crystallographically intermediate.

A very remarkable relation exists between the first five compounds in the table, all of which contain iodine and are arranged in the order of their molecular weights. The ratio of two axes remains nearly constant throughout, while the third varies.† Exactly the same relation exists between the

\* The ratios are given in two ways: I, with  $\bar{b}$  as unity, as is customary; and II, with  $\bar{a}$  as unity, in order to show more clearly the relation between  $\bar{a}$  and  $\bar{c}$ .

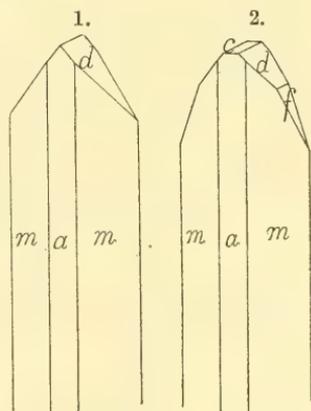
† Several series of organic compounds with analogous axial relations have been observed by Groth (Berichte, iii, 449) and by Hintze (Berichte, vi, 593.)

three compounds containing no iodine, but in this series the ratio between the two constant axes varies slightly from the corresponding ratio in the iodine compounds.

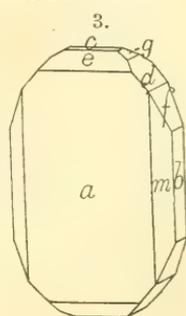
If an arrangement according to molecular weights is made with all the compounds containing bromine, or in like manner with all those containing chlorine, a symmetrical series of axial ratios is not formed. This leads to the conclusion that the two series given in the table have a special significance, and that iodine, with the highest atomic weight, plays an important part in the constitution of the first, while bromine acts in the same way in the second. Since several of the compounds contain only a single halogen atom of highest atomic weight, it follows that a single atom throughout exerts an influence on the symmetry of the series. This peculiar part played by an iodine or bromine atom may be explained by supposing it to be closely united either with the caesium or with one of the other halogen atoms. It seems probable from these considerations that the three halogen atoms in these compounds do not have similar positions in the molecule, and consequently that the trihalides are not compounds of trivalent caesium but have some other structure.

*CsI<sub>3</sub>*.—Of this salt, crystals from both aqueous and alcoholic solutions were examined. On the former the forms *a*, *c*, *m*, *d* and *f* were observed. The habit was different from anything else in the series, being needle-like, with *a* and *m* in the prismatic zone, terminated by *d*, fig. 1, or by *c*, *d*, and *f*, fig. 2. The crystals did not give very satisfactory reflections, but the best measurements, from a number of selected crystals, agreed closely with those given in the table. The crystals examined were 20–30<sup>mm</sup> in length and seldom over 2<sup>mm</sup> in diameter. On the crystals from alcohol, the forms *a*, *b*, *c*, *m*, *g*, *d*, *f* and *e* were observed. The habit is shown in fig. 3. There was a tendency in the crystals to arrange themselves in parallel position forming plates, showing large *a* faces, but the separate individuals were small, scarcely over 3<sup>mm</sup> in greatest diameter. The faces gave excellent reflections. The crystals are black, transmit a brownish red light only on the thinnest edges, and are too opaque for optical examination.

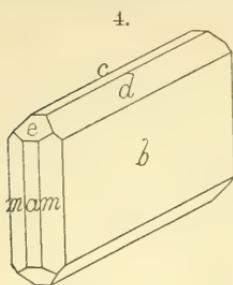
*CsBrI<sub>2</sub>*.—On two separate samples of this salt the forms *a*, *b*, *c*, *m*, *d*, *f* and *e* were ob-



The habit is

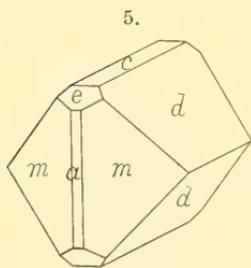


served. The crystals are thin tables somewhat lengthened in the direction of the brachy-axis, fig. 4. On examining the general table, it will be seen that this is the only one of the first five salts, in which the angle  $e \wedge e$  varies considerably from  $78^\circ$ . Here, the variation amounts to a little over one degree, but, in all probability, this is not to be accounted for by imperfections in the crystals or inaccuracy in the observation, for from two different crops of crystals good reflections and almost identical measurements were obtained. The crystals



were only a fraction of a millimeter in thickness and not over  $10^{\text{mm}}$  long in the direction of the brachy-axis. With the polarizing microscope the tables show a decided pleochroism. For rays vibrating parallel to the  $e$  axis the color is dark brown, almost opaque, while for vibrations parallel to  $\bar{a}$  it is a rich reddish brown. A similar, though less marked, pleochroism was observed in the remaining salts of the series, but owing to the inability to obtain orientated pinacoid sections, it could not be studied satisfactorily. In convergent polarized light, the phenomena were not very distinct, but with the tables of  $\text{CsBr}_2$  apparently an obtuse bisectrix could be seen, the optical axis being in the macro-pinacoid  $\bar{a}$ .

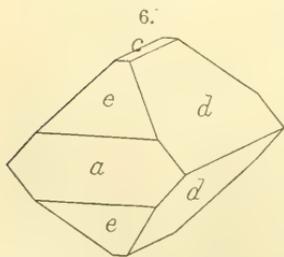
$\text{CsBr}_2$ .—On this salt the forms  $a$ ,  $c$ ,  $m$ ,  $d$ ,  $f$  and  $e$  were observed. The habit is shown in fig. 5. The crystals were brilliant and gave excellent reflections. Those submitted for measurement were about  $3^{\text{mm}}$  in greatest diameter.



$\text{CsClBr}$ .—On this salt the forms  $b$ ,  $c$ ,  $m$ ,  $d$ ,  $f$  and  $e$  were observed. The habit is like fig. 5, but much longer, or prismatic, in the direction of the brachy-axis. The crystals were about  $2^{\text{mm}}$  in diameter

and 10 in length.

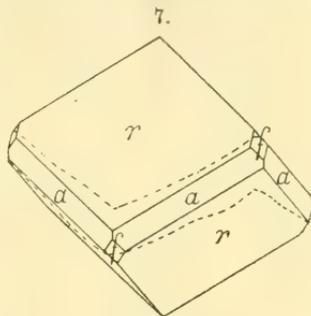
$\text{CsCl}_2$ .—This compound is dimorphous.



On the orthorhombic modification the forms  $a$ ,  $c$ ,  $m$ ,  $d$ ,  $f$  and  $e$  were observed, but  $m$  and  $f$  are usually wanting. The habit is shown in fig. 6. The crystals were about  $2^{\text{mm}}$  in diameter.

The hexagonal, rhombohedral, variety occurred in curious saddle-shaped scales, with bright crystal faces only along the edges. The forms which were observed are  $r$  (1,  $10\bar{1}1$ ),  $f$  ( $-2, 02\bar{2}1$ ) and  $a$

( $i-2, 11\bar{2}0$ ), fig. 7. Only that portion is perfect which is included between the irregular dotted lines, the upper and lower angles of the rhombohedrons being truncated by irregular warped surfaces. In their growth the individuals of a whole series of crystals, with similar orientation, are piled upon one another in the direction of the vertical axis. The scales are about 6<sup>mm</sup> in diameter.



The measurement which was taken as fundamental is :

$$r \wedge r, \text{ over } a, 10\bar{1}1 \wedge 01\bar{1}\bar{1} = 99^\circ 48'$$

giving for the length of the vertical

axis,  $c = 0.96363$ . The following measurements were also made :

$a \wedge a = 60^\circ 0'$ ,	$60^\circ 1'$ ,	$59^\circ 59'$	Calculated $60^\circ 0'$
$a \wedge f, \bar{1}2\bar{1}0 \wedge 02\bar{2}1 =$	$37^\circ 45'$		" $37^\circ 49'$

The remaining compounds containing no iodine, were much more unstable than those previously described. By making the measurements in a cold room very satisfactory results were obtained, the crystals retaining enough luster to give good reflections, even after they had suffered considerable decomposition.

$CsBr_3$ .—The forms observed on this salt are  $b, m$  and  $d$ . The habit is short prismatic, with either  $m$  or  $d$  predominating, while  $b$  is usually wanting. Single crystals are sometimes 10<sup>mm</sup> in length, but groups of small crystals are more apt to occur.

$CsClBr_2$ .—The only forms observed on this salt are  $m$  and  $c$ . The habit is short and stout prismatic. Single crystals are sometimes 15<sup>mm</sup> in length.

$CsCl_2Br$ .—The forms observed on this salt are  $c, m$  and  $d$ . It crystallized in stout prisms, over 10<sup>mm</sup> long, terminated like fig. 1.

#### Method of analysis.

The samples were prepared for analysis by pressing on paper. The drying was not always very good, both on account of the haste sometimes necessary to avoid too much decomposition, and on account of the great tendency of the crystals to contain cavities filled with liquid.

Caesium was invariably determined by weighing the normal halide produced by heating. In some cases where the resulting normal halide was slightly contaminated by a higher halogen, this was replaced by the proper one before weighing.

Where two halogens were present they were determined in the usual way by weighing their silver salts and determining the loss in weight of these when heated in chlorine. In the cases where all three halogens were present, use was made of the extremely satisfactory method described by Gooch and Ensign.\*

### $CsI_3$ .

This can be made by dissolving about one-fourth the theoretical amount of iodine in a solution of one part of caesium iodide in ten parts of water. It generally gives a crop of brilliant, slender crystals. If a larger proportion of iodine is used, the substance generally separates in the form of crystalline plates without distinct faces. They are possibly a dimorphous form of the substance. If weak alcohol is used as a solvent instead of water, the theoretical amount of iodine can be taken and a well-crystallized product is obtained.

The following numbers show the composition :

	Found		Calculated for
	Slender Crystals.	Plates.	$CsI_3$ .
Caesium .....	25.41	23.71	25.88
Iodine .....	72.67	---	74.12

When iodine is being dissolved in a warm aqueous solution of  $CsI$ , or when an attempt is made to dissolve  $CsI_3$  in warm water, a heavy black liquid is formed at about  $73^\circ$  which solidifies on cooling to a crystalline mass. It is much richer in iodine than  $CsI_3$  and probably contains a higher polyiodide. Analyses of the substance gave varying results, and although most of these approached the composition  $CsI_7$ , it is still uncertain what body this is. The low melting point of the substance is remarkable since  $CsI_3$  melts at  $210^\circ$  and iodine at  $114^\circ$ .

To find the solubility of  $CsI_3$  in an aqueous solution of  $CsI$ , the mother-liquor from a crop of crystals deposited at about  $20^\circ$  was analyzed. It gave :

$CsI$  16.99 per cent.  
 $I$  (free) 0.416 per cent or  $CsI_3$  0.842 per cent.

The specific gravity of this mother-liquor was 1.154, hence 1 c.c. contained 0.0097g $CsI_3$ . The body is so insoluble that, were we to use  $CsI$  in the place of  $KI$  in making a volumetric iodine solution, we could only obtain, at ordinary temperatures, a solution which would be about  $\frac{1}{24}$  normal.

\*This Journal, III, xl, 145, 1890.

*CsBrI<sub>2</sub>*.

Iodine dissolves in considerable quantity in a hot aqueous solution of caesium bromide, but it nearly all separates on cooling. It is therefore necessary to use a mixture of alcohol and water in preparing this trihalide. A good crop of crystals was obtained by dissolving one-half the theoretical iodine in a solution of one part of caesium bromide dissolved in two parts of water and one part (by volume) of alcohol.

The following numbers show the composition of the crystals.

	Found.	Calculated for CsBrI <sub>2</sub> .
Caesium .....	28.54	28.48
Bromine .....	18.11	17.13
Iodine .....	52.01	54.39

*CsBr<sub>2</sub>I*.

This may be made by dissolving the theoretical amounts of iodine and bromine in a solution of one part of caesium bromide in ten parts of water. A considerable excess of bromine does not interfere with its formation.

The crystals have the following composition :

	Found.	Calculated for CsBr <sub>2</sub> I.
Caesium .....	31.32	31.67
Bromine .....	37.63	38.09
Iodine .....	29.57	30.24

The solubility of this substance in water was approximately determined by estimating the free halogens volumetrically in the mother-liquor from a recrystallization at about 20°. The amount found corresponded to 4.45 per cent of CsBr<sub>2</sub>I.

[*CsClI<sub>2</sub>*.]

Repeated attempts to make this substance, by using concentrated solutions of caesium chloride and iodine in mixtures of water and alcohol and cooling to low temperatures, invariably failed.

*CsClBrI*.

This may be made by dissolving about one-fourth of the theoretical bromine and iodine in a solution of one part of caesium chloride in five parts of water. If an excess of caesium chloride is not taken the product will contain too little chlorine and too much bromine.

An analysis of the product, properly prepared, gave :

	Found.	Calculated for CsClBrI.
Caesium .....	34·24	35·42
Chlorine .....	9·36	9·45
Bromine .....	19·96	21·30
Iodine .....	32·36	33·83

If a large excess of bromine is used, an impure product results as is shown by the following analysis of a sample thus made:

	Found.
Caesium .....	36·11
Chlorine .....	9·36
Bromine .....	27·70
Iodine .....	24·83

On attempting to recrystallize the CsClBrI a product of a darker red color is formed, sometimes accompanied by the separation of some iodine. The following analyses were made of products of recrystallization:

“A” was from a single recrystallization. “B” was recrystallized three times, a little alcohol being added the last time to keep iodine in solution. “C” was recrystallized five times, each time with the addition of a large excess of bromine.

	A.	B.	C.	Calculated for CsClBrI.	Calculated for CsBr <sub>2</sub> I.
Caesium...	32·69	33·22	----	35·42	31·67
Chlorine ..	3·32	5·02	2·70	9·45	0
Bromine ..	31·56	28·30	32·50	21·30	38·09
Iodine ....	30·91	31·78	30·99	33·83	30·24

These analyses show that the recrystallized body approaches CsBr<sub>2</sub>I, but that a part of the chlorine is very tenaciously held. The excess of bromine used in the case “C” had apparently no effect, probably because caesium and iodine were present in equivalent quantities, whereas, in the case previously given, in which an excess of bromine was used in presence of much caesium chloride in preparing the body, there was evidently a contamination with CsClBr<sub>2</sub>.

#### *CsCl<sub>2</sub>I.*

This body is dimorphous, the form apparently depending upon the presence or absence of a large excess of caesium chloride in the solution from which it crystallizes.

The rhombohedral variety is usually obtained by adding iodine in the proportion of one atom to one molecule of caesium chloride dissolved in about ten parts of water, then passing chlorine into the liquid heated nearly to boiling until the iodine just dissolves, and finally cooling. If an excess of

chlorine is used, the body  $\text{CsCl}_4\text{I}$  is formed corresponding to  $\text{KCl}_4\text{I}$  discovered by Filhol.\* This new caesium compound will be described in a future article in connection with several other new bodies of the same class.

The orthorhombic variety of  $\text{CsCl}_2\text{I}$  can be obtained by using three or four times as much caesium chloride as in the other case, the other conditions remaining unchanged.

The following analyses of two separate products of each of the two varieties were made.

	Rhombohedral. Found.		Orthorhombic. Found.		Calculated for $\text{CsCl}_2\text{I}$ .
Caesium ----	39.20	39.92	38.43	40.00	40.18
Chlorine ----	20.72	21.08	19.78	20.75	21.45
Iodine -----	37.81	38.21	38.97	38.88	38.37

On recrystallizing either form of this substance, from solution in hot water, the rhombohedral variety is usually formed, owing to the lack of an excess of caesium chloride. It is not unusual, however, to obtain at first, as the solution cools, slender needles evidently of the orthorhombic variety, which afterward become surrounded by rhombohedral crystals.

#### $\text{CsBr}_3$ .

To make this substance, one half the calculated amount of bromine is added to a solution of one part of caesium bromide in three parts of water, the whole is heated with vigorous shaking until the liquid bromine disappears and then slowly cooled. Crystals gave on analysis:

	Found.	Calculated for $\text{CsBr}_3$
Caesium -----	35.12	35.66
Bromine -----	61.53	64.34

In preparing this body, there usually remains, when the liquid bromine disappears on heating the solution, a heavy reddish liquid much lighter in color than bromine. It is without doubt a higher polybromide and it probably corresponds to the easily fusible substance already mentioned as a probable higher polyiodide. An investigation of its composition will soon be made.

#### $\text{CsClBr}_2$ .

The formation of this body was mentioned at the beginning of this article in connection with the discovery of the new series of salts. It can be made by adding about one half the theoretical bromine to a solution of caesium chloride in about five parts of water, dissolving by heat and cooling.

\* Michälis, "Anorgan. Chem.," 3, 102; Gmelin-Kraut, II, 1, 82.

The analyses of two products are given below. The "precipitate" resulted from adding bromine to a cold caesium chloride solution, and, being finely divided as well as the most unstable compound of the series, it suffered a considerable amount of decomposition although time was not taken to dry it thoroughly.

	Found.		Calculated for CsClBr <sub>2</sub> .
	Precipitate.	Crystals.	
Caesium .....	40·62	42·14	40·49
Chlorine .....	12·64	13·24	10·81
Bromine .....	39·61	42·93	48·70
Water .....	6·45	1·72	0·
	99·32	100·03	100·00

*Cs Cl<sub>2</sub> Br.*

This substance may be made by adding the calculated amount of bromine to a solution of caesium chloride in five parts of water, warming enough to keep CsClBr<sub>2</sub> in solution, and passing chlorine in excess.

	Analysis gave	Calculated for CsCl <sub>2</sub> Br.
Caesium .....	46·25	46·83
Chlorine .....	24·15	25·00
Bromine .....	26·05	28·17

[*Cs Cl<sub>3</sub>.*]

Efforts to prepare this substance by passing chlorine into saturated aqueous solutions of caesium chloride cooled by a freezing-mixture did not succeed. It was noticeable that the compound Cl 5H<sub>2</sub>O was not formed under these circumstances.

*Other Trihalides.*

Johnson's KI<sub>3</sub>\* is undoubtedly analogous to the caesium compounds. An investigation of this and other potassium trihalides as well as the corresponding rubidium compounds is now in progress in this laboratory, and an effort will be made to prepare similar compounds with still other metals.

The compound KI<sub>2</sub>(CN)† and the body NH<sub>4</sub>I<sub>3</sub>, which Johnson describes‡ as very similar to KI<sub>3</sub>, should be mentioned in this connection.

There have been described a great number of trihalides of both natural and artificial organic bases. These are mostly triiodides but there are among them a number of tribromides

\* J. Chem. Soc., 1877, i, 249.

† Langlois, Ann. Chim. Phys., [III] lx, 220.

‡ J. Chem. Soc., 1878, 397.

and also mixed trihalides, especially of the type  $\text{RCl}_2\text{I}$ . These organic bodies\* are evidently analogous to the caesium compounds under consideration, but since they have not been sufficiently studied to throw any light on the structure or crystalline form of trihalides in general, they will not be described in detail here.

### Theoretical Considerations.

Thus far in this article the simplest possible formulæ have been used. The probable structure of the compounds will now be discussed.

The trihalides previously known have been usually considered as weakly combined addition-products. Mendelejeff,† for example, says that the instability with which  $\text{I}_2$  unites with  $\text{KI}$  and  $\text{N}(\text{CH}_3)_3\text{I}$  is analogous to the instability of many crystal-hydrates, e. g.,  $\text{HCl} \cdot 2\text{H}_2\text{O}$ . It must be noticed that some of the caesium trihalides are very stable, but this fact is evidently due to the strong positive character of the metal, and, since others among them are comparatively unstable, it can have no important bearing on their structure.

Johnson‡ advances the formula  $\text{K}_2\text{I}_6$  for potassium triiodide with no better reason than the existence of a higher iodide of mercury,  $\text{HgI}_6$ .§ This formula may be dismissed at once, for there is no more ground for it than for writing  $\text{K}_2\text{I}_2$ , because  $\text{HgI}_2$  exists, and moreover if the caesium salts were  $\text{Cs}_2\text{X}_6$ , we should expect to find in the series such compounds as  $\text{Cs}_2\text{Cl}_3\text{I}$ ,  $\text{Cs}_2\text{Cl}_2\text{I}_2$ , etc., none of which were discovered.

Since the members of the caesium series are crystallographically isomorphous they must all have the same structure, and, as has just been shown, no multiple of the formula  $\text{CsX}_3$  is probable.

A possible explanation of the caesium trihalides may be made by supposing the metal to act trivalently, and the following arguments seem to favor this view:

1st. Caesium has the highest atomic weight of the alkali-metals, and it is a noticeable fact that, among the elements in general, those with higher atomic-weights in a group have the greater tendency to act with variable quantivalence. 2d. Caesium is univalent in its ordinary compounds, and, following

\* See the following articles: Weltzien, *Ann. Ch. Ph.*, xci, 33; xcix, 1. Müller, *ibid.*, cviii, 5. Hubner, *ibid.*, ccx, 368. Ladenburg, *ibid.*, ccxvii, 122. Zinke and Lawson, *ibid.*, ccxl, 123. Zinke and Artzberger, *ibid.*, ccxlix, 366. Jörgensen, *J. pr. Ch.*, II, vols. ii, iii, xiv and xv. Dafert, *Monatshefte*, iv, 496. Dittmar, *Berichte*, xviii, 1612. Ostermayer, *ibid.*, xviii, 2298. Kamensky, *ibid.*, xi, 1600. Tilden, *J. Chem. Soc.*, xviii, 99. Hoogewerff and Dorp, *Rec. Trav. Chim.*, iii, 361.

† "Grundlagen der Chemie," p. 563, foot-note 63.

‡ *J. Chem. Soc.*, 1878, 183.

§ Jörgensen, *J. pr. Ch.*, II, ii, 357.

the general rule, the next higher quantivalence should be three. 3rd. Caesium is in the same group as gold, in Mendelejeff's periodic system of the elements, and it is well known that this element acts univalently and trivalently.

On the other hand, the following arguments are in favor of considering the bodies double salts: 1st. The compounds IBr, ICl and BrCl are definite bodies and all the trihalides may be considered as molecular compounds of these, and also the molecules  $I_2$  and  $Br_2$ , with normal halides. 2d. The fact that  $CsBr_2I$  is more stable than  $CsBrI_2$ , and that  $CsCl_2Br$  is more so than  $CsClBr_2$ , showing that the stability of these bodies does not entirely depend upon the volatility of the halogens contained in them, indicates that the halogen atoms have much influence on each other, and that at least two of them are probably bound together. A consideration of the fact that  $CsCl_2I$  is a very stable body while  $CsClI_2$ , probably cannot be prepared leads to the same conclusion. 3d. It has been pointed out by Godeffroy\* that the simple salts of caesium are as a rule more soluble than the corresponding rubidium and potassium salts, while with the double-salts the reverse is true. Work now in progress in this laboratory shows that the rubidium and potassium trihalides, as far as they have been investigated, increase in solubility towards potassium, hence, if the rule holds true, they must be double-salts. 4th. The new salt  $CsI.AgI$ ,† an undoubted double-salt, shows a close relation to the trihalides in its system of crystallization, in the ratio of the two axes, which alone were determined, and in its cleavage.‡ The salt  $KI.AgI\ddot{S}$  has been prepared, but it has not yet been procured in crystals fit for measurement. Work will be continued on this class of compounds.

\* Berichte, ix, 1365.

† This was made by dissolving AgI in a concentrated, hot solution of CsI and cooling. It forms tufts of hair-like crystals, very seldom large enough to measure.

	Analysis gave	Calculated for CsI.AgI.
Silver -----	19.03	21.82
Iodine -----	50.91	51.32
Caesium -----	----	26.86

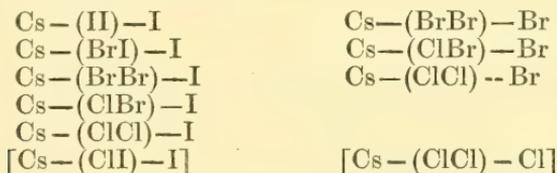
‡  $CsI.AgI$  crystallizes in the orthorhombic system. It was obtained in long needles, not over  $\frac{1}{3}$  mm. in diameter and too small to show distinct end faces. A pinacoid and two other forms occur in the prismatic zone which correspond to  $c(001)$ ,  $g(012)$  and  $d(011)$  of the trihalide series. Of these  $c$  and  $g$  are the best developed while  $d$  is very small. Five independent measurements of  $c \wedge g$  gave values varying between  $27^\circ 29'$  and  $27^\circ 44'$ , the average being  $27^\circ 36'$  which gives the ratio  $\bar{b} : \bar{c} = 1 : 1.0456$ . The crystals show a imperfect cleavage parallel to  $a(100)$  and probably a second parallel to  $c$ , but they were too small to allow of this being determined with certainty. Under the polarizing microscope they show parallel extinction.

§ Boullay, Ann. Chim. Phys., II, xxxiv, 377.

The evidence which has just been given points strongly towards considering the trihalides as double-salts. The considerations based on the axial relations of the crystals, which have been given in the crystallographic part of this article, also indicate that these bodies cannot be viewed as compounds of trivalent caesium, and, moreover, that a single halogen atom of highest atomic weight plays an important part in their structure. One view of the possible position of this peculiar atom may be that it is a trivalent atom united to the others in the manner indicated by the general formulæ  $\text{Cs}-\text{I} < \begin{matrix} \text{X} \\ \text{X} \end{matrix}$  and  $\text{Cs}-\text{Br} < \begin{matrix} \text{X} \\ \text{X} \end{matrix}$ . This view may be objected to because the strongest halogen atom is not directly united to the caesium.

The structure  $\text{Cs} - \text{X} < \begin{matrix} \text{X} \\ \parallel \\ \text{X} \end{matrix}$  is scarcely admissible in the compound  $\text{CsI}.\text{AgI}$  on account of the probable invariable univalence of silver.

Another view of the position of the peculiar iodine or bromine atom may be based upon the idea, so ably advocated by Remsen,\* that a bivalent group of two halogen atoms acts the same part in double halides that oxygen takes in ordinary oxygen salts. Supposing that a halogen atom of highest atomic weight is linked to the caesium atom by means of the other two halogen atoms, acting as a bivalent group, the trihalides have the following formulæ:



These formulæ allow the supposition that the most negative halogen atom is in direct union with the caesium. They are consistent with the view that there are two symmetrical series of compounds, one with an iodine atom, the other with a bromine atom in a special position. On these grounds they seem quite plausible.

Assuming that the structure of the trihalides is represented by the above formulæ, a comparison of their relative stability leads to the view that the linking group of two halogen atoms causes greater stability when composed of like atoms than when these atoms differ. The groups (II) (BrBr) and (ClCl) occur in the comparatively stable compounds, while (ClBr) is in the most unstable body of the "bromine series," (BrI) is in

\* On the Nature and Structure of Double Halides, *Am. Chem. Jour.*, xi, 291.

the least stable one of the "iodine series" and the compound which should contain (ClI), with the least closely related halogens, could not be prepared. There is a possible exception in the body Cs-(ClBr)-I, for it has not been noticed that the stability of this varies to any marked extent from Cs-(ClCl)-I. The same view of the effect of the identity of the linking halogen atoms will probably apply to all double halides, for it is certain that very few of these containing different halogens are known, although this may be partly due to the fact that mixed double halides have not been sufficiently studied. An investigation of the double halides of caesium and mercury, now in progress, indicates that the generalization will apply in this case. Whatever may be the true structure of double halides, this influence of the identity of the halogens in the combining simple salts probably depends upon the same broad chemical law which causes, for example, two oxides or two sulphides to combine more readily than an oxide and a sulphide of the same elements, and which causes sulphates to combine with other sulphates more readily than they combine with nitrates and other dissimilar salts.

The present communication may be considered as preliminary to a wider study of polyhalides and double halogen salts. It is hoped that other series, studied chemically and crystallographically, may give valuable results.

Sheffield Scientific School, December, 1891.

ART. V.—*The Law of Elastic Lengthening*,\* by J. O. THOMPSON, Haverford College.

IN the theory of elasticity the assumption is usually made that the lengthening of an elastic rod or wire is directly proportional to the stretching weight. Moreover experimental results have apparently justified this assumption in all cases where the lengthening was within the so-called limit of elasticity. Hooke† was the first to formulate this as a law, and his assertion "*ut tensio sic vis*," although occasionally questioned seems to have stood the test of experiment up to the present time. Wertheim‡ in his well-known investigations concerning the elasticity of the metals, and later Edlund§ in his measure-

\* Translation made by the author for this Journal of a paper which appeared in Wiedemann's *Annalen*, vol. xlv, No. 11, 1891.

† R. Hooke, *Lectures and Collections*, London, 1679.

‡ Wertheim, *Pogg. Ann., Ergänzt*, ii, (1848), p. 1.

§ Edlund, *Pogg. Ann.*, cxiv, (1861), p. 1, and cxxvi, (1865), p. 539.

ments of the thermal effects produced by the stretching of wires find no inaccuracy in the law. Neither did Morin,\* although the distance between the upper and lower marks on his wires amounted to 21 m.

Miller† too endeavors to prove that the elastic lengthening is proportional to the force. As far as I am aware, the old law has generally been regarded as axiomatic, and no one has ever made the attempt to replace it by a new one.

At the time of some experiments here made by Mr. Stradling this subject came up for discussion, and Prof. F. Kohlrausch invited me to investigate it in a series of careful experiments. In this place I desire to express my sincerest thanks to my honored teacher, Prof. Kohlrausch, for his advice and help in the course of these investigations.

In the first place it should be noticed that there is no good *a priori* reason why Hooke's law should be strictly true. When one examines the case closely it seems highly probable that deviations from the law should appear. When a wire is subjected to a tension the relative positions and distances of its molecules are altered, its thermal state is changed, and it becomes in these respects a new body. Accordingly that there should be in one and the same body a definite relation between the modulus of elasticity and the amount of deformation ought to occasion no surprise.

Since the experiments of others have amply proved that deviations from the old law of lengthening, if any really exist, must be very small, it is evident at the outset that the measurements, in order to detect these deviations, must possess a high degree of accuracy. The following experimental conditions must accordingly be secured: The wire must be long and free from all curvature. The temperature of the place where the experiments are made must remain approximately constant during an experiment. Further, account must be taken of several secondary phenomena the most important of which are the thermal effects due to the changing volume of the wire, and the elastic after-effect. The influence of these secondary phenomena will later be separately discussed.

The wires made especially for these experiments by Herr Obermaier of Nürnberg, gave me the first of the above mentioned conditions. The tower of the Physical Institute of the University of Strassburg, permitted the use of wires of the requisite length; and, since it was situated on the north side of the building, it possessed such a uniform temperature that

\*Morin, *Comptes Rendus*, liv, (1862), p. 235.

†Miller, *Aus d. Sitzungsber. d. math-phys. Classe der k. bayer. Akd. d. Wiss*, 1882, Heft 4.

the total change in an entire forenoon amounted usually to less than half a Celsius degree. The length of the wires used was about 23 m.

In order to determine the mean temperature of the tower at any time, as well as the changes in the temperature, I used at first six thermometers hung at regular intervals in the tower. Afterwards at the suggestion of Prof. Kohlrausch I used in place of the six thermometers a fine brass wire 23 m. long, bearing a constant weight, and running parallel with the main-wire, the wire on which the measurements were made.

Since this thermometer-wire was only 9 cm. distant from the main-wire, and both were equidistant from cathetometer I, I was able, without changing the focus of the telescope, to observe the mark on the thermometer-wire and to determine the temperature accurately to the fortieth of a degree.

#### *Description of Apparatus.*

In the tower of the Institute are four solid brick piers, three of which terminate within the tower near the top. A large square beam 25 cm. thick was laid across two diagonally opposite piers, and this furnished an inflexible support for the upper end of the wire. A smaller beam was laid parallel with the larger, and on this was mounted a microscope focused on the upper mark on the wire. The larger beam rested on iron feet which were so adjusted that the whole arrangement stood absolutely firm. A movable cross-wire in the eye-piece of the microscope enabled one to measure a displacement of the mark of 0.005 mm. Since a weight of 70 kg. on the middle of the beam produced a sinking of only 0.03 mm. and since the heaviest weight used in any of my experiments was 18 kg. we may regard the upper mark as constant. Still to avoid all uncertainty the position of the mark was often noted and found to be unchanged.

At the lower end of the wire the following arrangement was used: Two cathetometers were mounted on the same stone block, one for the purpose of noting the position of the mark when no weight was on the pan, the other to note the exact point to which the mark was brought by any stretching weight. In order that a measurement might be made quickly, before the after-effect had time to make itself apparent, a damper immersed in glycerine was used. In this way one was enabled to make an accurate setting of the cathetometer within 10 sec. after the weight had been placed on the pan. To render impossible any friction between the damper and the sides of the surrounding vessel, the damper was fastened to the upper end of a light rectangular frame, to the lower end of which the pan

was attached. The frame thus surrounded the vessel without touching it or the board on which it stood. Without some such arrangement there would have been friction between the damper and the sides of the vessel whenever the weight failed to be exactly in the centre of the pan. Furthermore in order to check quickly all motion the wire was passed through a fine hole in a stiff piece of leather, and the side of the frame playing between the prongs of a fork was prevented from swinging through a large arc. The weights used had been carefully calibrated so that the average inaccuracy was less than  $\frac{1}{20000}$ .

At first I used as lower mark a fine diamond-mark on the wire itself or on a glass bead. Later I used instead a very fine arrow-point printed on paper, and this secured an accuracy of 0.005 mm. in the setting of the cathetometer. Since in some cases the observed stretching of the wire amounted to more than 66 mm. it is apparent that when one, besides all this, takes mean values of many series of measurements, it is possible to attain a high degree of accuracy.

*Thermal Effects within the Wire.*

It was easy to foresee that the chief difficulties in measuring the true elastic lengthening would be those arising from the elastic after-effect and from the thermal effects due to changes in the volume of the wire. These thermal effects according to theory and observation are proportional to the stretching weight, provided that the stretching is not carried beyond the so-called limit of elasticity. By means of special observations with a thermo-pile I was able to prove that in all my experiments there was no perceptible deviation from this proportionality, and this fact may be taken as evidence that in the experiments the stretching was not carried beyond the proper limit. These thermal effects were in every case of greater influence than the after-effect.

The formula given by Sir Wm. Thomson for the diminution in temperature  $\Delta t$  caused by the stretching weight  $\Delta p$  is

$$\Delta t = \frac{AT\alpha}{wc} \Delta p$$

where A is the heat equivalent of the unit of work, T the absolute temperature,  $\alpha$  the coefficient of linear thermal expansion,  $w$  the mass of the unit of length of the wire, and  $c$  the specific heat of the metal by constant pressure.

Clausius\* derives the same equation and states that Joule has corroborated it experimentally. Still the investigation of Joule on this point aimed at and attained merely a rough proof

\* Clausius, Mech. Wärmetheorie, 3 Aufl. I, p. 199, 1887.

of the above equation. Edlund\* who later repeated these investigations with the best methods then known obtained thermal effects which were some  $\pm 0$  per cent smaller than the theoretical. Taking Edlund's results as a basis of calculation I found that in some cases these thermal effects could affect my measurements by as much as  $\cdot 1$  mm. The influence of the after-effect was much less, as will be shown later.

On account of the uncertainty in determining at any given instant the exact temperature of the wire after it had been stretched, I used in nearly all my experiments fine wires of from  $0\cdot 2$  mm. to  $0\cdot 3$  mm. diameter, for such wires assume quickly the temperature of the surrounding air. In order to estimate the rapidity with which the wire returned to its normal temperature after a weight had been placed upon the pan, I used a thermo-pile with mirror-galvanometer and scale. The thermo-pile consisted of two very fine wires, one of iron and the other of german-silver, fastened to the main-wire with the least possible amount of solder.

The sensitiveness as determined by the mean result of four experiments was 73 scale-divisions for  $1^\circ$  Celsius. In every case only the first deflection was recorded. The time of vibration of the needle was  $6\cdot 5$  sec. In determining the sensitiveness of the thermo-pile the junctions of the iron and german-silver wires with the galvanometer wires were immersed in petroleum of constant temperature, while the junctions with the main-wire, which were some 15 mm. apart, were immersed in a little rubber vessel containing distilled water. The temperatures of the water and of the petroleum were accurately determined, the circuit closed, and the deflection of the needle noted.

In measuring the thermal effects produced by the stretching of the wires the junctions of the thermo-pile wires with the main-wire were protected against air currents by a little cotton. Without this cotton the rapidity with which the wire near the junctions reassumed its normal temperature would have been even greater than it was. In a series of 8 consecutive determinations the mean position of rest of the galvanometer-needle was  $635\cdot 7$ , the cooling of the brass wire occasioned by a weight of  $1\cdot 5$  kg. caused an average first deflection of  $9\cdot 1$  scale divisions toward the smaller numbers, and after 13 sec. or two vibrations the mean position of rest was  $635\cdot 9$ .

A further proof of the rapid disappearance of the thermal effects is given by this very deflection of  $9\cdot 1$  scale-divisions. The first deflection was, as already mentioned, 73 scale-divisions for  $1^\circ$ . The cooling of the wire produced by the weight

\* Edlund, Pogg. Ann., cxxvi, p. 557, 1865.

of 1.5 kg. amounted to  $0.225^\circ$  according to Edlund, and this difference of temperature, if it had remained constant during the time of the first deflection, would have produced a deflection of 16.4 scale-divisions instead of the actual 9.1. From this one can draw conclusions as to the rapidity of the disappearance of the thermal effects.

In all my experiments, even in extreme cases, I uniformly found that after a weight had been placed on the pan the needle would be deflected so as to indicate a certain cooling and then return with scarcely perceptible delay to its former position. Thus it was clear that after 13 sec. no visible trace of the cooling effect remained. If a difference of temperature of  $\frac{1}{80}^\circ$ , enough to produce a contraction of 0.005 mm. in the length of the wire, had remained, the galvanometer would surely have indicated it.

The indications of the galvanometer were confirmed by noting the gradual contraction or lengthening of the wire immediately after unloading or loading the scale pan. In the first 10 or 12 sec. there would be a change of say 0.07 mm. in the length of the wire, and then in the following minute a further change of 0.01 mm. The first change one would naturally attribute chiefly to the thermal changes, the second to the after-effect. Since it is hardly possible in less than 12 sec. to place a weight on the pan and set the cathetometer with accuracy, it was to me a matter of indifference how much quicker the wire returned to its normal temperature.

Here it may be mentioned that Wertheim did not make his measurements until 5 or 10 min. after loading the pan. He waited, as he says, until the position of the mark became constant. In other words he did exactly what he should have avoided, he allowed his measurements to be affected by the most active part of the after-effect. Miller on the contrary went too far in the opposite direction and made measurements 2 sec. after stretching the wire. His results are obviously affected by temperature errors which he in a later article\* seeks to correct.

#### *The After-effect.*

The complete calculation of the influence of the after-effect on my results would have required a large amount of time and trouble.

In the first place these phenomena have been studied chiefly in the cases of torsion and bending, and the laws of the after-effect in the case of stretching, at least as far as the metals are concerned, are unknown. Further in the present case we have

\* Miller, *Wied. Ann.*, xx, p. 94, 1883.

to deal with the superposition of different after-effects, and the problem becomes much more complex. The after-effect in the case of a strip of india-rubber is approximately proportional to the magnitude of the stretching.\* Probably this applies to the metals as well, and if this is the case, the after-effect becomes of no account in the question we are discussing, provided the measurements are made always a definite time after the stretching of the wire. Moreover, since the after-effect in my experiments was invariably small I shall introduce in my results no correction for that factor.

Whenever the heaviest weights were used I set the cathetometer 13 sec. after placing the weight on the pan. This could be done by setting the cathetometer approximately beforehand. Careful measurements showed that this precaution was necessary only when the heaviest weights were used. In other cases it made no apparent difference whether the reading was made at the end of 13 sec. or a few seconds later. The measurements were made with rare exceptions at intervals of two minutes. In this time the after-effect following the release of the wire had almost entirely disappeared, as the results of two series of experiments given on pages 40 and 42 will show.

Still I wished to know exactly how soon this after-effect disappeared, and accordingly used the following plan: A fine flexible linen thread was tied to the bottom of the pan and then passed through a pulley beneath which was fastened to the floor. The thread was then made fast to the axle of a wheel, and thus by turning the wheel I could impart to the wire any desired tension.

In order to compare the influence of the after-effect with that of the thermal changes I proceeded as follows: By means of the thread a tension corresponding to a certain weight was imparted to the wire. The wire was kept stretched for about 13 sec. and then, by turning the wheel, released. During this process it was not necessary to remove my eye from the telescope. The wire came to rest without vibration in about one second, and a second later I had the telescope sighted on the mark. Then by means of the micrometer screw on cathetometer II, I measured the change in position of the mark in the following 11 sec., then the change from the 13th to the 30th second. By this time the mark had come back to its previous position. The results of the measurements with the brass wire are given in the following table:

\* F. Kohlrausch, Pogg. Ann., clviii, p. 360, 1876.

Preceding Tension. kg.	Change from 2-13 sec. mm.	From 13-30. mm.	Total change. mm.
0·6	0·035	0·001	0·036
1·2	0·062	0·010	0·072
1·8	0·100	0·020	0·120

The figures in each column are mean values of 10, 20 and 8 measurements respectively. That the changes given in the second column come mostly from the thermal effects within the wire itself and not from the after-effect can be proved in the following way: If we insert in the equation which we have already mentioned in place of  $A$  the value  $\frac{1}{682\frac{1}{2}\cdot 7}$  as obtained by Edlund we get

$$\Delta t = \frac{1}{682\cdot 7} \frac{T \alpha}{w c} \Delta p.$$

In these experiments  $T=285^\circ$ ,  $\alpha=0\cdot 000018$ ,  $w=0\cdot 000528$  kg. per m., and  $c=0\cdot 094$ . Consequently according to the equation  $\Delta t=0^\circ\cdot 15$  when  $\Delta p=1$  kg. Since the wire was 22·7 m. long the change in its length for  $1^\circ$  was 0·409 mm., or 0·0614 mm. when  $\Delta t$  was  $0^\circ\cdot 15$ . Therefore on removing stretching weights of 0·6, 1·2 and 1·8 kg. the lengthenings of the wire caused by the evolution of heat in the first instant should be 0·037, 0·074 and 0·111 mm. respectively. These figures approximate those in the second column of the above table as closely as we could expect in an experiment of this kind.

From what has been said it is safe to conclude that the necessary correction on account of the after-effect is very small. The stretching of the wire caused by a weight of 1·2 kg. was 43·55 mm., and the change of 0·01 mm. which took place after the first 13 sec. is insignificant in comparison.

#### *Method of Measurement.*

The method followed in making all measurements was the same. After noting the position of the mark on the thermometer-wire the telescopes of both cathetometers were sighted on the mark on the main-wire, and careful readings were made. Then a weight of 0·2 kg. was put on the pan, the consequent lowering of the mark was quickly measured by cathetometer I, and then the weight was immediately removed.

Two minutes later any shifting of the zero-point was measured by means of the micrometer screw of cathetometer II, and then the same process was repeated with a weight of 0·4 kg. In some cases the weight was increased to as much as 1·8 kg.

By means of the micrometer screw of cathetometer II, I could measure the shifting of the zero-point accurately to 0.005 mm. In this direction only an extremely small inaccuracy was possible because almost without exception the gradual lowering of the zero-point, in consequence of rising temperature and other causes, allowed the screw to be turned always in the same direction.

At the end of each series of observations the zero-point was again noted by both cathetometers, and the displacement measured. The difference in the results given by the two instruments was on an average less than 0.005 mm. Finally, in order to eliminate the influence of any change of temperature in the tower, the position of the mark on the thermometer-wire was again noted.

*Experiments with Brass Wire.*

As an example of the process just described I give the following series of measurements:

Apr. 25, 10h. 5m. Thermometer-wire, 540.71  
Temperature, 9°·5

Added weight. kg.	Time. h. m.	Cath. I. mm.	Cath. II. mm.	Lengthening. mm.
0	10 8	548.96		
0.2	9	41.84	0.15	7.12
0.4	11	34.70	"	14.26
0.6	13	27.46	"	21.50
0.8	15	20.18	"	28.78
1.0	17	12.81	0.14	36.14
1.2	19	5.39	"	43.56
1.4	21	497.885	"	51.065
1.6	23	90.26	0.135	58.685
1.8	25	82.60	0.125	66.335
·0	27	548.92	0.105	

10 h. 30 m. Thermometer-wire, 540.68

The lowering of the zero-point during these measurements was 0.04 mm. according to cathetometer I, and 0.045 mm. according to cathetometer II. The thermometer-wire, which was just like the main-wire, lengthened by 0.03 mm. during this time. The rise in temperature was accordingly  $\frac{3}{4}\frac{3}{10}^{\circ}$ , about twice the ordinary rise. The above table indicates, as already shown by the table on p. 39, that with an added weight of 1.8 kg. the after-effect begins to be noticeable. The lengthening produced by this weight I have given, but not taken into account in my later calculations. The initial load plus 1.8 kg. amounted to nearly half the breaking weight.

*Table of 10 Series of Measurements.*

Kg.											Mean mm.
0.2	7.10	.13	.12	.11	.105	.12	.11	.11	.12	.09	7.111
0.4	14.25	.265	.26	.28	.285	.27	.265	.27	.28	.27	14.269
0.6	21.47	.50	.50	.50	.485	.495	.49	.475	.49	.49	21.489
0.8	28.76	.775	.78	.77	.75	.785	.77	.77	.79	.77	28.772
1.0	36.11	.125	.14	.145	.115	.13	.13	.11	.12	.12	36.124
1.2	43.53	.57	.56	.55	.555	*	.57	.55	.545	.56	43.554
1.4	51.05	.07	.065	.07	.065	.06	.065	.09	.055	.08	51.067
1.6	58.66	.71	.685	.71	.66	.69	.675	.68	.69	.675	58.683
1.8	66.33	.355	.335	.36	.32	.35	.31	.32	.34	.32	66.334

Ten additional series of measurements were made. The mean values derived from the 20 series are given in the following table under *x* observed.

<i>p.</i>	<i>x</i> observed.	<i>x</i> calculated.	Observed-calc.
0.2 kg.	7.111	.110	+0.001
0.4	14.272	.271	+ 1
0.6	21.488	.488	± 0
0.8	28.770	.770	± 0
1.0	36.119	.122	— 3
1.2	43.554	.554	± 0
1.4	51.076	.071	+ 5
1.6	58.679	.681	— 2
1.8	66.341	----	----

Mean temperature, 9°.

Cross-section of wire, 0.0627 mm.<sup>2</sup>

Length of wire, 22700 mm.

Specific gravity of wire, 8.42

Initial load, 0.665 kg.

*p* = added weight, and *x* = lengthening.

Expressing the result of the measurements by an equation of the form

$$x = ap + bp^2 + cp^3$$

I obtained the equation

$$x = 35.4385 p + 0.5353 p^2 + 0.1487 p^3$$

The calculation of the most probable values of the constants *a*, *b* and *c*, was effected in this case, as in all the other cases, by means of the method of least squares. The mean error of the individual measurements calculated from the 10 lengthenings produced by a weight of 1.4 kg. and given in the table on p. 41, is 0.011 mm. and the probable error of the mean result is 0.0024 mm. Two minutes after the weighting and release of the wire the mean lowering of the zero-point was 0.009 mm.

\* No measurement was made. If I had waited for the mark to come to rest the after-effect would have been noticeable.

The initial load, consisting of frame, scale-pan, damper, and half the weight of the wire itself, amounted to 665 kg. This was probably twice as much as was really necessary to keep the wire straight. In later measurements a lighter frame was used.

*Experiments with Copper Wire.*

The following is one of ten series of measurements made May 23rd.

Time 4 h. 7 m. Thermometer-wire 540.70

Added weight. kg.	Time. h. m.	Cath. I. mm.	Cath. II. mm.	Lengthening. mm.
0	4 9	554.82		
0.2	10	49.29	0.15	5.53
0.4	12	43.73	"	11.09
0.6	14	38.14	"	16.68
0.8	16	32.51	"	22.31
1.0	18	26.84	0.14	27.97
1.2	20	21.14	0.13	33.66
0	22	554.795	0.12	

Lowering of zero-point, 0.025 0.03

4 h. 27 m. Thermometer-wire 540.70

At 4 h. 33 m., the beginning of the next series of observations, the zero-point had risen 0.015 mm. on account of the after-effect. This was generally the case between any two series. The influence of the after-effect, although rather more marked here than in the case of the other metals experimented upon, was not enough to affect the value of the measurements.

On this day the temperature was remarkably constant. The total steady lengthening of the thermometer-wire between 2 h. 50 m. and 5 h. 23 m. amounted to only 0.02 mm.

The following table gives the results of eight successive measurements made with the copper wire May 23rd.

<i>p.</i> kg.									Mean mm.
0.2	5.535	.535	.54	.53	.53	.53	.53	.535	5.533
0.4	11.085	.08	.10	.085	.09	.09	.09	.095	11.090
0.6	16.675	.675	.685	.685	.685	.68	.67	.68	16.680
0.8	22.31	.305	.31	.31	.30	.31	.31	.31	22.308
1.0	27.97	.94	.98	.985	.95	.97	.94	.945	27.960
1.2	33.665	.65	.72	.685	.67	.66	.64	.62	33.664

The following table gives the mean values derived from 16 series of measurements with copper wire.

<i>p.</i> kg.	<i>x</i> observed. mm.	<i>x</i> calculated. mm.	Observed-calc. mm.
0·2	5·531	·529	+ 0·002
0·4	11·084	·086	— 2
0·6	16·671	·673	— 2
0·8	22·298	·294	+ 4
1·0	27·949	·951	— 2
1·2	33·646	·646	± 0

Mean temperature, 13°·5  
 Cross-section of wire, 0·0641 mm.<sup>2</sup>  
 Length of wire, 22690 mm.  
 Specific gravity of wire, 8·99  
 Initial load 0·192 kg.

The figures of the third column were calculated according to the equation

$$x = 27·578 p + 0·3193 p^2 + 0·0538 p^3.$$

The initial load was 0·192 kg. Measurements showed that 0·15 kg. sufficed to hold the wire straight, while 0·10 kg. was insufficient.

*Experiments with Steel Wire.*

The following table gives the mean result of 20 series of measurements.

<i>p.</i> kg.	<i>x</i> observed. mm.	<i>x</i> calculated. mm.	Observed-calc. mm.
0·2	7·078	·077	+ 0·001
0·4	14·196	·197	— 1
0·6	21·358	·358	± 0
0·8	28·558	·558	± 0
1·0	35·792	·793	— 1

Mean temperature, 13°  
 Cross-section of wire, 0·03263 mm.<sup>2</sup>  
 Length of wire, 22700 mm.  
 Specific gravity of wire, 7·74  
 Initial load, 0·491 kg.

The figures in the third column were calculated according to the equation

$$x = 35·2725 p + 0·5725 p^2 - 0·0525 p^3$$

An evidence of the insignificance of the after-effect may be seen in the fact that in ten successive series of measurements the lengthening caused by the maximum load deviated in no case more than ·0225 mm. from the mean. Two minutes after the release of the wire the mean position of the zero-point was ·01 mm. lower than immediately before this maximum load was put on the pan.

*Experiments with Silver Wire.*

The following table gives the mean result of eight series of measurements.

<i>p.</i> kg.	<i>x</i> observed. mm.	<i>x</i> calculated. mm.	Observed-calc. mm.
0·2	7·898	·896	+ 0·002
0·4	15·820	·822	— 2
0·6	23·775	·776	— 1
0·8	31·758	·756	+ 2
1·0	39·762	·762	± 0

Mean temperature, 14°  
 Cross-section of wire, 0·0687 mm.<sup>2</sup>  
 Length of wire, 22690 mm.  
 Specific gravity of wire, 10·00  
 Initial load, 0·593 kg.

The figures in the third column were calculated according to the equation

$$x = 39\cdot4030 p + 0\cdot3905 p^2 - 0\cdot0313 p^3$$

This wire was not so free from curves as the others, and consequently it was necessary to begin with a comparatively heavy initial load.

The influence of the after-effect was as a rule so slight that it could not be measured. After each release of the wire the mark returned quickly to the zero-point, and the sinking of the zero-point was explained almost entirely by the gradual rise in temperature in the tower.

*Calculation of the True Modulus of Elasticity.*

From the results given above it follows that the modulus of elasticity is not a constant, but in every case a function of the tension. From the equation

$$x = ap + bp^2 + cp^3$$

which gives the relation between the elastic lengthening and the stretching weight we obtain

$$\frac{dx}{dp} = a + 2bp + 3cp^2$$

and with the help of this latter equation we can compute the modulus for any tension whatever.

The almost perfect agreement between the observed and calculated values of *x* makes it extremely probable that, inasmuch as the initial load was slight, we may extend the application of this equation backwards to an initial load of zero.

Thus we shall be in a position to determine the true modulus of elasticity, the modulus of the body before it has been subjected to any deformation whatever.

In order to determine this true modulus we may proceed as follows :

Let  $X_0$  be the lengthening caused by the initial load  $P_0$ .\*  
 “  $X$  “ “ “ “ “ total weight  $P_0 + p$

Then the observed lengthening  $x = X - X_0$ .

$$\text{Let } X = \alpha P + \beta P^2 + \gamma P^3 \quad (1)$$

$$\text{and } X_0 = \alpha P_0 + \beta P_0^2 + \gamma P_0^3 \quad (2)$$

Equation (2) subtracted from (1) gives

$$x = (-\alpha P_0 - \beta P_0^2 - \gamma P_0^3) + \alpha P + \beta P^2 + \gamma P^3 \quad (3)$$

The results of the measurements were given in the following form

$$\begin{aligned} x &= a(P - P_0) + b(P - P_0)^2 + c(P - P_0)^3 \\ &= (-aP_0 + bP_0^2 - cP_0^3) + (a - 2bP_0 + 3cP_0^2)P + (b - 3cP_0)P^2 + \\ &\quad cP^3 \quad (4) \end{aligned}$$

Equating the coefficients of like powers of the variable  $P$  in the two expressions for  $x$  in (3) and (4) we obtain

$$\alpha = a - 2bP_0 + 3cP_0^2$$

$$\beta = b - 3cP_0$$

$$\gamma = c$$

Equation (1) which gives the relation between elastic lengthening and stretching weight when one begins with an initial load zero becomes in the case of the steel wire for instance

$$X = 34.672P + 0.6498P^2 - 0.0525P^3$$

and  $\left(\frac{dX}{dP}\right)_{P=0} = 34.672$

With an infinitesimal stretching weight the formula for the modulus of elasticity is

$$E = \frac{l}{q} \cdot \frac{dP}{dX}$$

where  $l$  is the length and  $q$  the cross-section of the wire. Therefore in this case

$$E = \frac{22683}{0.03263} \cdot \frac{1}{34.672} = 20050$$

The length of the unstretched wire  $l$  can be found with the help of equation (2).

\*  $P_0$  represents the weight of the frame with pan and damper, increased by half the weight of the wire.

The equations giving the relation between elastic lengthening and stretching weight when one begins with zero load are as follows :

$$\begin{aligned}
 \text{Steel} & \dots\dots\dots X=34\cdot672P+0\cdot6498P^2-0\cdot0525P^3 \\
 \text{Brass} & \dots\dots\dots X=34\cdot924P+0\cdot2386P^2+0\cdot1487P^3 \\
 \text{Silver} & \dots\dots\dots X=38\cdot907P+0\cdot4462P^2-0\cdot0313P^3 \\
 \text{Copper} & \dots\dots\dots X=27\cdot461P+0\cdot2883P^2+0\cdot0538P^3
 \end{aligned}$$

The specific gravities, cross-sections, and moduli calculated by the above method are given in the following table.

	Sp. Gr.	Cross-section.	True Modulus.	Modulus I.	Modulus II.
Steel ----	7·74	0·03263	20050	19430	19230
Brass ---	8·42	0·0627	10370	9820	9450
Silver ---	10·00	0·0687	8490	8300	8250
Copper..	8·99	0·0641	12890	12620	12420

In order to show still more clearly the dependence of the modulus on the tension I add two more columns. The next to the last column gives the modulus which one would obtain if only the lengthening caused by the maximum added load were taken into account. The last column, the modulus which would be obtained if only the increase of lengthening caused by the last 0·2 kg. should be made the basis of calculation. As will be seen, the true modulus of elasticity of the brass wire is nearly 10 per cent greater than the one given in the last column.

*Influence of Contraction of Cross-Section.*

When a wire is stretched so that each unit of length increases by  $\delta$ , the cross-section becomes  $Q_0(1-2\mu\delta)$  if  $Q_0$  is the original cross-section. Theoretically  $\mu$  can have in different bodies any value between the limits 0 and  $\frac{1}{2}$ . Supposing that in the case of steel  $\mu=0\cdot294$ , as Kirchoff states, we find that for a weight of 1 kg.  $\delta=35\cdot8\div22700=0\cdot0016$  and the cross-section is accordingly  $Q_0(1-0\cdot00094)$ . If we wished to refer the modulus of elasticity in this case to this diminished cross-section, the coefficients of our equations would suffer a perceptible change. But it is not customary to do this, and we shall refer the modulus to the condition of the unstretched wire. Further it should be noticed that the value of  $\mu$  is not definitely known ; in fact, there is ground for believing that in one and the same body it is a variable quantity.

*Larger Wires.*

In order to be perfectly sure that the phenomena which I have described were not confined to fine wires, I made careful measurements with larger wires. The loads placed on these

were gradually increased to a maximum of 18 kg. and without exception the results obtained were similar to those which I have reported. The reasons however why I preferred to use fine wires are first, because in these the thermal effects vanish more rapidly, and second, because the loading and unloading can be done in shorter time, and thus the after-effect is more completely eliminated.

*Earlier Investigators.*

Since these investigations have yielded results which are at variance with those hitherto obtained, it is desirable to search for an explanation of the discrepancy. It is evident that the presence of curves and bends in the wire would give to  $\frac{x}{p}$  too large a value which would gradually decrease as the wire grew straight. This circumstance would account for Stradling's remark\* according to which the modulus of elasticity would increase with the tension, and is the probable explanation of the fact that Wertheim† in the case of annealed platinum finds the modulus increasing with the weight. Further the almost universal result obtained by other investigators, namely that  $\frac{x}{p}$  has a constant value, can be explained in the very same way. The diminution of the modulus alone considered would make  $\frac{x}{p}$  larger, while the gradual straightening of the wire would tend to make it smaller. The combination of these two factors could easily lead to the conclusion that within the limits of errors of observation  $\frac{x}{p}$  has a constant value.

*Discussion of Results.*

Whatever the nature of elastic force may be, whether it is an essential property of matter, or a derived property which can be accounted for by the rotation of atoms, the fact was established by Wertheim that between the elasticity of a body and its density there exists an intimate relation. Conclusion I of his investigation is as follows:‡ “The coefficient of elasticity is not a constant for one and the same metal. All circumstances which increase the density make it larger, and conversely.” These words justify a deduction which Wertheim

\* Stradling, Wied. Ann., xli, p. 332, 1890.

† Wertheim, Pogg. Ann. Ergänz., ii, p. 46, 1848.

‡ Wertheim, l. c. p. 69.

himself seems not to have made, for conclusion VII shows that he did not look for any change in the modulus of elasticity until the density of the body had been permanently altered. Wertheim proved that the density of a wire before an experiment differs very slightly from its density after it has been broken by its load. He therefore concludes that in one and the same wire, even when it is in different conditions of equilibrium, the modulus of elasticity can vary only a very little.

But it should be kept in mind that, although on account of the contraction of cross-section the change in density is slight, the mean molecular distance in the direction in which the tension is exerted probably increases by a very considerable amount. And it is probable that the variability of the modulus of elasticity should be attributed not so much to the alteration in density of the body considered as a whole, as to this change of mean molecular distance in the direction of the tension. According to Wertheim's own assumption we should have in one and the same metal

$$\text{Mod. of elasticity} \times a^7 = \text{constant},$$

where  $a$  represents the mean molecular distance. According to this any change in  $a$  would produce in the modulus a change proportionally seven times as great, and this in the case of the stretching of a wire can become very noticeable. According to my own measurements to be sure a much higher power than the seventh must be assumed in the formula.

If it is universally true that an increase of the mean molecular distance causes a diminution of the modulus of elasticity according to a definite law, then in those metals which have the largest coefficients of thermal expansion the decrease of the modulus of elasticity with the temperature ought to be most rapid. That this is actually the case has been already mentioned by Miller\* and Katzenelsohn.† A further deduction would be that since by higher temperatures the coefficient of thermal expansion grows larger, the modulus should here decrease more rapidly than by lower temperatures. That this is also true has been proved by the measurements of Kohlrausch and Loomis‡ and Pisati.§

Further if a substance like india rubber has a negative coefficient of thermal expansion, it would follow from our principle that as the temperature increases the modulus should increase too. Just such an increase in the modulus of elasticity

\* Miller, Wied. Beibl., xi, p. 211, 1887.

† Katzenelsohn, Wied. Beibl., xii, p. 307, 1888.

‡ F. Kohlrausch and Loomis, Pogg. Ann., cxli, p. 498, 1870.

§ Pisati, Wied. Beibl., i, p. 305, 1877.

of india rubber has been observed by Miller\* *These facts and the results of my experiments justify the conclusion that in every case the modulus of elasticity of a body is a function of the molecular distance, and that every agency, whether it be heat or mechanical force, which increases this molecular distance, produces a diminution of the modulus of elasticity.*

This relation which is enunciated here for the first time as a general law has, as far as I am aware, no exception which cannot be explained by the necessary errors of observation.

It is interesting to notice that in many instances the theory of probabilities is able to deduce from the measurements of Wertheim results similar to mine. The following values for the moduli of pure gold (Wertheim, l. c. p. 30), and pure silver (p. 45) show on their face an evident diminution as the stretching weight increases.

kg.	gold.	silver.
3	7030	
4	6391	
5	5021	7701
6	5492	7578
7	5340	6476
8	5291	7555
9	4972	7213
10	5140	7123

In other cases, for instance in the measurements made with copper (p. 35) and silver (p. 31) where consecutive values of the modulus differ by as much as 10 per cent it is necessary to apply the theory of probabilities.

In the previously mentioned measurements with annealed platinum the opposite tendency can probably be explained by curvature of the wire.

Whether in the method of flexure it is possible to detect a dependence of the modulus on the amount of the load I have not had time to investigate. Since however the compression on one side of the neutral layer is equal to the extension on the other, and consequently the density remains either exactly or very nearly the same, it is probable that in this case no change in the modulus of elasticity could be observed.

A number of relations and applications of this true law of elastic lengthening to other physical laws, and other phenomena observed in the course of my experiments, I shall discuss at some future time.

\* Miller, l. c.

*Conclusions.*

I. The generally accepted law of elastic lengthening  $x = aP$ , according to which the lengthening  $x$  is proportional to the stretching weight  $P$ , is only an approximation.

II. The relation between elastic extension and stretching weight can be expressed by an equation of the following form :

$$X = \alpha P + \beta P^2 + \gamma P^3$$

III. The modulus of elasticity of the undeformed body can be calculated with the help of the equation

$$\left( \frac{dX}{dP} \right)_{P=0} = \alpha$$

IV. The true moduli of elasticity calculated in this way may be as much as 10 per cent larger than those determined in the ordinary way. Consequently it will be necessary to recalculate physical constants which depend on the modulus of elasticity.

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ART. VI.—*A Method for the Quantitative Separation of Strontium from Calcium by the Action of Amyl Alcohol on the Nitrates* ; by P. E. BROWNING.

[Contributions from the Kent Chemical Laboratory of Yale College—XI.]

AT the suggestions of Prof. F. A. Gooch, and following the general mode of procedure laid down in his paper\* upon the separation of sodium and potassium from lithium by the action of amyl alcohol on the chlorides, I undertook a series of experiments looking toward the separation of strontium from calcium by the action of amyl alcohol on the nitrates. On boiling several portions of the so-called chemically pure calcium and strontium nitrates with amyl alcohol, nearly complete solubility was observed in case of the calcium salt, while corresponding insolubility seemed to be characteristic of the strontium salt, and these results seemed to warrant proceeding with the work.

For the quantitative tests to be described standard solutions of specially purified strontium and calcium nitrates were prepared. In general the preparation was effected by precipitating a soluble salt of either element with ammonium carbonate in the presence of ammonium chloride, washing thoroughly with boiling water, dissolving in the least possible amount of

\* Amer. Chem. Jour., vol. ix, p. 33.

nitric acid, and making up to measure. In the earlier experiments other methods of purification were used, such as the precipitation of the strontium nitrate by alcohol, and in case of the calcium salt the preparation of the nitrate from the carbonate precipitated by ammonium carbonate from a solution of calcium sulphate. The method first described, however, gave satisfactory results, the spectroscope failing to show in the product thus obtained any trace of intermixture of calcium and strontium salts, or the presence of any other appreciable impurity. In the determination of the standards of these solutions definite amounts were drawn off from burettes into counterpoised beakers or crucibles (according as the method of determination was by precipitation or evaporation) and weighed as a check on the burette reading. The strontium nitrate in each portion was converted into the sulphate either by precipitation in the presence of alcohol, or by evaporating and igniting, these methods yielding results closely agreeing. The calcium was determined by evaporation with sulphuric acid. The first series of experiments was directed toward an investigation of the action of amyl alcohol upon strontium nitrate alone. Accordingly several amounts of the strontium salt were measured from a burette into counterpoised Bohemian beakers of about 100 cm<sup>3</sup> capacity, and weighed. The water was then evaporated over a water bath, and the dry salts dissolved in a few drops of water and boiled with 30 cm<sup>3</sup> of amyl alcohol, that amount being determined upon for convenience. Care should be taken not to add more than the necessary amount of water to dissolve the salt, inasmuch as the presence of much water delays the process (it being necessary to expel all the water before the amyl alcohol can do its work) and tends to cause spattering due to the superheating of the water and consequent sudden generation of steam under the alcohol. It has been my experience that in the presence of a few drops of water the boiling goes on quietly, the water escaping easily through the amyl alcohol, so that in the course of a few minutes the alcohol reaches its normal boiling temperature (128°–130° C.) In order that the inflammable fumes of the alcohol might not reach the flame during the boiling the beaker was placed upon a piece of asbestos board about 15 cm. square. When the temperature of the alcohol reached its normal boiling point (128°–130° C.), as shown by a thermometer, the beaker was removed and the strontium nitrate filtered off upon an asbestos felt in a perforated platinum crucible, the crucible and felt having been previously dried and weighed.

The filtration was carried on under gentle pressure, the filtrate being received in a beaker standing under a bell jar upon a ground glass plate. The last traces of strontium nitrate

were removed from the beaker by washing with small amounts of previously boiled amyl alcohol contained in a wash-bottle the mouthpiece of which consisted of a small chloride of calcium tube passing through the stopper and drawn out and plugged at the lower end with cotton to exclude particles of the calcium salt from the alcohol. By this device the introduction of moisture into the amyl alcohol was guarded against. The crucible containing the strontium nitrate was placed in an air bath and heated to  $150^{\circ}$  C. to drive off all amyl alcohol, and weighed. A constant weight was obtained uniformly in one treatment. Series I contains the results of these experiments, the strontium being calculated as oxide.

## SERIES I.

(1)	SrO taken	0.1229	grm.	SrO found	0.1220	grm.	Loss	0.0009	grm.
(2)	"	"	0.1231	"	"	0.1221	"	0.0010	"
(3)	"	"	0.1230	"	"	0.1219	"	0.0011	"
(4)	"	"	0.1227	"	"	0.1213	"	0.0014	"

These results suggested a possible solubility of the strontium salt, and, accordingly, experiments were made to test this point. Amounts of strontium nitrate closely agreeing with those above were taken and treated in the same manner. The filtrates amounting, without the washings, to about  $25\text{ cm}^3$  were evaporated to dryness. The residue was ignited to burn off organic matter from the amyl alcohol, treated with sulphuric acid, heated to low redness, and weighed. In two cases the residue of strontium sulphate was found to contain of the oxide respectively  $0.0009\text{ grm.}$  and  $0.0010\text{ grm.}$  As will be seen the solubility of the strontium nitrate averages about  $0.0010\text{ grm.}$  of the oxide to  $30\text{ cm}^3$  of amyl alcohol used. The exact extent of this solubility depends, of course, upon the amount of amyl alcohol remaining after boiling; and, since the source of heat is removed as soon as the normal boiling temperature of the alcohol is reached, very little decrease in the volume of the previously boiled alcohol results. On measuring the amounts of the alcohol remaining in several experiments I found them to approximate closely to  $25\text{ cm}^3$ . It seemed justifiable, therefore, to add as a correction to the apparent amount of strontium oxide found  $0.0010\text{ grm.}$  for every  $25\text{ cm}^3$  of amyl alcohol remaining, or for every  $30\text{ cm}^3$  originally taken. Experiments were also made to determine whether the strontium nitrate might have been at all broken down in the process of boiling and heating so that some strontium might be present in the final residue in the form of oxide or nitrite. In two of these experiments portions of strontium nitrate left by the treatment with amyl alcohol were dissolved, precipitated as the

sulphate and weighed as such, and the results of these experiments (5 and 6) go to show that the composition of the strontium nitrate is not appreciably changed in the process of separation and drying. In certain other experiments directed to the same end, the residues of the process of separation were, after weighing and drying, treated with a drop of nitric acid, and again dried at  $150^{\circ}$  C. and weighed. These tests (7) and (8) confirm the indications of the previous experiments. Finally a third experiment was made upon strontium nitrate dried at  $150^{\circ}$  C. to see what decomposition might result by heating to temperatures somewhat higher than  $150^{\circ}$  C.—the temperature at which the residues of the previous experiments had been dried. The result shows that the loss in the twenty-five degrees above  $150^{\circ}$  C. is exceedingly slight.

(5)	{	Sr(NO <sub>3</sub> ) <sub>2</sub> calculated as SrO .....	0.1219 gm.
		The same dissolved and precipitated as SrSO <sub>4</sub>	
		calculated as SrO .....	0.1219 gm.
(6)	{	Sr(NO <sub>3</sub> ) <sub>2</sub> calculated as SrO .....	0.1213 gm.
		The same dissolved and precipitated as SrSO <sub>4</sub>	
		calculated as SrO .....	0.1214 gm.
(7)	{	Sr(NO <sub>3</sub> ) <sub>2</sub> calculated as SrO .....	0.1228 gm.
		The same dried at $150^{\circ}$ C. after adding a drop of	
		HNO <sub>3</sub> .....	0.1228 gm.
(8)	{	Sr(NO <sub>3</sub> ) <sub>2</sub> calculated as SrO .....	0.1239 gm.
		The same dried at $150^{\circ}$ C. after adding a drop of	
		HNO <sub>3</sub> .....	0.1239 gm.
(9)	{	Weight of Sr(NO <sub>3</sub> ) <sub>2</sub> dried at $150^{\circ}$ C. ....	0.2482 gm.
		Weight of the same portion dried at $165^{\circ}$ C. ....	0.2480 gm.
		Weight of the same portion dried at $175^{\circ}$ C. ....	0.2478 gm.

When calcium nitrate was treated in a similar manner by boiling with amyl alcohol the mass of the salt dissolved, but minute portions separated out on the bottom or sides of the beaker. Such residues were, however, very small and on weighing were found not to exceed 0.0003 gm. or 0.0004 gm. of the oxide. In several instances this insoluble residue was washed thoroughly with ethyl alcohol, dissolved in water, tested before the spectroscope and found to give the characteristic calcium spectrum. All experience pointed to the fact that the formations of the residue was due to some very slight change of composition of the calcium nitrate. On one or two occasions the acidified solution of the residue appeared to reduce a drop of an extremely dilute solution of potassium permanganate, and this action suggested the presence of a nitrite. Treatment of this residue with nitric acid and subsequent evaporation of the excess of acid failed, however, to leave the calcium salt in a condition to be dissolved by amyl alcohol.

It is possible, therefore, that the real cause of insolubility is to be sought in the oxidation of the amyl alcohol and consequent formation of an organic acid, and, subsequently, of the corresponding calcium salt, but the amounts of the residue were so extremely small that it was not practicable to solve this question, at once, exactly and satisfactorily without directing attention too far from the main issue. Moreover, the error introduced by this peculiar behavior of the calcium salt proved to be insignificant in its effects upon the quantitative determination of the calcium, and accordingly, it was disregarded in the subsequent tests.

The next experiments were directed toward a separation of strontium and calcium nitrates. Definite amounts of a solution of strontium nitrate were measured from burettes into counterpoised beakers and weighed, as already described, the calcium nitrate was then added in solution, and the weight taken again. The water was evaporated and the dry salts dissolved again in the least possible amount of water, and boiled with amyl alcohol, (30 cm.<sup>3</sup>) as before. The strontium salt was filtered off into a perforated platinum crucible containing an asbestos felt, dried and weighed as previously described. The calcium was determined in the form of the sulphate, by evaporation of the alcohol, treatment with an excess of sulphuric acid, and ignition.

Correction was made for the solubility of the strontium nitrate, and its consequent presence with the calcium, by calculating the amount dissolved in the portion of amyl alcohol employed to the condition of sulphate and subtracting that quantity from the apparent amount of calcium sulphate found. The results of this mode of proceeding are recorded in experiments (10) and (11).

SrO taken.	SrO found. (corrected.)	Error.	CaO taken.	CaO found. (corrected.)	Error.
(10.) 0.0911 grm.	0.0932 grm.	0.0021 grm. +	0.0932 grm.	0.0907 grm.	0.0025 grm. —
(11.) 0.0915 grm.	0.0945 grm.	0.0030 grm. +	0.0933 grm.	0.0899 grm.	0.0034 grm. —

After making the correction in the manner specified it is evident that the amount of strontium indicated is greater than that originally taken. It is apparent, therefore, that the strontium nitrate must have been contaminated, probably mechanically, by the calcium salt, as the calcium salt is found to be correspondingly deficient in amount. It was thought best, therefore, to have recourse to a double treatment with the alcohol. Accordingly after the first boiling already described the alcohol carrying the greater part of the calcium in solution was decanted upon an asbestos felt under the conditions previously described and collected in a beaker placed to receive

it. The residue was then dried at a gentle heat over a radiator to remove amyl alcohol, dissolved in a few drops of water, treated with a drop of nitric acid to assure the condition of nitrate, and evaporated to dryness. After dissolving in a few drops of water 30 cm.<sup>3</sup> of the alcohol were added, and the boiling repeated. The residue was filtered off upon the same felt through which the first portion had been decanted, and washed with amyl alcohol, care being taken to remove all particles of the residue from the beaker by careful rubbing. The crucible and residue were heated in an air bath at 150° C. as before, and then weighed. The filtrate from the two treatments and the washings were treated differently in two series of experiments. In Series II, the filtrate was precipitated with sulphuric acid, ethyl alcohol being added to secure thorough mixture. The precipitated sulphate was filtered off upon asbestos, heated to low redness and weighed. In Series III, the alcoholic filtrate was evaporated to a small volume, transferred to a weighed platinum crucible and evaporated. The residue was ignited to burn off organic matter, treated with sulphuric acid and again ignited at low redness and weighed.

## SERIES II.

SrO taken.	SrO found. (corrected.)	Error.	CaO taken.	CaO found. (corrected.)	Error.
(12) 0.1235 gm.	0.1239 gm.	+0.0004 gm.	0.1290 gm.	0.1271 gm.	-0.0019 gm.
(13) 0.1237 "	0.1228 "	-0.0009 "	0.1246 "	0.1226 "	-0.0020 "
(14) 0.1239 "	0.1239 "	0.0000 "	0.1248 "	0.1223 "	-0.0025 "
(15) 0.1974 "	0.1972 "	-0.0002 "	0.3502 "	0.0492 "	-0.0010 "
(16) 0.1979 "	0.1978 "	-0.0001 "	0.0496 "	0.0482 "	-0.0014 "

## SERIES III.

(17) 0.0148 "	0.0155 "	+0.0007 "	0.0256 "	0.0254 "	-0.0002 "
(18) 0.0183 "	0.0183 "	0.0000 "	0.1030 "	0.1015 "	-0.0015 "
(19) 0.0364 "	0.0366 "	+0.0002 "	0.0516 "	0.0511 "	-0.0005 "
(20) 0.0365 "	0.0365 "	0.0000 "	0.0515 "	0.0513 "	-0.0002 "
(21) 0.0493 "	0.0494 "	+0.0001 "	0.0515 "	0.0502 "	-0.0013 "
(22) 0.0497 "	0.0497 "	0.0000 "	0.0519 "	0.0511 "	-0.0008 "
(23) 0.0497 "	0.0503 "	+0.0006 "	0.0249 "	0.0245 "	-0.0004 "
(24) 0.0729 "	0.0732 "	+0.0003 "	0.0257 "	0.0251 "	-0.0006 "
(25) 0.0730 "	0.0732 "	+0.0002 "	0.0255 "	0.0255 "	0.0000 "
(26) 0.0744 "	0.0744 "	0.0000 "	0.0258 "	0.0260 "	+0.0002 "
(27) 0.0912 "	0.0910 "	-0.0002 "	0.1286 "	0.1276 "	-0.0010 "

The average error in the determination of strontium in both series is less than 0.0001 gm. + on the oxide; that of the calcium amounts to 0.0017 gm. - on the oxide in Series II, and to 0.0005 gm. - in Series III.

In both processes the correction for the solubility of strontium nitrate in amyl alcohol, determined as previously described, was applied—0.0020 gm. being added to the weight of the strontium oxide found after the double treatment with amyl alcohol, and 0.0035 gm. being deducted from the apparent weight of the calcium sulphate found before calculating it

to the form of the oxide. The latter of the two processes, which are identical so far as handling of the strontium is concerned, yields the better results in the determination of the calcium, doubtless because a trifling amount of calcium sulphate remains in solution in the final filtrate in the former process, while in the latter every trace should be recovered. The deposition of minute traces of calcium in the precipitation of the strontium nitrate, to which reference has been previously made, is evidently a matter of no significance in comparison with the ordinary errors of manipulation.

ART. VII.—*The Relation of Melting Point to Pressure in Case of Igneous rock fusion*; by C. BARUS.

To determine this important constant for diabase, I made use of the thermodynamic principle (Clausius, I, chap. vii, § 2). From my last note\* the fusion specific volumes, solid and liquid, are known. Hence it is merely necessary to determine the latent heat of fusion.

Two series of measurements of the thermal capacity of diabase, containing 27 independent measurements, were made between 700° and 1400°. The first series gave me, in gram calories, for the mean specific heat, solid, between 800° and 1100°, .304; for the mean specific heat, liquid, between 1200° and 1400° .350; for the latent heat of fusion (1200°), 24; and for the heat set free on solidification (1100°), 16. Similarly the second series gave me, .290, .360, 24, and 16, respectively. The last series is much the more trustworthy and its accuracy may be inferred from the following pairs of values of temperature and thermal capacity: (solid) 781°, 180; 873°, 202; 948°, 227; 993°, 238; 1096°, 268; 1171° (incipient fusion?), 302; (liquid) 1166°, 310; 1194°, 318; 1197°, 319; 1215°, 327; 1218° 330; 1248°, 339; 1251°, 340 and 342; etc. Now whereas in my last note (l. c.), solidification did not set in above 1100°, evidences of fusion do not here show themselves until 1170° is reached. Rock fusion is therefore accompanied by hysteresis,† the lag being apparently as much as 70°. It is this property which makes it possible to obtain sharp values of latent heat, for the rock can be operated on, either solid or liquid, at nearly the same temperature. In view of the great difficulty of obtaining the value of the melting point, however, I shall in the following state the conditions for 1100°

\* This Journal, December, 1891.

† This Journal, xlii, p. 140, 1891.

and 1200° respectively, the latter being very near the melting point.

Combining the present series I with the former series III, I obtain for the relation of melting point and pressure,  $dT/dp$ , at 1200°, since  $T=1470^\circ$ ,  $\sigma-\tau=0.394/2.72$ ,  $r'=24$ ,  $dT/dp=0.21$ ; and at 1100°, since  $T=1370^\circ$ ,  $\sigma-\tau=0.385/2.72$ ,  $r'=16$ ,  $dT/dp=0.29$ . Similarly combining the present series II with the former series IV, at 1200°, since  $\sigma-\tau=0.352/2.72$ ,  $r'=24$ ,  $dT/dp=0.19$ ; and at 1100°, since  $\sigma-\tau=0.341/2.72$  and  $r'=16$ ,  $dT/dp=0.26$ .

Hence the probable *silicate* value of  $dT/dp=0.25$  at 1170°, falls nicely within the margin (0.20 to 0.36) of corresponding data for organic substances (wax, spermaceti, paraffin, naphthalin, thymol). I may therefore infer that the relation of melting point to pressure in case of the normal type of fusion, is nearly constant, irrespective of the substance operated on, and in spite of enormous differences of thermal expansibility and (probably) of compressibility. A portion, in a given substance changed only as to temperature and pressure, the relation of melting point and pressure is linear.

The immediate bearing of all of this on Mr. Clarence King's geological hypothesis is now ripe for enunciation.

ART. VIII.—*The discovery of Clymenia in the Fauna of the Intumescens zone (Naples beds) of Western New York, and its Geological Significance*; by JOHN M. CLARKE.

THE ammonoid genus *Clymenia* Münster, has not heretofore been found in North America. As early, however, as 1843, Professor Hall doubtfully referred\* to this genus, a fossil from the Portage shales, the *Clymenia? complanata*, and in 1862† re-described the species without the mark of doubt, at the same time adding a new specific name, *C. Erato*, for a fossil from the same fauna. Subsequently these fossils were proved to be of the same species, and though the name *Clymenia* was still retained as late as 1876,‡ it was finally and quite properly abandoned in 1879.§

The present discovery of a true *Clymenia* in a lower Upper Devonian fauna containing *Goniatites intumescens* and various other primordial goniatites, was unexpected and is of considerable geological importance.

\* Geology of New York, Report of the Fourth District, p. 244.

† Fifteenth Ann. Rept. N. Y. State Cab. Nat. Hist., pp. 63, 64.

‡ Illustrations of Devonian Fossils, expl. pl. 70, figs. 6-11.

§ Palæontology of New York, vol. v, pt. 2, p. 455.

The material obtained is from a calcareous concretion found in Shurtleff's Gully in Livingston County, N. Y., not far up in the shales of the Naples beds. This concretion has also afforded specimens of an undescribed *Gephyroceras* of very common occurrence in this fauna, *Tornoceras uniangulare* Conrad, *Bactrites* sp. nov., or very like *B. carinatus* Münster, *Loxonema* Noe Clarke, *Palæotrochus præcursor* Clarke, *Platystoma minutissimum* Clarke, *Bellerophon*, sp. indes., *Styliolina fissurella* Hall, *Cardiola* [?] *Doris* Hall, *Lunulicardium*, sp. nov., common throughout the fauna.

The specimens consist of about thirty examples of a single species in an exceptionally fine condition of preservation, affording the various stages of growth from the protoconch to maturity. As the exterior of the shell is so exquisitely retained and the earlier whorls are compactly filled with silica it has been a difficult task to determine with precision the variations in the form of the suture.

*Description of the species.*—The mature individuals are of small size, the largest example retaining the chamber of habitation having a diameter of 14<sup>mm</sup>. The outer chamber is long, extending nearly three-fourths the length of the last revolution. The shell is widely umbilicate, the successive whorls scarcely overlapping; the number of revolutions from the proximal end of the protoconch is 5½ or 6. The chamber of habitation is subtrapezoidal in section, widening at the base where its sides are rather abruptly incurved to embrace the ventral surface of the inner whorl. The sides slope outward with some convexity and the ventrum is flattened, sometimes very slightly convex or concave.

The *protoconch* is broad, transversely ellipsoidal, and has a diameter of 9<sup>mm</sup>. In adolescent growth stages it is not prominent on account of the absence of any contraction of the tube at the beginning of the first chamber. In the *Goniatiinæ* this contraction is an important character especially well-developed in the genera of the *Primordiales*. The early whorls are broad and very shallow in section, and in them the flattened ventrum of the body whorl is not apparent. For the first four revolutions of the tube, the union of the successive whorls is essentially an apposition, the slight overlapping at maturity indicating a tendency to diminution of umbilication as a geratologous character. The 2d, 3d, 4th and 5th whorls are very broad on the periphery, their vertical to ventral diameter being as 1 to 3·2, 1 to 3, 1 to 2·5, 1 to 2, respectively. In the 4th whorl the ventral surface becomes rapidly convex by the filling out of the ventro lateral slopes, and with the 5th and 6th whorls the increasing lateral appression brings into prominence the narrow flattening of the ven-

trum characterizing maturity. The body-chamber is covered with fine, elevated, falciform striæ which make a broad retral curve in crossing the latera, are bent forward sharply along a low depression just within the ventrum; along the low external carinæ they are again bent backward forming a series of filose festoons on the ventrum itself. On the early whorls these lines are not apparent; there the ornamentation consists of a series of lamellar spinous processes occurring at regularly increasing intervals. These originate on the median and outer portions of each whorl and are projected against the inner edge of the succeeding whorl. They present a concave face anteriorly and are, when entire, considerably extended at right angles to the axis of the shell. These varices appear on the first half of the third volution and from this point on, in a selected example, nine may be counted for the next volution; the whole number exhibited by the specimen to the last contact with the body whorl being seventeen. On the exposed whorl no further trace of the processes is observable than a tendency on the earlier half of the volution to the formation of pilæ or a bunching of the striæ.

*The siphon.*—The dorsal or internal position of the siphon has been observed in several instances. The siphonal funnel is long, conspicuously developed, and open along its inner surface. It does not appear to have extended across the air-chamber, as in the *Nothoclymenia* and I have seen no evidence of a true siphonal tube connecting these funnels.\*

*The sutures.*—At maturity the septum is concave medially, convex at the sides. There is no ventral saddle; the ventral lobe is broad, about equal in width to, but less acute than the ventro-lateral saddle; the lateral lobe is narrower and there is a small, but well developed dorso-lateral saddle. On the internal edge of the septum there is an acutely angled external lobe and an elongate, narrow saddle from which the suture is continued into the siphonal funnel. Of the immature suture but a single example has been observed; at the end of the second revolution the ventral lobe is comparatively narrow, the ventro-lateral saddle very broad, neither the lateral lobe nor dorso lateral saddle is developed, the lateral saddle being continued directly into the external lobe of the internal margin. It is, thus, evident that the accessory lobe and saddle of maturity are developed at a later stage of growth from the broad lateral saddle.

\* Hyatt compares this arrangement of the siphonal funnels in Gumbel's group of the *Euclymenia*, to which our species belongs, to the "imperfect siphons which occur not infrequently among the Nautiloids, the connective wall being destroyed by maceration." Proc. Boston Soc. Nat. Hist., vol. xxii, p. 313.

The ornamentation of our species (which may be termed *Clymenia* (*Cyrtoclymenia*) *Neapolitana*, from its occurrence in the Naples beds) restricts its comparison to three well known species, namely: *Clymenia spinosa* Münster, *C. binodosa* Münster, and *C. subarmata* Münster. The last may be left out of consideration on account of important differences in the mature suture. The other two species belong to the same group, *Cyrtoclymenia* Gümbel (genus *Cyrtoclymenia* Hyatt) and in *C. spinosa* the figures given by Münster\* and the description and illustration by Gümbel† show a similar structure and arrangement of the spinous processes on the ventro-lateral slopes of the whorls. The intervals between these on the earlier whorls are covered by fine concentric lines bending slightly forward over the ventrum but they have not the falciform curve of the striæ in *C. Neapolitana*. Gümbel described a specimen of that species (figures 2a, b, on his plate xvi) in which, over a portion of the last volution, the spinous nodes are reduced to bundles of striæ, strongly defined over the inner margin of the whorl, but spreading and losing their identity over the ventrum. In *C. binodosa* the ornamentation is less like that of the American form but the flattened ventrum is better defined and the suture more like that of *C. Neapolitana* than is that of *C. spinosa*.

The geological interest attaching to this fossil is very great. The genus *Clymenia* has been, wherever found, a most important horizon-marker of the uppermost Devonian. It appeared abruptly and quickly attained a prolific and exceedingly variant development. Hyatt observes that "the whole range of transformations of the Goniatitinæ are paralleled in this short series (Clymeninæ) whose principal differential characteristic lies in the dorsal position of the siphon."‡

Kayser has shown that the *Clymenia* fauna occurring on the summit of the Enkeberg in Westphalia, is of later date than the Cypridinen-schiefer of Nehden (horizon of *Goniatites curvispina* and *Verneuilli*) and is therefore the topmost member of the deep-sea upper Devonian series of the continent of Europe. Wherever found it has maintained this time-value. Richter, Gümbel and Kayser have demonstrated its position in its richest development in the Fichtelgebirge (Schübelhammer, Gattendorf, etc.). Tietze has described it in Silesia (Grafschaft Glatz), Siemiradski in Poland, Frech in Cabrières (Languedoc), Stur, Stache, Hoernes and Frech have established the horizon in Graz (Styria), and Karpinsky and Tschernyschew have identified it in the Urals. In Cornwall (South Petherwin) species

\* Beitrag zur Petrefactenk. v, pl. 11, fig. 15.

† Ueber Clymenien in den Uebergangsgestalten des Fichtelgebirges, p. 48, pl. 16, figs. 1, 2.

‡ Proc. Boston Soc. *loc. cit.*

were long ago described by Phillips and McCoy and more recently the position of the *Clymenia* beds in South Devon (Lower Dunscombe) has been located by Ussher, Kayser, Tschernyschew and Frech. In his "Lehrbuch der geologischen Formationskunde," recently published (1891, p. 109), Kayser states that the genus is limited to the uppermost Devonian. Its presence therefore, in the Naples beds, at a horizon probably not more than 200–250 feet above the top of the Genesee shales, in association with a distinctly developed *Intumescens*-fauna, is an unique phenomenon.

The composition of this fauna in its first appearance in the *Styliola limestone* of the Genesee shales and its reappearance in the Cashaqua-Gardeau division of the Portage group has been recently discussed by the writer in brief.\* In the concluding portion of my paper in the *American Geologist* attention was called to the abundance in the fauna of certain species of coniferous woods, and to the observations made upon them by their describers, Dr. Sir William Dawson and Professor D. P. Penhallow. The most abundant of these species is the *Dadoxylon (Cordiaoxylon) Clarkii* Dawson, which Sir William has recently stated to be most near it its structure to *Araucarites Unger* Gœppert, from the Cypridinen-schiefer of Thuringia. *Cladoxylon mirabile* Unger, from the same flora, was identified some years ago by Dawson in the *Styliola* layer. Of accessory importance is the occurrence of *Kalymma grandis* Unger, (the original also from the Cypridinen-schiefer of Saalfeld) from the Black (Genesee) Shale at Moreland, Kentucky,† in association with a primordial goniatite not unlike *G. intumescens*. Thus we have in our *Intumescens*-zone a very important representation of the flora of the Cypridinen-schiefer as developed in Thuringia, and though the characteristic fossil, *Entomis serrato-striata*, is not known to occur here, yet there is an undescribed *Entomis*, abundant in places in the *Styliola* layer, which is not greatly unlike that species. It does not yet appear that the New York *Intumescens*-fauna furnishes any forms especially characterizing the cephalopod facies of the Cypridinen-schiefer (the *Nehdener-schiefer* or horizon of *Goniatites curvispina* = middle Upper Devonian of the Continent). Some collateral evidence of the *Clymenia*-kalk fauna, but not of the most satisfactory kind, is furnished by the abundance of species of *Tornoceras*, *Cardiola retrostriata*, an undescribed *Bactrites*, which may be compared with *B. carinatus*, Münster, *Loxonema Noe*, not unlike *L. arcuatum* Münster; there is also a species of finely striated

\* Neues Jahrbuch für Min., vol. i, p. 161, 1891; *American Geologist*, Aug., 1891, p. 86.

† Discovered by Dr. C. E. Beecher.

*Lunulicardium* not dissimilar from an unidentified form of this genus known to me from the Enkeberg. These are, however, molluscan types, occurring with, but not especially characteristic of the *Clymenia* fauna. Closer comparisons must await the fuller elucidation of our *Intumescens*-fauna, as a large number of its known species are yet undescribed.

It may be provisionally suggested that the fauna of the Naples beds embraces representatives of the whole series of the European Upper Devonian faunas from the base of the Goniatite limestone to the base of the Culm; that it is, therefore, a condensed time-equivalent of a series highly differentiated in the transatlantic Upper Devonian succession. There the indicial brachiopods, *Spirifer disjunctus*, *Orthis striatula*, *Rhynchonella acuminata*, range through the entire series; here the *Intumescens*-fauna at least, is almost entirely without representatives of these species, their allies or associates.\* On the other hand, in rare instances, the members of the cephalopod or deep-sea facies of the lower Upper Devonian fauna are found in the succeeding brachiopod fauna; for example, *Goniatites intumescens*, *G. sinuosus* (= *G. intumescens*), *G. simulator* (= ? *G. intumescens*) and *G. Chemungensis*.

Tschernyschew has found† these index brachiopods of the Upper Devonian in the *Clymenia* beds of the Urals (Horizont von Mursakaeva), and Hébert at an earlier date reported *Clymenia* with *Spirifer disjunctus* and *Orthis striatula* in the Ardennes near Etroëungt.‡

#### EXPLANATION OF FIGURES.

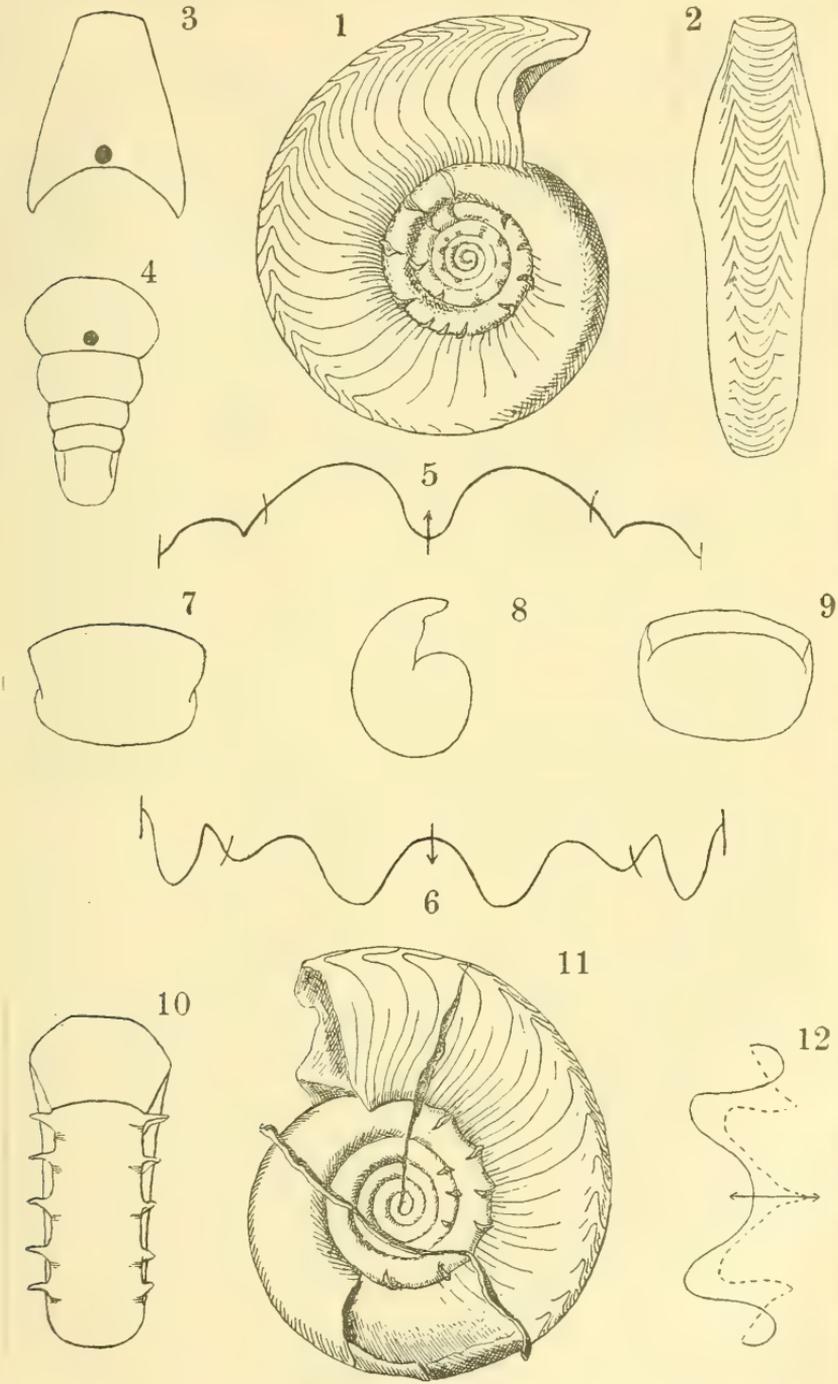
##### *Clymenia Neapolitana*, sp. nov.

- Fig. 1. A nearly complete shell, slightly broken at the aperture. × 4.  
 Fig. 2. Profile of the same; showing the broad ventrum and recurved striae.  
 Fig. 3. Transverse section near the beginning of the 5th whorl. × 6.  
 Fig. 4. Transverse section at the end of the 1st, 2d, 3d and 4th whorls. × 6.  
 Fig. 5. The form of the suture at  $2\frac{1}{4}$  revolutions.  
 Fig. 6. The mature suture.  
 Figs. 7, 8 9. Three views of the protoconch. × 10.  
 Fig. 10. Ventral view of an immature shell; showing the character of the spinous projections; these are somewhat restored on the left of the figure. × 6.  
 Fig. 11. A mature shell, showing a nodation of the ventral margin of the body-chamber. × 4. The specimen is crossed by projecting seams of quartz.  
 Fig. 12. The mature suture viewed from above, the dorsal course being in a dotted line. These figures of the suture are not drawn to scale.

\* The only member of this fauna suggesting the brachiopod facies of the lower Upper Devonian of Europe is a small *Strophalosia* or *Productella* recalling the species usually identified by European writers with the *Productus subaculeatus* Murchison.

† Fauna des mittleren und oberen Devon am West-Abhange des Urals, 1887.

‡ Bull. de la Soc. géol. de France. 2e ser. tom. 12, p. 1178, 1855.



ART. IX.—*A new Meteoric Iron from Garrett Co., Maryland*; by A. E. FOOTE. With Plate I.\*

A PHYSICIAN residing near the Maryland line of Pennsylvania recently brought to me an iron mass to learn if it was meteoric, and this it has proved to be. It was discovered in Garrett Co., Md., about twelve miles from the Post Office of Lonaconing, not far from the boundary. It was ploughed up about three or four years ago by a boy in a field. According to an analysis by Dr. Koenig, it contains over 11 per cent of nickel and cobalt, the proportion of cobalt being unusually high.

It is one of the best octahedral etching irons known, being even more characteristic than the most of those that have been used for printing directly on paper. Besides the striking reticulated octahedral structure, it shows a large number of secondary lines regularly disposed with reference to the principal markings. These I believe to be similar to those described by Prof. J. Lawrence Smith, in a Wisconsin meteorite,† under the name of Laphamite markings. The original weight was 45 oz. but it has been reduced by analysis, cutting, polishing etc. to 36½ oz. The locality is especially interesting since this is one of the very few discovered in the Middle or Eastern States.

The following is Prof. J. Lawrence Smith's description of the Laphamite markings on the Wisconsin iron, and it applies to the Garrett County siderite, except that the bright figures are the ones that show the secondary marking.

“The Widmanstätten figures are, *a*, bright metallic, with convex ends and sides; *bc*, of a darker color, are the other markings, usually smaller, and with the sides and ends concave. The material of which these dark figures are composed seems to have enveloped the lighter colored portion, which serves to make the dark lines so beautifully conspicuous. A good pocket-glass will show that the dark figures are striated, with lines at right-angles to the bounding surfaces. When the figure is nearly square the lines extend from each of the four sides, but when much elongated, as at *c*, they are parallel with the longer sides. Often these lines do not reach the middle of the figure, where only a confused crystallization can be detected. In the interior of the elongated figures the lines are quite irregular, often running together and showing a striking resemblance to woody fiber. The nature of these markings may be easily understood. They indicate the axes of minute columnar crystals, which tend to assume a position at right-angles to the surface on cooling.”

\* A verbal notice of the discovery was made to the Academy of Natural Sciences of Philadelphia, in November.

† This Journal, xlvii, 271, 1869.

ART. X.—*Farmington, Washington Co., Kansas Aerolite;*  
by GEORGE FREDERICK KUNZ and ERNEST WEINSCHENK,  
P.H.D.

ON Wednesday, June 25, 1890, at 12.55 central time, a roaring, rumbling sound was heard within a radius of one hundred miles around Washington, Washington County, Kansas, and many observers noted a meteorite traveling from south to north, which in its course left a double trail of smoke. The sun at the time was shining brightly, and hence no light was seen. The explosion was likened by various observers to a bolt of lightning, the bursting of the boiler of an engine, or the report of a distant cannon. The largest portion of the meteorite, weighing 180 pounds, fell on the farm of Mr. W. H. January, who was greatly alarmed, as it struck very near him while he was under his wagon repairing it. This piece penetrated the hard shaly earth to a depth of four feet. Forty pounds of it were broken off and distributed before it was placed on exhibition after which it was sold and resold several times, and now belongs to Prof. Henry A. Ward of Rochester. Its dimensions now are  $16\frac{1}{2} \times 16\frac{1}{2} \times 8$  inches; weight 136 pounds. A distinct mass weighing nine pounds, now in the possession of George F. Kunz, was found on the farm of John Windhurst; and it is evidently this piece which made the second trail of smoke.

The sound was noticed throughout a number of counties, both in Kansas and Nebraska, as a thunderous roar, which at Clifton, twenty-five miles from the point of fall, was heard above the noise of a passing railroad train. The meteorite was seen over a much wider area even than its sound covered. Reports of observers are given from many places, ranging from Beatrice, Nebraska, 40 miles northeast of the point of fall, to Cedar Junction, Kansas, 130 miles southeast, and Halstead, Kansas, an equal distance south by west. To those north of the point of fall, it appeared as a brilliant object moving southward, while to observers south of that point, its motion seemed northward. As Prof. F. H. Snow, who gives a full account of the circumstances attending the fall, remarks,\* these facts indicate that its descent must have been not far from vertical, as is also shown by the nearly perpendicular hole, about four feet deep, which it made in the earth.

The actual fall was witnessed by Mr. January, as he came out from under his wagon alarmed by the extraordinary noise,

\* Science, July 18, 1890.

and also by Miss Guild, a teacher in the Washington County Normal Institute, who was driving on the neighboring road, a hundred yards distant. Both came to the spot in a very few minutes; and Mr. January began promptly to dig for the object, and with the aid of neighbors reached its upper surface in an hour. But so firmly had it embedded itself in the shaly clay, that it was three hours before it was removed. When reached it was not hot. It had cracked into two portions, the the smaller of which was the forty-pound mass broken up and carried away by the people of the neighborhood.

At the moment of its fall, the earth was thrown upward and outward for a distance of eight to ten yards or more.

The following analysis was made by Mr. L. G. Eakins through the courtesy of Prof. F. W. Clarke, chief chemist of the U. S. National Museum, Washington, D. C.

Approximate composition of the mass.		Analysis of the iron.	
Nickeliferous iron -----	7.7	Fe	86.76
Troilite -----	5.0	Ni	12.18
Siliceous part soluble in HCl..	46.0	Co	.83
“ “ insoluble “ “	41.5		
	<hr/>		<hr/>
	100.2		99.77

Analysis of the siliceous part from which all magnetic material had been extracted.

	Soluble in HCl.			Insoluble in HCl.	
	[1]	[2]		[3]	[4]
SiO <sub>2</sub>	19.15	38.50	SiO <sub>2</sub>	24.29	53.80
FeO	16.15	23.54	Cr <sub>2</sub> O <sub>3</sub>	.64	1.41
NiO	.34	.69	Al <sub>2</sub> O <sub>3</sub>	1.95	4.32
CoO	tr.	tr.	FeO	5.41	11.98
MnO	.17	.34	MnO	tr.	tr.
CaO	.06	.12	CaO	1.84	4.08
MgO	18.31	36.81	MgO	10.10	22.37
S	1.97	-----	K <sub>2</sub> O	.12	.27
			Na <sub>2</sub> O	.80	1.77
	<hr/>	<hr/>		<hr/>	<hr/>
	56.15	100.00		45.15	100.00

Analysis No. 1 is the direct analysis of the portion soluble in HCl. Analysis No. 2 is calculated to equal 100. Analysis No. 3 the composition of the insoluble part. Analysis No. 4 calculated to equal 100.

The nickel-iron of this specimen shows, as is generally the case in stony meteorites, a higher percentage of nickel and cobalt than is usual in meteoric irons. The constituent in this stone which was dissolved by hydrochloric acid, is shown by that fact to be olivine, in which the proportions of magnesia

and iron are as three to one. The crust on this meteoric stone is black and dull, frequently over 1 mm. in thickness. Macroscopically the Washington meteorite resembles a doleritic lava, of dark gray color and splintery fracture, with white radiated chondri which protrude from the ground-mass. The specimens also contain druses lined with crystals of sulphide of iron, the faces of which are rounded and present the appearance of having flowed through fusion, thereby rendering it impossible to measure the angles. No analysis of this material was made, although from the total lack of oxidation it might have promised good results.

Nickeliferous iron, which in the fracture, is only slightly visible, becomes conspicuous on a polished surface, showing that it is present in many grains, some exceedingly minute, others up to 4 mm. in diameter. In one instance a vein 10 mm. long and 1 mm. wide penetrated the mass, and on the surface of a polished section appeared bright serpent-like veins. The crust of the meteorite is black, hard and uneven, and the surfaces 0.8 mm. large are dull and often of beadlike form. Under the microscope, the porphyritic character of this meteorite is readily recognized; radiated and broken chondri and crystals of various minerals make up the microfelsitic groundmass.

All these are entirely enveloped in an opaque, evidently glassy magma, the dark shade of which gives the color to the whole. This dissolves in cold HCl, imparting a yellow tint to the acid. Heating to redness does not destroy the color, which fact surely precludes the idea of its being due to the presence of any organic matter. Prominent are crystals and fractured masses of olivine, which feature is of rather rare occurrence. This olivine is rich in orientated opaque inclusions, and has also a distinct cleavage, which is seldom observed in olivine. The optical character was perhaps disturbed through the rapidity of its crystallization.

Distorted undulation is common. Rhombic pyroxene is readily identified, frequently with a fibrous cleavage and monosymmetric augite; also the monticellite-like silicate described by Tschermak. The Washington county meteorite belongs to the black chondrites and has the greatest resemblance to the meteorite of Sevenkof. It is undoubtedly not a polygenius conglomerate but was rapidly formed out of the fluid glassy magma.

The thanks of the describers are due to Prof. F. W. Clarke and Mr. L. G. Eakins of the U. S. Geological Survey for the analysis, to Prof. Henry A. Ward for facts concerning his mass, and to Mr. Daniel Scheckler of Washington, Kansas, for obtaining one mass and information attending the fall.

## SCIENTIFIC INTELLIGENCE.

## I. CHEMISTRY AND PHYSICS.

1. *On Isomorphism.*—In an elaborate paper, RETGERS has given the results of his later investigations upon isomorphism. In an earlier paper he had pointed out the indefinite capability of admixture of two crystalline isomorphous substances, and shown that the best experimental proof of isomorphism was the continuous variation in the physical properties of these mixed crystals. The physical property selected for the present research was color. The substances made use of were potassium perchlorate  $\text{KClO}_4$  which is colorless, and potassium permanganate  $\text{KMnO}_4$  which is dark purple-red; or potassium sulphate  $\text{K}_2\text{SO}_4$  and potassium manganate  $\text{K}_2\text{MnO}_4$ , the latter being green. The two salts to be examined was dissolved in water and a drop of each of the warm solutions were placed on a microscopic slide; these drops being allowed to touch or being connected with each other by a narrow channel of liquid so that slow diffusion might go on between them. If the salts are really isomorphous, like those above mentioned, crystals are obtained having all depths of color. Moreover a crystal may have its ends of different depths of color, with all intermediate shades between. But if the salts experimented on are not isomorphous, no such gradation of color is observed in the crystals. Adopting the axiom that if a substance B is isomorphous with a substance A and also with a substance C, the substances A and C are isomorphous with each other, the author finds the perchlorates of ammonium, potassium, rubidium and caesium to be isomorphous with potassium permanganate and with each other.  $\text{LiClO}_4 \cdot (\text{H}_2\text{O})_3$  and  $\text{LiMnO}_4 \cdot (\text{H}_2\text{O})_3$  form mixed crystals.  $\text{AgClO}_4$  crystals were colored by an unstable rhombic modification of  $\text{AgMnO}_4$ ; the mixed crystals being highly pleochroic, changing from blue-green to ruby-red on rotating the nicol prism. Mixed crystals containing manganate retain their blue-green color for weeks.  $\text{K}_2\text{SO}_4$ ,  $(\text{NH}_4)_2\text{SO}_4$ ,  $\text{Rb}_2\text{SO}_4$ ,  $\text{Cs}_2\text{SO}_4$ ,  $\text{Tl}_2\text{SO}_4$ ,  $\text{K}_2\text{SeO}_4$ ,  $\text{Rb}_2\text{SeO}_4$ ,  $\text{Cs}_2\text{SeO}_4$ ,  $\text{Tl}_2\text{SeO}_4$ ,  $\text{K}_2\text{CrO}_4$ ,  $\text{Rb}_2\text{CrO}_4$ ,  $\text{Cs}_2\text{CrO}_4$ ,  $\text{K}_2\text{MnO}_4$ ,  $\text{Rb}_2\text{MnO}_4$  and  $\text{Cs}_2\text{MnO}_4$  are all isomorphous forming rhombic (pseudo hexagonal) prisms and pyramids.  $(\text{NH}_4)_2\text{SeO}_4$  crystallizes in monoclinic plates.  $(\text{NH}_4)_2\text{CrO}_4$  and  $\text{Tl}_2\text{CrO}_4$  are only slightly soluble; the former being probably isodimorphous with  $\text{K}_2\text{CrO}_4$ . The sulphates and selenates of sodium and silver are isomorphous, crystallizing in rhombic pyramids strongly double-refracting. The chromates of sodium and silver and the manganate of sodium are isomorphous, probably; as are the sulphate, chromate and selenate of lithium, when anhydrous.  $\text{KLiSO}_4$  and  $\text{KLiSeO}_4$  are not isomorphous but morphotropic.  $\text{K}_2\text{WO}_4$  and  $\text{K}_2\text{MnO}_4$  are isomorphous with  $\text{K}_2\text{MnO}_4$ . The author points out that between sulphates and sele-

nates there is mostly direct isomorphism ; between sulphates and chromates, isodimorphism is common ; while between sulphates and molybdates or tungstates it is the rule.—*Zeitschr. physikal. Chem.*, viii, 6, July, 1891 ; *J. Chem. Soc.*, lx, 1151, October, 1891.

G. F. B.

2. *On Crystallized Persulphates.*—In 1878, Berthelot obtained persulphuric oxide  $S_2O_7$  by subjecting a well cooled mixture of sulphurous oxide and oxygen to the silent electric discharge, and persulphuric acid by electrolyzing strong sulphuric acid.\* MARSHALL, in the course of an investigation on the oxidation of double cobalt salts by electrolysis, observed the production of colorless crystals in the electrolytic cell, which at first were supposed to be potassium sulphate ; but which gave only a slight precipitate with barium chloride, until the solution was heated and were therefore persulphate. To prepare the persulphate in larger quantity, a saturated solution of hydrogen potassium sulphate was electrolyzed, the kathode being contained in sulphuric acid placed in a porous cell. On passing a current of 3 to  $3\frac{1}{2}$  amperes for two days, a white crystalline deposit began to form, which was separated from the solution, drained and dried on porous plates ; the process being repeated with the mother-liquor until sufficient material was collected. By solution in hot distilled water and cooling, the salt is deposited in minute prisms, the decomposition being inconsiderable. By slow cooling large tabular crystals are formed, apparently asymmetric. On analysis, the formula  $KSO_4$  was obtained, the size of the molecule being determined from the conductivity of the solution. Potassium persulphate is sparingly soluble in cold water, 100 parts of water at  $0^\circ$  dissolving 1.75 parts of  $KSO_4$ . Its solution gradually decomposes at ordinary temperatures with evolution of oxygen, though slowly ; a pure solution even after three months containing the greater part of the persulphate undecomposed. By similarly electrolyzing hydrogen ammonium sulphate, ammonium persulphate was obtained, in the form of long thin prisms, apparently rhombic, which on spontaneous evaporation, may become large, transparent lozenge-shaped monosymmetric tables. It is very soluble in water, 100 parts at  $0^\circ$  dissolving 58.2 parts of the salt. In consequence of this solubility, this salt was used in the preparation of the other persulphates. By treating a saturated solution of ammonium persulphate with barium hydrate, barium persulphate is produced, which after re-crystallizing at a low temperature, is obtained in beautiful prisms ; or when the mother-liquor is concentrated in a vacuum, in large interlocking prisms having a monosymmetric appearance. This barium salt has the formula  $Ba(SO_4)_2 \cdot (H_2O)_2$ . It is very soluble in cold water, 100 parts dissolving 39.1 parts of the anhydrous or 52.2 parts of the crystallized salt. Lead persulphate was obtained as a solid crystalline mass, very deliquescent and having the probable for-

\* This Journal, III, xv, 209, March, 1878.

mula  $\text{Pb}(\text{SO}_4)_2 \cdot (\text{H}_2\text{O})_4$ . Zinc and copper persulphates were also produced as deliquescent crystalline needles. All attempts to prepare sodium, lithium and magnesium persulphates were unsuccessful owing apparently to their exceeding solubility.—*J. Chem. Soc.*, lix, 771, October, 1891. G. F. B.

3. *On the Preservation of Sodium.*—According to ROSENFELD, when sodium which has been kept under mineral oil and is covered with a crust, is immersed in a mixture of petroleum three parts and amyl alcohol one part, or rubbed with a cloth soaked with this mixture, it acquires at once a silvery luster. If now it be put into petroleum containing 5 per cent amyl alcohol, then washed with pure petroleum and kept in petroleum containing one half to one per cent of amyl alcohol, it preserves this luster for a long time; becoming covered very slowly however with a film of sodium-amyl oxide which is easily removed with filter paper. Potassium and lithium can be purified similarly. Sodium thus cleaned combines at once with mercury, evolving light. By pressing clean sodium and potassium together under a mixture of one part amyl alcohol and nine parts petroleum, the liquid alloy of these metals is easily obtained. By mixing one gram of the clean sodium rubbed to a fine powder with three grams of salt, with 0.7 grams of sulphur, avoiding pressure, combination takes place with the evolution of light and sodium sulphide is formed. Selenium and tellurium behave similarly.—*Ber. Berl. Chem. Ges.*, xxiv, 1658; *J. Chem. Soc.*, lx, 982, Sept. 1891. G. F. B.

4. *On New Oxygen Compounds of Molybdenum and of Tungsten.*—PÉCHARD has examined the yellow coloration produced by the action of hydrogen peroxide upon molybdates and tungstates, and concludes that it is due to higher oxygen compounds of these metals. When potassium trimolybdate is treated with hydrogen peroxide it dissolves forming an orange-yellow solution which deposits on concentration yellow crystals apparently triclinic, having the composition  $\text{K}_2\text{Mo}_2\text{O}_8 \cdot (\text{H}_2\text{O})_4$ . Heated gently in a vacuum, the crystals lose water and oxygen and leave a residue of acid potassium molybdate. The ammonium salt is similarly prepared. Both salts are decomposed by alkalies with evolution of oxygen. They evolve chlorine when treated with hydrochloric acid and set free iodine from potassium iodide. In the same way, sodium paratungstate boiled for a few minutes with hydrogen peroxide becomes yellow in color and is no longer precipitated by nitric acid. On evaporation the solution deposits white crystals having the composition  $\text{Na}_2\text{W}_2\text{O}_8 \cdot (\text{H}_2\text{O})_2$ . The above salts are regarded by the author as establishing the existence of per-molybdic and per-tungstic oxides  $\text{Mo}_2\text{O}_8$  and  $\text{W}_2\text{O}_8$ , as well as the corresponding acids,  $\text{H}_2\text{Mo}_2\text{O}_8$  and  $\text{H}_2\text{W}_2\text{O}_8$ .—*C. R.*, cxii, 720, 1060; *J. Chem. Soc.*, lx, 988, Sept. 1891. G. F. B.

## II. GEOLOGY AND MINERALOGY.

1. *Bibliography undertaken by the International Congress of Geologists.*—Mr. G. K. Gilbert communicates to the Journal the following letter from Mr. Em. de Margerie, Secretary of the International Committee on the Bibliography of Geology. It sets forth the organization and plans of the Committee. Geologists residing in North America who have prepared or are preparing bibliographies of any portion of the literature of geology are requested to communicate with Mr. Gilbert. (Address: G. K. Gilbert, U. S. Geological Survey, Washington, D. C.).

International Congress of Geologists: Committee on the Bibliography of Geology. Paris, Rue de Grenelle 132, Nov. 20, 1891.

SIR: At the meeting of Tuesday, September 1, 1891, the International Congress of Geologists, assembled at Washington, on motion of Messrs. H. S. Williams and de Margerie, appointed a permanent international committee charged with the duty of centralizing the information relating to geologic bibliography. This committee, which is authorized to add to itself new members in unlimited number, comprises at present Messrs. Frech (Germany), Gilbert (North America), Golliez (Switzerland), Gregory (England), de Margerie (France), Reusch (Scandinavia), Steinmann (South America), Tschernyschew (Russia), Tietze (Austria-Hungary), and Van den Broeck (Belgium).

The end to be attained is threefold: (1) to prepare a list of the geologic bibliographies already in existence; (2) to prepare an inventory of those parts of geologic literature which have not as yet been the subject of such methodic abstracting, in order to prepare the way for undertaking comprehensively the retrospective bibliography of the science; and (3) to proceed to the periodic registration of its current bibliography.

The first meeting of the committee took place during the excursion to the Rocky Mountains. The following are the minutes:

“The International Committee on the Bibliography of Geology met September 20th, at 8 o'clock in the evening, in one of the cars of the special excursion train, between Manitou and Denver (Colorado). Present, Messrs. Frech, Gilbert, Golliez, de Margerie, Reusch, Steinmann, Tschernyschew, Tietze and Van den Broeck. Prof. H. S. Williams also was present at the meeting.

“Mr. Gilbert was by acclamation elected President of the Committee and Mr. de Margerie, Secretary. Mr. de Margerie will take charge of the correspondence for Europe, and undertakes to transmit to Mr. Gilbert all the documents intended for printing.

“In regard to retrospective bibliography, Mr. Golliez announced to the committee that the Geological Survey of Switzerland is preparing a geologic bibliography of Switzerland, which it will probably take several years to complete. Mr. Tschernyschew announced the existence of a catalogue of the same nature

on the north of Russia, as yet unpublished, of which he is the author. Finally, Mr. Van den Broeck called attention to the general bibliography of Belgium, which is to comprise a list of all documents relating to the geology of that country published in the course of the 19th century.

"After a short discussion, the committee decided to confine its efforts for the time being to the preparation of a list of the partial geologic bibliographies already in existence. Each member of the committee is to perform that part of the work which relates to the country he represents. For Spain, Italy and Portugal, which countries sent no representatives to Washington, the committee will address itself to the directors of the geological surveys of these three states. Mr. Tietze agrees to take charge of the bibliography of the Balkans, and Mr. de Margerie will try to fill out any gaps that may exist in the collection of documents gathered by the various members of the committee as regards Asia, Africa and Oceanica. The manuscripts must be sent to the Secretary before Easter, 1892, in order to be printed with the proceedings of the Washington meeting.

"The projected list will comprise the detailed titles of works entering into the following categories :

"(1) *Regional or local bibliographies*. (Examples: Geological Bibliography of Italy; Geological Bibliography of the counties of England, by Whitaker; Catalogue of the publications of the American surveys, by Prime).

"(2) *Systematic bibliographies*, that is to say, relating to a defined group of facts, (e. g. Bibliography of the various classes of rocks, inserted in Rosenbusch's Petrography; Bibliography of the Upper Jurassic, by Neumayr; glaciers, volcanoes, etc.)

"(3) *Personal bibliographies*. (Catalogues of the geologic publications of one author, like those that often accompany necrologic notices; Royal Society's catalogue of scientific papers, etc.)

"(4) *Catalogues of geologic maps*, (e. g. Mapoteca geologica Americana, by Marcou).

"(5) *Annual geologic bibliographies*, either general (e. g. Geological Record; Revue de geologie, by Delesse and de Lapparent; Annuaire geologique, by Dagineourt) or special (e. g. Revue geol. Suisse, by E. Favre and Schardt; Bibliotheque geologique de la Russie, by Nikitin; Record of American Geology, by Darton.)

"(6) *General tables of special periodicals or series*, (e. g. the Repertorium to the Neues Jahrbuch für Mineralogie; Index to the publications of the Geological Society of London, by Ormerod; Table of Paleontographica; List of geological maps published in the Quarterly Journal, by R. Bliss.)

"(7) *Printed catalogues of special libraries*, (e. g. Catalogue of the library of the Geological Society of London; Catalogue of geologic works found in the libraries of Belgium, by Dewalque.)

"As regards the scope to be given the work, the committee thinks proper for the present to exclude all documents of purely

mineralogic or paleontologic nature; on the other hand, information relating to petrography, physical geography, applied geology, mineral waters, and prehistoric archeology will be included. For the rest, full latitude is left in this respect to the collaborators, the editor being empowered to extend or abridge manuscripts with a view of securing proper uniformity in publication.

“Important manuscript bibliographies, the existence of which may be known to the members of the committee, are to be indicated in the proper places, stating name and address of author.

“The publication will be in French, but manuscripts may be prepared in the language of the country whence they come, to be translated afterward under the direction of the editor.

“Titles must always be given in the language of the original publication; they will not be followed by a French translation except in case they belong to a language other than English, German, Italian or Spanish. The indication of the author’s name, place of publication (with the publisher’s name in the case of a separate work), date, size and number of pages, shall be as exact and detailed as possible: furthermore it is desired to have stated the approximate number of entries contained in each bibliography, adding summary information regarding its nature, such as: “Alphabetic catalogue by authors’ names; Catalogue classified by order of dates; Simple list of titles; Each article is followed by a resumé; The number of plates is not given, etc.” The limiting dates of the publications catalogued in the bibliographies are also to be noted, (e. g. 1802 to 1888.)

“In case a bibliography bears no printed title, which often happens with such as are appended to special works or memoirs, it will be proper to define its subject by means of a phrase in brackets: [ . . . ], giving after this the complete title of the document in which the bibliography is comprised.

“Publications which, without pretending to take the form of a methodic bibliography, contain the detailed history of the study of a question of general interest or of a country, are to be mentioned.

“In order to facilitate the final classification of subjects for the purpose of printing, the collaborators are requested to prepare their work on separate slips.”

The Secretary, EMM. DE MARGERIE,

To Mr. G. K. Gilbert, Member of the Committee for North America.

2. *Experimental recherches* (1) *On the deformations of a Sphere by contraction and pressure, and* (2) *On the part played by Vapors in different geological phenomena*; by Prof. A. DAUBRÉE.—Professor Daubrée has been continuing his very valuable researches in experimental geology by new experiments on the effects produced by pressure and by vapors in different geological phenomena. The effects of contraction, described in the *Comptes Rendus*, for May, 1890, are obtained by covering a distended ball of caoutchouc, arranged to have the form of a flattened sphere

roid, with a coating of paraffin or beeswax, and then allowing it to slowly contract. Folds, fractures, and elevations are obtained having interesting relations to those which have been observed in the earth's structure and features. In other experiments, on subjecting a ball of caoutchouc to pressure, the effects of pressure normal to the surface were obtained.

The new experiments on the effect of vapors, are described in papers in the *Comptes Rendus* for 1890 and 1891 (the last in August, 1891), and also in part in a communication to the Geological Society of France of February, 1891. Two of the subjects illustrated are (1) the pressure of exploding materials, as gun-cotton, and (2) the production of more or less cylindrical perforations, tunnel-like, along fissures by vapors suddenly developed, a form of fracture called by Daubr e a diatreme. The origin of the conduits of volcanoes and explosive eruptions, and of the diamantiferous pipes of South Africa is thus explained by the author; and also the extrusion of the trachyte of trachytic domes, the lofty throws of volanic cinders and rocks and other related volcanic products, and the forms of the ejected broken blocks and lapilli. To these projected rocks or fragments, the name *ecphyseme* is proposed, from the Greek for *something blown out*. The explosive agent recognized in the natural operations is, in general, the vapor of water suddenly generated. Other effects obtained are the erosion and fusion of granite, and other substances; the production of molecular transfer or flow, resembling that of plasticity, and a resoldering or remoulding of a crushed rock. The great heights of the more remarkable volcanic mountains are reviewed and their groupings. On the occurrence of similar heights in the mountains of a group and their origin through diatremes, Prof. Daubr e says: "it is as if each corresponded to a maximum of pressure proceeding from the same infra-granitic reservoir, or from similar reservoirs of whose pressure it gives a measure, like the tube of a manometer in the open air.

The paper published in the *Bulletin* of the Geological Society of France contains figures illustrating the methods of experiment and the various results, and reviews their general applications to volcanic and other geological phenomena. Prof. Daubr e observes that in contrast with the forms of fractures of the earth's crust which are linear, parallel, and are produced by horizontal pressure attending contraction, diatremes or "topic dislocations" are the effect of action concentrated on a single point, of vertical projection by a gaseous material acting with great velocity under heavy pressure "une sorte de coup de canon, dont l' me serait une diatr me qui viserait le z nith." These memoirs of Prof. Daubr e will be read with great profit by geologists.

3. *A classification of Mountain Ranges according to their Structure, Origin and Age*; by WARREN UPHAM (Appalachia, vi, April, 1891).—Mr. Upham divides mountain elevations into (1) folded, (2) arched, (3) domed, (4) tilted, (5) erupted, and (6) eroded. The first division is exemplified in the Appalachian

structure; the second, in the Uinta Range; the third in those of laccolite origin, as the Henry Mts.; the fourth, in the Wasatch, it having been "elevated along fault-planes which form its western boundary," and in the Sierra Nevadas, its "fault lines bounding it on the east; the fifth, in volcanic cones and ridges; The sixth, in elevated plateaus sculptured into mountain shapes. Elevations of the first kind are attributed to force acting laterally, due to the earth's contraction, and those of the following four to force acting vertically upward. Mr. Upham remarks that greater pressure of some portions of the crust than of others upon the plastic interior would induce each phase of upward force in mountain-building. Where the relations of intense heat, immense pressure, and chemical influences, with presence of water or its farther ingress, have allowed portions of the interior, often of great extent, to become liquid lava, its extravasation by the same pressure has formed laccolite mountains and erupted mountain masses, while many volcanic cones have been mainly built up of fragments of solidified lava, much of it so fine as to be called ashes explosively ejected.

4. *On the Geology of Quebec City, Canada*; by HENRY M. AMI, M.A., F.G.S., of the Geological Survey of Canada.—From the Canadian Record of Science, April, 1891.—Much diversity of opinion has existed as to the exact geological position of some of the terranes at and about Quebec City, as also along the whole line of the great Appalachian or St. Lawrence-Champlain. With regard to the rocks forming the Citadel Hill or promontory of Quebec (Cape Diamond), an elaborate review of the opinions that have been presented is given in Dr. Ells's last report to Dr. Selwyn (1888), published by the Geological Survey of Canada, which includes the history from Dr. Bigsby's paper published in 1827, down to Prof. Lapworth's Report, etc., published in the Transactions of the Royal Society of Canada for 1887.

The Rocks of Quebec have been referred to the age of the Quebec Group (Levis Division); but the majority at present regard them as newer than the Trenton limestone, viz: of "Trenton-Utica," "Utica-Hudson," or "Lorraine" age. The fauna of the Norman's Kiln shales, that of the Marsouin, of the Tartigo River, Griffin Cove and Gagnon's Beach Rocks, as well as that from Crane Island, N. W., or False Point of the Island of Orleans, Quebec City, Etchemin River, between St. Henry and St. Anselme, Drummondville, and other localities in Maine, Vermont and New York States constitutes one large assemblage of forms peculiar to one terrane.

The fauna of the Lorraine shales, on the other hand, as it is characterized at Montmorency Falls, Côte Sauvageau, in the St. Charles Valley near Quebec, at Charlesbourg (near the Church), two miles above St. Nicholas, Yamaska River, Rivière des Hurons, and in the undisturbed regions in Ontario at Ottawa, Toronto, Weston, Oakville, Collingwood, etc., intermediate between

the Utica terrane and the base of the Silurian, marks another terrane.

These two faunas are very distinct both in their paleontological and stratigraphical relations. The Lorraine terrane, according to Dr. Selwyn's classification of formations ("Index to the Colours and Signs used by the Geological Survey of Canada,") has a definite position, viz: at the summit of the Cambro-Silurian or Ordovician system. The strata of Quebec, either on physical or paleontological grounds, cannot be referred to the Lorraine, nor to the Utica, the Trenton or the Black River formation.

Sir William Logan referred the Quebec City rocks to the Levis division of the Quebec group. From examinations recently made, the fauna which Mr. Weston, Mr. Giroux, l'Abbé Laflamme and the writer have been able to obtain from the rocks of that locality, presents some fifty species, including graptolites, brachiopods, ostracods and trilobites, different from Levis forms and yet capable of being correlated with forms from a portion of the Quebec group of Logan, as described in his Newfoundland section, as also with Cambro-Silurian strata in the Beccaguimic valley of New Brunswick.

The strata at Quebec City appear to me to occupy a position in the Ordovician system higher than the Levis formation, being akin to it, but lower than the Trenton, and are probably an upward extension of that peculiar series of sedimentary strata in the St. Lawrence valley, which, owing to the conditions of deposition Sir William Logan advisedly classed under the term "Quebec Group." This would make the rocks about equivalent to the Chazy formation of New York. As to the propriety of retaining the term "Hudson River" group, in geological nomenclature, there may be doubt. It would very naturally follow, however, that some such designation as the "Quebec terrane" or "Quebec formation" would be most acceptable for the Quebec City rocks, or those which constitute the citadel and main portion of Quebec City and other synchronous strata. The term "Hudson River" is extensively used throughout North American geological nomenclature to designate the series of strata above the Trenton limestone, much more so than the equivalent term, "Lorraine," defined and very carefully used by Emmons. While neither term is objectionable, and both have been used by various authors for the same horizon, it appears most practical now to retain the term Hudson River, or Hudson Terrane, which has been most extensively used and adopted in North American geology, as this would entail much less confusion, and would thus serve the ends of geological science more effectively.

The most characteristic species of graptolites peculiar to the Quebec terrane are the following:—*Cenograptus gracilis* Hall, *Dicellograptus sextans* Hall, *D. divaricatus* Hall, *Dicranograptus ramosus* Hall, *Diplograptus foliaceus* Murchison, *D. Whitfieldi* Hall, *D. marcidus* Hall, *Climacograptus bicornis*

Hall, *C. bicornis*, var. *tricornis* Lapworth, *Corynoides calycularis* Nicholson.

In a paper which the writer is now preparing for the Royal Society of Canada, the various forms characterizing the Sillery, Levis and Quebec divisions of the Quebec Group in Canada as now understood, and constituting the natural series of sedimentary strata to which Sir William Logan had given that very appropriate term will be tabulated and the paleontological grounds for their separation made evident.

5. *Geological and Natural History Survey of Canada*. Annual Report (new series) vol. iv, 1888-89.—This large volume, recently issued, contains after the summary reports of the operations of the Geological Survey for the year 1889, by the Director, (65 pp.), the following papers :

On a portion of the West Kootanie District, British Columbia, by G. M. Dawson, (65 pp.) On an exploration in the Yukon and Mackenzie Basins, by R. G. McConnell, (144 pp.) Exploration of the glacial Lake Agassiz in Manitoba, by Warren Upham, (121 pp.) On the mineral resources of the Province of Quebec, by R. W. Ells, (158 pp.) On the surface geology of Southern New Brunswick, by R. Chambers, (88 pp.) Chemical contributions to the geology of Canada, by G. Christian Hoffmann, (7 pp.) Mining and Mineral Statistics of Canada, by H. P. Brumell, (81 pp.) Report of the Division of Mineral Statistics and Mines, by E. D. Ingall and H. P. Brumell, (123 pp.) Annotated list of the minerals occurring in Canada, by G. C. Hoffmann, (67 pp.)

6. *Notes on Brazilian Mineralogy*.—Dr. E. HUSSAK in the "Boletim da Comissão geographica e geologica do Estado de S. Paulo" No. 7, (40 pp., S. Paulo, 1890,) gives some valuable observations on some minerals and rocks from Southern Brazil.

*Heulandite*, *mesolite*, *desmine* (stilbite) and *scolezite* are minutely described. They occur in amygdaloidal cavities in the great trap sheets of presumably Triassic age that abound in Southern Brazil, in association with calcite, chalcedony, chloritic minerals, native copper, etc. The heulandite and mesolite were from the Serra de Botucatú; the stilbite from the Serra de Brotas, and the scolezite from Santa Catharina. The form and optical characters of these zeolites are given and also the following analyses :

	SiO <sub>2</sub>	Al <sub>2</sub> O <sub>3</sub>	CaO	Na <sub>2</sub> O	K <sub>2</sub> O	H <sub>2</sub> O
Heulandite,	58.10	16.67	5.90	0.61	3.26	16.16 = 100.70
Mesolite,	47.61	26.80	7.08	7.80	----	12.11 = 101.40
Stilbite,	60.82	16.67	4.25	1.73	----	18.12 = 101.59
Scolezite,	45.96	26.03	13.53	----	----	13.67 = 99.19

A careful study was made of the virgin auriferous gravel from the valley of the Ribeira. From an abandoned placer mine on the Pedro Cubas, a small branch of the Ribeira, the following species were identified: *Andalusite*, *chiastolite*, *staurolite*, *tourmaline* and *corundum* all abundant; *magnetite*, *titaniferous magnetite*, *ilmeneite*, *rutile* (with *sagenite*) *anatase*, *titanite*, *zircon*, *gold*, *native*

iron and an *undetermined mineral*, rare. The most abundant and characteristic of these species, andalusite, chiastolite, tourmaline and corundum, are typical of schists (phyllites) altered by contact with eruptive rocks, and since the river Pedro Cubas flows mainly over schists with frequent injections of granite, the association suggests that the gold may be a contact mineral. In the washings from the sands of the main stream (Ribeira) these contact minerals (except tourmaline) are entirely lacking and the most abundant minerals are indicative of crystalline schists, with probably, granite and syenite.

In regard to the occurrence of the *native iron*, it is noted that grains of the size of several millimeters are found. They are irregular battered flakes with metallic luster, and strongly magnetic, that exposed to damp air soon become rusty. In order to determine if these grains came from the iron instruments of the old miners, gravel that was unquestionably virgin was extracted with wooden instruments. The washing gave as great an abundance of iron as those from the gravel heaps previously washed by the old miners.

Among the other notes, which include an account of pseudomorphous crystals of leucite in phonolyte, the occurrence of corundum in São Paulo, etc., may be noted a description of *phyllites with ottrelite and magnetite from São Paulo*. In the zone of phyllites traversed by the river Tieté, layers rich in ottrelite are met with intercalated with others entirely free from this mineral. The ottrelite is in discs or distinct hexagons of about 0.25<sup>mm</sup> diameter. Basal sections show distinct cleavage in two directions, making an angle of 120° approx. Pleochroism tolerably strong between plum-blue and olive-green. Angle of optical axes very small and the inclination of the bisectrices to the vertical axis also small. In the rectangular longitudinal sections pyramidal faces are occasionally seen showing the crystals to be deformed hexagons. Polysynthetic twins parallel to (001) and an hour-glass structure shown by the arrangement of inclusions are almost constant. An intergrowth according to the base of two individuals, one full of twin lamellæ and the other free from them was observed. In another case the twins presented a wedge shape. Crossed and contact twins according to one of the faces of the dome are also common, the angle of inclination of the basal faces being between 110° and 125°. Similar twins are described by d'Achiardi from the Apuan Alps and are seen in preparations from the Ardennes.

Basal sections often show a distinct division into three rhombic fields with extinction parallel to the diagonals of the rhombs. As from its optical properties ottrelite is certainly monoclinic, this twinning should be referred to that often observed in mica, that is, twinning planes normal to the base (001) and parallel to the edge (001):(110).

In longitudinal sections the basal cleavage is very distinctly indicated by lines parallel to the basal edges. A prismatic cleavage indicated by lines normal to the base is also distinct. Lines

forming an angle of  $72^\circ$  with the base are frequently seen between crossed nicols; the extinction is at times parallel to the edges of the base, but generally with a slight inclination (maximum  $15^\circ$ ). Pleochroism strong;  $c$  = greenish yellow,  $b$  = plum-blue,  $a$  = olive-green.

The layers of schist with ottrelite often alternate with layers of the thickness of the finger of schist with magnetite and of normal schist free from mineral inclusions.

7. *Estimation of the Optical Angle*: A correction by ALFRED C. LANE. (Communicated).—In my article on the estimation of the optical angle in this Journal,\* I notice an error, which I knew enough to have avoided, as the whole subject was long ago thoroughly treated in the "Mineralogie Micrographique" of Fouqué and Lèvy. The maximum extinction-angle in the prismatic zone of common hornblendes is *not* the clinopinacoidal section. This the above writers explained theoretically and I have experimentally verified the fact. The extinction-angle increases slightly and then decreases, and even on the cleavage faces the extinction-angle is but little less than in the clinopinacoidal section.

8. *Systematic Mineralogy based upon a Natural Classification*, with a general introduction, by THOMAS STERRY HUNT. 391 pp. 8vo. New York, 1891. (The Scientific Publishing Company).—This volume is a development of Dr. Hunt's views on mineral classification, as in part before brought out, more particularly in the volume entitled "Mineral Physiology and Physiography." The work covers, however, a rather wide range. It begins with a historical summary of the different systems since the time of Werner; then follows an explanation of the principles of chemistry and chemical notation as related to the subject in hand, and further the special subject upon which the author has laid most stress: the relation of specific gravity, hardness and solubility to mineral condensation, finally a chapter on crystallization. This occupies about one-half the work, after which follow the "new mineralogical classification" and synopsis of mineral species; in the latter the successive species recognized by the author, arranged by genera in tabular form with summary of chief characters, are provided with dual Latin names after the methods of Natural History and further each "genus" is briefly characterized. For an understanding of the methods employed and detailed results reached, the student must be referred to the original volume. How far the new system and nomenclature are permanent contributions to science, the future will show.

9. *The Phosphates of America*. When and how they occur; how they are mined, and what they cost. With practical treatises on the manufacture of sulphuric acid, acid phosphate, phosphoric acid and concentrated superphosphates, etc.; by FRANCIS WYATT. Second Edition. 187 pp. 8vo. New York, 1891. (The Scientific Publishing Company).—The phosphate industry in this

\* This Journal, vol. xxxix, 1890, p. 56, line 1.

country has been of remarkably recent development, when its present importance is considered. It was in 1867, that the mining of the phosphatic deposits in South Carolina commenced, while the mining of apatite in Canada dates only from 1872. It is not strange then, that an interesting, well illustrated and thoroughly practical book upon this subject has been appreciated at once, as shown by the fact that the first edition was exhausted before it had been on sale more than a few days. The scope of the work is given in the comprehensive title. The most original part of the book and perhaps that in which most interest will be felt is the chapter upon the newly discovered phosphate deposits in Florida, at which mining was not fairly begun until 1889. A good map of the state shows the points where operations are now being carried on, and some sixteen excellent full page illustrations give a good idea of the methods of occurrence, of exploitation, etc.

9. *The Kiowa Co. (Kansas) Meteorites*; by ROBERT HAY. (Communicated)—This spring some more meteorites were found, which extend the area of the find as described by Kunz, Snow and Winchell nearly a mile farther east and increase the number of meteorites *several thousand*. One mass eighty pounds in weight has been obtained, but the rest of the find represents a new feature in the remarkable fall. There has been one distinct meteorite of nineteen ounces in weight besides the large one, but the rest were found in groups of small meteorites from about a pound in weight to the size of a pea. Each group was scattered over an area of 15 to 30 square yards. The larger individuals of the groups show themselves true Pallasites and even some very small ones, but many of these latter are largely oxidized, the metallic iron having all disappeared. All stages of oxidation are shown in each group. The large mass and three groups—the smallest weighing three pounds and numbering 400 individuals—are in possession of the writer, Junction City, Kansas.

10. *Geological Survey of Kentucky, John R. Procter, Director*.—This survey has recently published a report of 20 pages, by G. M. SULLIVAN, on the Geology of parts of Jackson and Rockcastle Counties, with a colored geological map.

#### OBITUARY.

HENRY NOTTIDGE MOSELY, the able Naturalist of the Challenger Expedition of 1872 to 1876, and since 1881 Professor of Human and Comparative Anatomy at Oxford, died on the 10th of November last, at the age of forty-seven.

PHILIP HERBERT CARPENTER, Science-Master of Eton College, and the author of extensive elaborate researches on the structure of echinoderms and especially living crinoids, died October 21, aged thirty-nine years. Mr. Carpenter was the fourth son of Dr. W. B. Carpenter.

## A P P E N D I X .

ART. XI.—*The Skull of Torosaurus*; by O. C. MARSH.  
(With Plates II and III.)

IN this Journal for September last, the writer described a new and remarkable genus of *Ceratopsidæ*, represented by two well-marked species.\* In the type specimen on which the genus was based, the greater portion of the skull is preserved, and this presents so many points of interest, that a figure of it, one-twentieth natural size, is here given in Plate II. The second species is represented also by the skull, which, although not complete, supplements the type in several important respects, and figures of its posterior portions are likewise given in the accompanying plates. Both specimens are of gigantic size, one skull measuring five and one-half feet across the parietal crest, and the other is nearly as large. They differ widely, moreover, from the huge horned Dinosaurs hitherto found in the same general horizon, and present characters in the skull of much interest.

In *Torosaurus latus*, the species first described, the skull appears wedge-shaped when seen from above, as shown in Plate II. The facial portion is very short and pointed, and somewhat suilline in form. The nasal horn-core is compressed, with a sharp apex directed forward. The frontal horn-cores are large, and strongly inclined to the front, extending apparently in advance of the nasal protuberance. The long, slender squamosals diverge rapidly as they extend backward, their outer margins being nearly on a line with the facial borders in the maxillary region.

\* This Journal (III), vol. xlii, p. 266, September, 1891. See also vol. xli, p. 167, February, 1891.

The parietal forms more than half of the upper surface of the skull, and is the most characteristic element in its structure. In the posterior part are two very large apertures, oval in outline, with their outer margin at one point formed by the squamosal. The rest of the border is thin and somewhat irregular, showing that the openings are true fontanelles. This is still better seen in the second species represented in the same Plate, fig. 2, *f'*. In the latter specimen, however, these vacuities are entirely in the parietal, a thin strip of bone separating them on either side from the squamosal. A second pair of openings, much smaller, apparently the true supra-temporal fossæ, are shown in the type specimen. These are situated mainly between the parietal and squamosal, directly behind the bases of the large horn-cores. (Plate II, fig. 1, *c*.) The same apertures are represented in the genus *Triceratops* by oblique openings, as in the skull shown on Plate III, fig. 4, where the front border of each is formed by the post-frontal.

Between these openings, in the type of *Torosaurus*, is a third pair of apertures (Plate II, fig. 1, *c'*). These are quite small, nearly circular in outline, and entirely in the parietal, although probably connected originally with the supra-temporal fossæ. Another pair of still smaller foramina may be seen in the same skull, close to the median line, and separated from each other by the anterior projection of the parietal. A deep groove leads forward to each of these foramina, along the suture between the parietal and post-frontal. The position and direction of these perforations suggest that they may correspond to the foramen seen in *Triceratops*, and shown on Plate III, fig. 4, *x*.

The extreme lightness and great expanse of the posterior crest in *Torosaurus* make it probable that it was encased in the integuments of the head, and that no part of it was free. The outer borders of both the parietal and the squamosals show no marginal ossifications, as in the other known genera of the group, but the presence of a large, separate, epijugal bone in one specimen suggests that epoccipitals may yet be found.

The open perforations in the parietal which have suggested the name *Torosaurus*, readily separate this genus from all the gigantic species hitherto known in the *Ceratopsidæ*, but may perhaps be found in some of the smaller and less specialized forms, from lower horizons of the same formation.

With the successive changes in the parietal there were corresponding variations in the squamosals, and these bones also will serve to distinguish the principal genera from each other. In Plate III, the squamosals of four genera of this group are shown, and the wide difference between them, when seen from

the inside, is especially noticeable. In figure 1, of this plate, the long, slender, right squamosal of *Torosaurus*, with its smooth outer border, is well represented. In figure 2 is seen the same bone of *Sterrholophus*, with a serrate outer margin, and smooth inner surface, also shown in figure 5. Next, in figure 3, is the small, short squamosal of *Ceratops*, nearly bisected by its deep quadrate groove. The free sculptured border of both the parietal and squamosals of *Triceratops* is clearly shown in both figures 4 and 6, especially in the latter, where the contrast with the corresponding parts in figure 5 is noteworthy.

Three other generic names have been applied by Cope to remains of *Ceratopsidae* found in this country, namely: *Agathaumas*, *Polyonax*, and *Monoclonius*.\* The first of these was based on part of a skeleton without the skull, found in Wyoming. The second name was given to various fragments from Colorado, including parts of horn-cores, regarded as ischia, but these may all be the same generically as the preceding specimen. The third name, *Monoclonius*, was used for a skeleton from Montana, with parts of the skull and teeth preserved. This animal was one of the smallest of the group, while the other remains pertained to reptiles of larger size, but not of the gigantic proportions of those more recently described. So far as can be judged from the descriptions and figures of the type specimens, the three generic names just cited cannot be used for any of those previously mentioned in this article. A comparison of the principal characters will place this beyond reasonable doubt.

In the type of *Agathaumas*, the remains best preserved are in the pelvic region, which according to Cope possesses the following features. The ilium has no facet nor suture for the pubis at the front of the acetabulum, and the base of the ischium is coösfied with the ilium. There are eight, or perhaps nine, sacral vertebrae, with the neural spines of the first five mere tuberosities. The diapophyses are in pairs, and the last sacral vertebra is reduced and elongate. These characters, and some others found in the description cited, are certainly distinctive, but do not apply to any of the allied fossils described by the writer. Portions of the type specimen, moreover, are in the Yale Museum, as well as other remains from near the same locality. The fossils described as *Polyonax*, and other similar specimens collected in the same region, afford at present no evidence for separation from *Agathaumas*.

\* Cretaceous Vertebrata, p. 53, Plates IV, V and VI; p. 63, Plates II and III, 1875. Also Proceedings Philadelphia Academy, p. 255, 1876, and American Naturalist, p. 154, 1886, and p. 715, Plates XXXIII, and XXXIV, for 1889, issued in 1890.

The small dinosaur, about as large as a Rhinoceros, for which the name *Monoclonius* was proposed, is perhaps generically distinct from *Agathaumas*, but no conclusive evidence of this has yet been presented. The description given makes the teeth, dorsal vertebrae, and pelvis, different from those of any of the larger forms, and the T-shaped parietal (figured first by Cope as an episternal bone), is especially distinctive. None of the other known *Ceratopsidae* have the parietal fontanelles except *Torosaurus*, one of the most gigantic forms discovered, and this genus differs from *Monoclonius*, as described, in various important points. The very long frontal horn-cores, directed forward, the narrow, elongate squamosals, the absence of a median crest on the parietal, as well as the form and anterior connections of this bone, all serve to clearly distinguish the former from the latter.

These points, and others relating to the nomenclature of the *Ceratopsidae*, will be fully discussed in a later communication, when the large acquisitions recently secured by the writer's able assistant, Mr. J. B. Hatcher, are ready for description.

New Haven, Conn., Dec. 22, 1891.

#### EXPLANATION OF PLATES.

##### PLATE II.

FIGURE 1.—Skull of *Torosaurus latus*, Marsh; seen from above.

FIGURE 2.—Posterior crest of *T. gladius*, Marsh; seen from above.

*c*, supra-temporal fossa; *c'*, anterior temporal foramen; *f'*, parietal fontanelle; *h*, horn-core; *h'*, nasal horn-core; *p*, parietal; *s*, squamosal.

Both figures are one-twentieth natural size.

##### PLATE III.

FIGURE 1.—Right squamosal of *Torosaurus gladius*; inner view.

FIGURE 2.—The same of *Sterrholophus flabellatus*, Marsh.

FIGURE 3.—The same of *Ceratops montanus*, Marsh.

FIGURE 4.—Skull of *Triceratops serratus*, Marsh; diagram; seen from above.

FIGURE 5.—Skull of *Sterrholophus flabellatus*; seen from behind.

FIGURE 6.—Skull of *Triceratops prorsus*, Marsh; seen from behind.

*d*, dentary; *d'*, epijugal bone; *e*, epoccipital; *f*, frontal; *g*, groove for quadrate; *fp*, postfrontal; *j*, jugal; *m*, maxillary; *n*, nasal; *pf*, prefrontal; *pm*, premaxillary; *s'*, suture for parietal.

All the figures are one-twentieth natural size.

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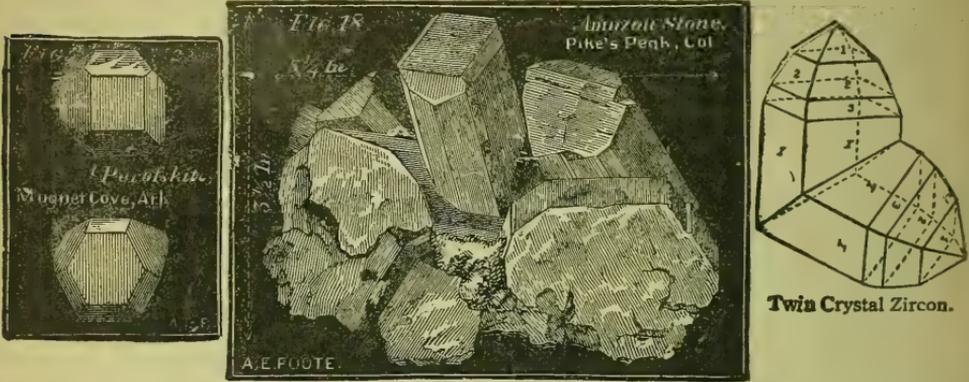
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[THIRD SERIES.]

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ART. XII.—*On the Use of a Free Pendulum as a Time Standard* ;\* by T. C. MENDENHALL.

THE use of the new half second pendulums in the gravitation work of the U. S. Coast and Geodetic Survey has suggested the possibility of employing a pendulum with the improved methods for ascertaining its period in terms of a clock or chronometer second, as a standard of time which in constancy and ease of application might go beyond anything now readily attainable.

The natural though not necessarily invariable unit of time is the sidereal day and while it is sufficiently constant to satisfy all requirements it is inconveniently long for nearly all operations, other than astronomical, in which great precision in time measurement is required. Its subdivision is, therefore, rendered necessary and this is accompanied by rather more uncertainty than usually belongs to the subdivision of a standard. Even the daily rate of our best clocks and chronometers is by no means constant and it is safe to say that in most cases little if anything is known regarding their hourly variation from the mean for the day. That such variations, due to fluctuations in temperature, pressure, and other less known causes, exist is well known to all. In the physical, physiological or other laboratory, in which it is desired to determine intervals of time with a high degree of accuracy it is common to depend upon the daily rate of chronometer or clock, which rate is itself determined by means of clock signals from an

\* Read at the meeting of the National Academy in New York, November 11th, 1891.

established astronomical observatory, or directly by the use of a transit instrument. In the former, rates are carried during bad weather and often for many days, by one or more clocks and with greater or less accuracy but the signals as received are subject to uncertainty and error arising out of telegraph transmission. In the latter, a few nights in succession of cloudy weather prevent the observer from getting a rate for his time-piece just when he most needs it. In both cases the daily rate is usually all that is known, although this may differ widely from that existing when the particular experiment was made for which the time is to be standardized. It is believed that a free pendulum, vibrating under constant conditions furnishes a much more reliable standard for short intervals than any clock or chronometer and that this standard may be easily utilized by methods about to be described.

The pendulum\* is for convenience, a half second's pendulum and is, therefore, about a quarter of a meter long. Its mass is only a trifle greater than a kilogram and the most of this is concentrated in the bob. The knife edge, rigidly attached to the pendulum, is of agate and it swings upon agate planes. These should be rigidly supported and may well be secured to a part of the casting which furnishes at once the support for the pendulum and the chamber in which it swings. It should be furnished with a starting and stopping apparatus and an arc for measuring the amplitude of its vibrations. If it is to be used only for comparing chronometers and clocks no arrangements for securing constant pressure and uniform temperature are necessary. If it is to be a time standard both should be provided. The first is easy and the second can generally be reached quite closely. Some method of knowing the temperature of the pendulum should be provided. When used under conditions of nearly constant temperature a "dummy" pendulum, in the same enclosure, with a thermometer properly embedded in its stem, will be sufficient. Its amplitude should not be greater than two degrees at first, and when the knife edge is properly prepared it will swing for a couple of hours without this being inconveniently reduced.

The period of the pendulum may be ascertained by means of a modified coincidence method, the elements of which were first applied by Herr Von Sternek in his use of short pendulums in gravity determinations.

A small mirror is placed in a vertical plane on the pendulum head, its center being as near as may be in a horizontal

\*The pendulums used in the recent gravitation work of the U. S. Coast and Geodetic Survey will be found figured and described in an Appendix to the Report for 1891.

plane passing through the knife edge. A similar mirror is placed parallel to this and as near to it as is possible without interfering with the motion of the pendulum, but it is rigidly attached to the support upon which the pendulum swings. What is called the "flash apparatus" is placed a meter or two meters in front of these mirrors and in a line normal to them. In this an electric spark may be used or the light of a lamp or candle. What is desired is that a flash of light should be produced every second, as determined by a break-circuit chronometer or clock. For use with a lamp Mr. E. G. Fischer has contrived an ingenious shutter operated by an electromagnet, by means of which an illuminated slit is exposed for an instant in the movement following the break only. An induction coil whose primary circuit is broken by an electromagnet in the chronometer circuit provides the electric flash. Just over the point where this flash is produced is placed a telescope.

When properly adjusted the flash is reflected from both mirrors, and assuming the pendulum to be at rest, two lines of light are seen as one in the telescope or better, one is made to overlap the other a little. Now suppose the pendulum to be in motion, it will be clear that, as the flash occurs only for an instant each second, whether it will be seen reflected from the moving mirror will depend on the position of that mirror at the instant of its appearance. If it should happen to be in the plane of its original adjustment when the flash occurs the appearance in the telescope will be precisely the same as when the pendulum is at rest. If the period of the pendulum be precisely one-half of that of the clock or chronometer it will return to this position in just one second and the appearance will be continually repeated. If, however, the pendulum be slightly slow or fast of the chronometer, the mirror will not be precisely in this position at the end of one second and the image from its mirror will be a little above or below that of the first mirror. In another second the distance separating them will be still greater and this will go on until the moving image is no longer seen in the field of the telescope. After a time, however (this period is conveniently about five minutes), the pendulum will have gained or lost one oscillation on the beat of the chronometer and a few seconds before the necessary period for this has elapsed the image re-appears in the field and approaches coincidence, to again recede on the other side.

It is only necessary to observe the instant of this coincidence of the two images. Under the conditions mentioned above it is not necessary to observe this closer than the nearest

second and only an inexcusably careless observer would ever be a second in error. After having ascertained the "coincidence interval" and observed the first coincidence, the happening of any one in the future can be quite closely predicted. It is desirable to allow the pendulum to swing through a period equal to ten coincidence intervals and although only the first and last observations may be used it is well to observe two or three at the beginning and end of the period as a check. An idea of the accuracy of the method may be formed by assuming that an error of one second is made in observing the coincidence either at the beginning or end of the swing. It will be seen that the error of the result will be less than one part in two and a half millions. As a sample of the uniformity of results which is sometimes attained under favorable conditions the periods of a pendulum known as A<sub>3</sub>, as obtained from a Negus break-circuit sidereal chronometer in three separate sets of vibrations extending through about an hour each, made on the afternoon of October 23, are here given:

1st .....	·5006279
2d .....	·5006281
3d .....	·5006280

If such a pendulum be properly cared for there appears to be no reason why under the same conditions, its oscillation period may not remain sensibly constant for an indefinite period. As an example of constancy during a short period, a little over half a year, but under unfavorable conditions the following results showing the oscillation period of three pendulums as measured in March last and in October. In both cases time is referred to the standard sidereal clock of the U. S. Naval Observatory. Between the first determination and the last, the pendulums traveled about fifteen thousand miles, were several times landed from a vessel in the surf and with difficulty, and were exposed to great changes of temperature and conditions of weather. The remarkable agreement in the case of all justifies the assumption that a sufficient degree of permanency is attainable.

	Mean Periods.	Washington.	
	A-1.	A-2.	A-3.
March, 1891 .....	·5008779	·5007667	·5006702
October, 1891 .....	·5008759	·5007668	·5006696

When one of these pendulums is compared by means of the flash apparatus above described with a good break-circuit chro-

nometer it is found to furnish a most delicate test of the equality of the seconds determined by the toothed wheel which breaks the circuit.

Any inequality in the spacing of the teeth or irregularity in the movement of the wheel, of the existence of which the ordinary chronograph record would show no evidence, is clearly and unmistakably shown, and if on account of bad workmanship such inequalities are considerable the result as viewed in the telescope is ludicrous although a chronograph sheet from such a chronometer might present a very good appearance. It will be readily understood that when the breaks are separated by uniform periods, the moving flash will advance regularly and steadily, movements corresponding to one thousandth of a second in time being easily perceived. When the breaks are irregular, however, the flash moves irregularly, at times standing still for a second or two, and often actually receding. The apparatus may be used therefore as a test of the regularity of breaks with chronometers or clocks.

It is often desirable to compare one chronometer with another or with a clock and to obtain a relative rate. As this rate is variable it is necessary to determine it by reference to as short an interval of time as possible. The ordinary chronograph record does not give satisfactory results unless the comparison extends over a number of hours or a whole day. By means of the apparatus described in less than an hour a daily rate can be determined, correct within about three-hundredths of a second, and a higher degree of accuracy can be secured if it is found desirable.

In this operation it is only necessary to observe coincidences with both chronometers and then again in forty minutes or after a longer period if a better result is wanted. No care need be taken to secure standard conditions of temperature, pressure, etc., as whatever changes may take place affect the coincidence interval of both time-pieces alike.

Indeed it has been found possible to get a fair rate from an observation of a single pair of coincidences, the time consumed being less than five minutes. It is evident that a method is here offered for studying the hourly variations of chronometers and clocks, due to temperature, pressure, or other changes and in making such investigations the time-piece under examination finds its severest critic not in another of its own kind, but in a free pendulum maintained under uniform standard conditions.

As an example of the comparison of two chronometers by this method the following is cited :

Chronometers. Negus.	1589.			1518.		
	h.	m.	s.	h.	m.	s.
1st coincidence .....	18	17	15	21	07	10
2d coincidence .....	19	14	21	22	03	48
Ten coincidence interval..		57	06		56	38
No. 1589—No. 1518 = 28 seconds.						

From which the rate is found to be one second per day.

If the claims here made for the free pendulum are justified it is likely to find its most useful application as an independent time standard. For this purpose not less than three of these pendulums should be used. They should have slightly different oscillation periods and these must be determined with great care, under standard conditions and referred to the most accurate mean time second available. Indeed for the first standard set it might be worth while to carry on comparisons during day and night for many days, that all errors incident to the determination of time may be eliminated as far as possible. Assuming the physical constancy of these pendulums and the possibility of reproducing with sufficient accuracy the conditions under which they were swung, no further reference to astronomical observations is necessary, if, only the force of gravity does not change. Such a set, or one derived from it may be issued to any point, with a certificate guaranteeing the periods of oscillation as a simple function of the force of gravity. If the latter is known the oscillation period is at once deduced. Whenever it is desired to rate a clock or chronometer it will only be necessary to observe a series of coincidences, using the pendulum and chronometer as described above. The use of three pendulums, whose differences must remain sensibly constant wherever they are, will serve as a check against changes of any kind and once in a few years a redetermination by means of astronomical time may be had as a further security against systematic error. The ease and accuracy with which their oscillation periods can be determined in terms of the second of a clock or chronometer, and the probable constancy of this period during long intervals of time encourages the belief that the issue of properly authenticated time standards is by no means an impossibility and as to the desirability of an early accomplishment of such an end there can certainly be no doubt.

ART. XIII.—*On the Bear River Formation, a Series of Strata hitherto known as the Bear River Laramie*; by CHARLES A. WHITE.

[Published by permission of the Director of the U. S. Geological Survey.]

IN the year 1859 a series of strata, constituting an important section, was discovered by Mr. Henry Engelmann at a locality in southwestern Wyoming, upon the bank, and near the mouth of Sulphur Creek, a tributary of Bear River one of the members of which section contain abundant remains of a peculiar non-marine molluscan fauna. During the fifteen years following that of their discovery, these non-marine strata were generally spoken of as the Bear River estuary beds, but later explorations have revealed their presence at other localities in Wyoming, Idaho and Utah which shows that they are of more than estuarine extent. During that time also no one expressed any doubt of the Tertiary age of these strata because their fossil fauna, although consisting of new species, included only types which were then regarded as characteristic of the Tertiary, and this view was supposed to be supported by their stratigraphical relation to the other members of the same section and their equivalents in that neighborhood.

About the year 1876 the various deposits, which are now properly referred to the Laramie, began to be generally recognized as constituting one great formation, and these non-marine strata of the Bear River valley district came to be generally known as the Bear River Laramie because they were thought to have been contemporaneous with the true Laramie and to hold the same taxonomic position with relation to other formations, although it was well known that their molluscan fauna is very different from that of the Laramie. They were then also subject to the doubt which certain geologists began to express as to whether the Laramie is properly assignable to the Tertiary or Cretaceous; but this doubt was confined to the question of their geological age and did not extend to that of their relation to those marine strata of undisputed Cretaceous age which constitute other members of the same section. This statement finds support in the fact that up to the year 1891\* none of the publications of the various geologists who have examined these non-marine Bear River strata contain any clearly expressed doubt that they are all of later origin than any of the marine Cretaceous strata which occur in that part of the continent. That is, it was understood by them that the

\* See Bull. U. S. Geol. Surv., No. 82, p. 153.

Bear River strata rest upon, or hold the same relation to, the equivalent of the Fox Hills group of Meek & Hayden's Upper Missouri section that the true Laramie is known to do.

The object of this article, and of the immediately following one by Mr. T. W. Stanton, is to show that *the strata which have hitherto been known as Bear River Laramie are not only not referable to the Laramie formation but that they occupy a lower position*, being overlain by marine Cretaceous strata the equivalents of which are known to underlie the true Laramie. For this reason I shall in this, and in future writings, designate these strata as the Bear River formation, omitting the term Laramie in that connection as being wholly inapplicable.

The following remarks are offered as a brief historical account of the growth and prevalence of opinion concerning this interesting group of strata, which is paleontologically so different from any other known North American formation.

The first published account of these strata was given by Messrs. F. B. Meek and Henry Engelmann jointly in 1860;\* and later in the same year Mr. Meek published descriptions of some of the fossils which characterize them.† In these publications both authors unhesitatingly assign the strata in question to the Eocene Tertiary.

No other publication concerning them seems to have appeared until 1869, when Dr. F. V. Hayden inserted a paragraph concerning them in one of his official reports‡ upon another region, in which he expressed the opinion that they are of Tertiary age and proposed to group them together with the coal-bearing strata of the Sulphur Creek section, those near Evanston and those at Coalville, Utah, as constituting one formation to which he gave the name of Bear River group.§

In 1870 Dr. Hayden published a short article containing a minute description, accompanied by figures, of the non marine strata originally discovered by Mr. Engelmann in which publication he continued to assign them to the Tertiary.||

In the same volume, and immediately following the article of Dr. Hayden just mentioned, Mr. Meek catalogued and described a number of new species of fossils among which are some that were obtained from the Bear River formation at and near the originally discovered locality. These Mr. Meek assigned to the Tertiary without comment or qualification.

\* Proc. Acad. Nat. Sci. Philad., vol. xii, pp. 126-131.

† Proc. Acad. Nat. Sci. Philad., vol. xii, pp. 308-315.

‡ Prelim. Rept. U. S. Geol. Surv. Colorado and New Mexico, p. 91.

§ The Bear River group as proposed by Dr. Hayden embraced strata belonging to three separate formations. I retain the name for only those which pertain to one of them. That is, for those to which the name "Bear River" has been most generally applied.

|| Proc. Am. Philos. Soc., vol. xi, 1870, pp. 420-425, pl. 12.

In his official report for 1870 Dr. Hayden republished the substance of his article in the Proceedings of the American Philosophical Society just referred to, in which he again assigned the Bear River formation to the Tertiary, stating its position to be at the top of the Sulphur Creek section. This volume of reports also contains a chapter by Mr. Meek\* concerning the fossils which were collected by Dr. Hayden during the previous year, in which he assigned to the Tertiary all those species which were obtained from the Bear River formation.

In Dr. Hayden's official report for 1871, Mr. Meek again catalogued the fossils from the Bear River formation under the head of Tertiary;† and in the same year Mr. T. A. Conrad referred this formation to the Lower Eocene upon paleontological grounds.‡

In 1872 Mr. Meek, in company with Dr. H. M. Bannister, visited Bear River valley and specially studied the section which is exposed along Sulphur Creek, near its mouth, and which includes besides a great thickness of marine strata those of non-marine origin which have just been mentioned as having been first discovered by Mr. Engelmann. The results of this study were published by Mr. Meek in 1873,§ in connection with which publication he gave a figure of the section referred to, accompanied by a detailed description of its members. In this publication he continued to catalogue the fossils of the Bear River formation under the head of Tertiary, but in his remarks upon these strata he for the first time expressed some doubt upon this point, and suggested that they might "belong to the Upper Cretaceous." It is evident, however, that he was still of the opinion that their position is at the summit of the section, and therefore above all the undisputed Cretaceous strata which constitute its other members.

The character of his discussions concerning the paleontology of the Bear River formation in this and in previous publications shows that the doubt referred to was not entertained on account of any evidence afforded by the fossils obtained from those strata, all of which he regarded as of Tertiary types, but he seems to have been influenced by the fact that dinosaurian remains had then for the first time been discovered in strata now known to belong to the Laramie which until then had been by all geologists regarded as of Tertiary age, as also had been the Bear River formation.

\* Fourth Ann. Rep. U. S. Geol. Surv. Terr., pp. 149-153.

† Fifth Ann. Rep. U. S. Geol. Surv. Terr., p. 376.

‡ This Journal, III, vol. i, pp. 381-383.

§ Sixth Ann. Rep. U. S. Geol. Surv. Terr., pp. 451-454.

Upon the sheet of the general atlas of the U. S. Geological Survey of the 40th parallel which shows the district traversed by Bear River, the Bear River formation is indicated as belonging to the Laramie, and the areas which it was then known to occupy are colored in the same manner as are the true Laramie areas. This atlas was published in 1876, and the geology of the Bear River district is understood to be the joint work of Messrs. Clarence King and S. F. Emmons.

In his final report also Mr. King assigned the Bear River strata in question to the Laramie;\* and he correlated those of the originally discovered locality near the mouth of Sulphur Creek with the uppermost beds of the true Laramie at Black Buttes. Mr. Emmons also, in his final report† assigned the same strata to the Laramie.

At this time the belief had become general that the Bear River formation, notwithstanding the material difference of its fossil fauna from that of the great formation which then began to be known by the name of Laramie, was contemporaneous with the latter, and that both hold the same relation to overlying and underlying formations. For these and other reasons the Bear River formation began, as already mentioned, to be known as the Bear River Laramie; that special designation indicating a recognition of the faunal difference between it and the Great Laramie formation.

The final report of Mr. Engelmann was not published until 1876,‡ sixteen years after the publication of his original report, when discussion as to the true geological age of the Laramie formation, including the Bear River strata, had become somewhat prevalent. Apparently influenced by these discussions Mr. Engelmann in this report expressed the belief that the Bear River strata are of Cretaceous age, although in his original report (*loc. cit.*) the opinion that they are of Tertiary age is plainly stated.

Mr. Meek's final report to Captain Simpson on the fossils of the Bear River formations is contained in the same volume with that of Mr. Engelmann (*op. cit.*); and in his discussion of them he too was disposed to assign them to the Cretaceous, but he nowhere indicates a doubt that the taxonomic position of the Bear River formation is the same as that of the true Laramie. He also expressed this opinion in his last published writing,§ where also he described and figured several of the characteristic Bear River species.

\* U. S. Geol. Surv. 40th Parallel, vol. i, p. 373 and map III.

† U. S. Geol. Surv. 40th Parallel, vol. ii, p. 327.

‡ See Simpson's Report Great Basin of Utah, pp. 247-336.

§ U. S. Geol. Surv. 40th Parallel, vol. iv, p. 163.

In 1876 also Major J. W. Powell, who had personally examined the geology of the district embracing the lower portion of Sulphur Creek and the adjacent portion of Bear River valley accepted the conclusions which Mr. Meek had reached concerning the order of superposition of the members of the Sulphur Creek section, and published a verbatim copy of Meek's description of it.\* In this publication Major Powell assigned the Bear River strata to his Point of Rocks Group, which is equivalent to the Laramie, but both of which he assigned to the Cretaceous, placing the Bear River strata at the summit of the Sulphur Creek section, as all the other geologists referred to had done. In the same volume I described several of the characteristic molluscan species of the Bear River formation.†

In certain of my writings which were published in 1877 and 1878 I assigned the strata which I now designate as the Bear River formation, as well as the coal-bearing beds near Evanston, which are also found in Bear River valley, to the great Laramie formation.‡ Both of these assignments, however, having been erroneous a part of the conclusions which were reached in their discussion were necessarily also erroneous.

The results of some extended field observations made by myself in Colorado, Utah and Wyoming were published in 1879.§ In the part of that publication which relates to the geology of Bear River valley I expressed the views which I then held concerning the relation to the Laramie formation of the Bear River strata and of the Evanston coal-bearing beds. These views were similar to those expressed in my publications of the two previous years except that in the later publication I suggested that the Bear River strata are older than the Laramie; but I based this opinion more upon paleontological, than upon stratigraphical ground. I repeated the expression of this opinion in 1883.||

In 1879 Dr. A. C. Peale published the results of his examination of the geology of a portion of western Wyoming,¶ in which publications he shows that the Bear River formation has a greater geographical extent than was ever before known. He found these strata occupying a belt of country of varying width, lying partly in Wyoming and partly in Idaho, and extending northward from near the place of their original dis-

\* Geology of the Uinta Mountains, p. 158.

† Geology of the Uinta Mountains, pp. 118, 122, 123.

‡ Bull. U. S. Geol. Surv. Terr., vol. iii, pp. 607-614. Ib., vol. iv, pp. 707-724.

§ Eleventh Ann. Rep. U. S. Geol. Surv. Terr., pp. 161-172.

|| Third Ann. Rep. U. S. Geol. Surv., p. 430.

¶ Eleventh Ann. Rep. U. S. Geol. Surv. Terr., pp. 511-644; and map accompanying the 12th Ann. Rep. Also Bull. U. S. Geol. Surv. Terr., vol. v, pp. 195-200.

covery to the 43d parallel of north latitude, a distance of about 100 miles. Besides this he reported the existence of a narrower and shorter belt lying parallel with the other, a few miles farther eastward.

Most of the strata throughout the district examined by Dr. Peale have been much displaced by orogenic movements and the structural geology there is therefore often found to be obscure. Doubtless because of this obscurity he failed to see any reason to oppose the then prevalent opinion that the Bear River formation is referable to the Laramie epoch, and reported that formation as overlying a series of strata which he assigned to the Cretaceous, but admitted that he found no paleontological evidence of their Cretaceous age.

In 1877 and 1878 Prof. Orestes St. John examined the geology of a portion of western Wyoming, his district lying immediately north of the one examined by Dr. Peale, but the results of his work were not published until 1882. In this report\* he shows that the Bear River strata which, following the then prevalent custom he assigned to the Laramie, occupy considerable areas in the district examined by him, one of them being a northward continuation of the principal belt reported on by Dr. Peale. These areas show a northward continuation of the Bear River formation of about 40 miles more than was shown by the results of Dr. Peale's observations, and they seem to mark the extreme northern limit of the formation.

The structural geology of Prof. St. John's district is even more obscure than that of Dr. Peale's but his report appears to indicate that no marine Cretaceous strata have been deposited in the immediate neighborhood of the Bear River strata which he found there. Furthermore a proper interpretation of the reports which have been made by various geologists upon western Wyoming and adjoining parts of Utah and Idaho indicate that no true Laramie strata exist within the district where those of the Bear River formation occur. This fact seems to have favored the erroneous identification of the Bear River formation with the Laramie.

From 1881 to 1885 inclusive I published several articles in which reference is made to certain of the characteristic fossils of the Bear River formation.† In all of those articles the

\* Twelfth Ann. Rep. U. S. Geol. Surv. Terr., Part I, pp. 175-269 and map.

† The following statement of the titles and places of publication of these articles, in addition to similar references in preceding foot notes, is given for the purpose of making bibliographical reference to the subject of this article as complete as practicable.

Tanganyika Shells. *Nature*, vol. xxv, pp. 101, 102.

On certain conditions attending the geological descent of some North American types of Fresh-water gill-bearing Mollusks. *This Journal*, vol. xxiii, pp. 382-386.

New Molluscan forms from the Laramie and Green River groups, with discussion

fossils of that formation are so referred to as to convey the idea of its equivalency to the Laramie. From the latter date to the year 1891, as already indicated, no direct reference to the taxonomic position of these strata seems to have been published.

During the preparation of a Review of the North American Cretaceous Formations which was published in 1891, I found it necessary to discuss the Laramie formation in that connection. While reviewing the literature and paleontology of that portion of my subject, in connection with the results of my personal visits to Bear River valley, I became convinced that the Bear River formation is older than the Laramie,\* and that it would somewhere be found overlain by Cretaceous strata. This opinion I expressed on page 153 of the work referred to.

In connection with my official duties upon the U. S. Geological Survey during the past season Mr. Stanton accompanied me to Bear River valley where we together reviewed its geology up to the point where my previous investigations had ceased. It being then impracticable for me to continue field work I left him to pursue his investigations alone, and the following article prepared by him is the result. I need only add that I regard as correct his conclusion that the Bear River formation is not equivalent to the Laramie, but that it occupies a position beneath the greater part, if not the whole, of the equivalent of the Colorado formation of the marine Cretaceous series. That is, instead of overlying the equivalent of the Fox Hills group, or No. 5, of Meek & Hayden's Cretaceous section, the Bear River formation underlies the equivalent of the Fort Benton, or No. 2, of that section.

It is known that certain strata exist in southern Utah in which several of the characteristic species of the Bear River formation occur. Their investigation in the near future, and in the light of the newly ascertained facts which have just been stated and referred to, is contemplated; but because of present want of sufficient knowledge of the relation of those strata to other formations in that district they have not been considered in the foregoing remarks.

of some associated forms hitherto known. Proc U. S. National Museum, vol. v, pp. 94-99, plates 3 and 4.

A Review of the Non-marine Fossil Mollusca of North America. Third Ann. Rep. U. S. Geol. Surv., pp. 411-550, plates 1-32.

Contributions to Invertebrate Paleontology, No. 4; Fossils of the Laramie Group. Twelfth Ann. Rep. U. S. Geol. Surv. Terr., Part I, pp. 49-103, pl. 20-30.

The genus *Pyrgulifera* Meek and its associates and Congeners. This Journal, vol. xxix, pp. 277-280.

\* Bull. U. S. Geol. Survey, No. 82.

ART. XIV.—*The Stratigraphic Position of the Bear River Formation*; by T. W. STANTON.

THE Bear River formation has been defined and the history of opinion concerning its age and position have been given in the preceding article by Dr. C. A. White. During July and August, 1891, nearly all the well known localities where this formation occurs were reëxamined for the purpose of determining if possible its relations to other formations in the same region. The results of this examination are now presented, and as they differ materially from the conclusions reached by a number of geologists who have visited the region it is thought necessary to give somewhat in detail the facts on which they are based.

The areas studied were (1) at Bear River City,\* on the Union Pacific railway twelve miles southeast of Evanston, Wyoming; (2) on Bear River seven miles north of Evanston; (3) near the mouth of Twin Creek and on Ham's Fork, both on the Oregon Short Line; (4) the valley of Smith's Fork from Cokeville, Wyo., twenty miles northward. These localities are scattered over a narrow belt in western Wyoming nearly one hundred miles long extending from latitude  $41^{\circ} 10'$  to  $42^{\circ} 20'$ . They will be discussed in the order in which they are named.

*The Bear River City Area.*—This is the place of the original discovery of these strata, as mentioned in Dr. White's article, and nearly all of the discussions of them and their equivalents have been based on observations and collections of fossils made at this place. There is here a small area of highly inclined, folded and faulted Cretaceous and other strata surrounded and overlapped by nearly horizontal Wasatch Tertiary beds. The structure of these older beds is very complicated and many of the softer beds of shale are not satisfactorily exposed. It is not claimed, therefore, that all the structural details of this area have been worked out, but sufficient has been learned to enable us to assign most of the exposed strata to their proper relative positions in the section.

The accompanying sketch map which shows the observed dips and strikes of some of the harder strata will render the descriptions more intelligible. Immediately east of Hilliard station there is a ridge of hard light-colored sandstone formed by a faulted anticlinal fold which at this point trends nearly north. The dip on the west side of the fold is about  $30^{\circ}$  west.

\* This is the site of one of the temporary terminal towns on the Union Pacific railway, at one stage in its construction. It is long since abandoned and the place is now locally known as Bear Town.

Associated with the sandstones there are shales and one or more thin beds of coal. Following this ridge northward it is soon seen to curve to the west and finally to the southwest so that it is carried to Bear River City where it ends abruptly.

1.

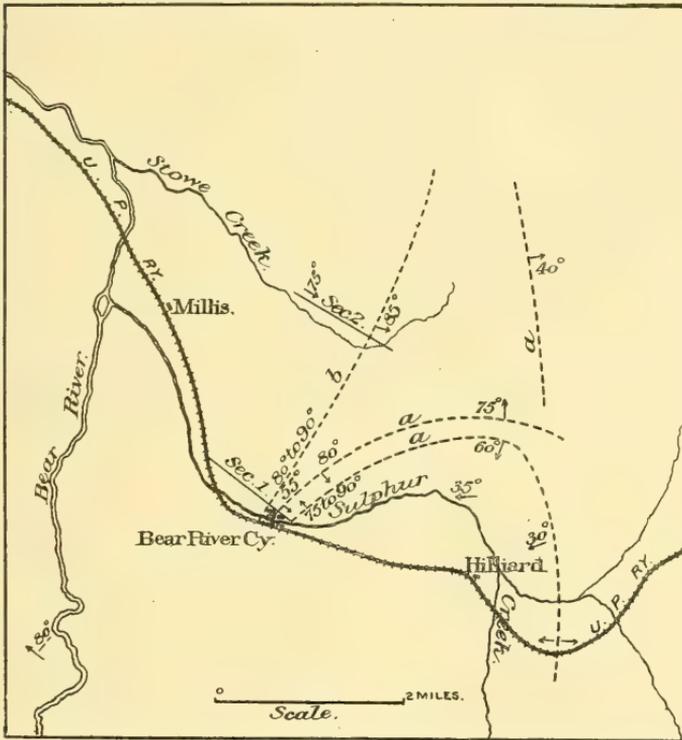


Fig. 1. Sketch map of small area at Bear River City, Wyoming, showing the location of the sections and the approximate dips and strikes of the more important strata.

*a, a, a*, ridges of Cretaceous coal-bearing sandstone. *b*, conglomerate ridge west of the Jurassic outcrop. The figures give the amount and the arrows indicate the direction of the observed dips.

The sandstones composing it are there nearly vertical and form the eastern part of Meek's section which will be quoted farther on. The semicircular space thus enclosed is occupied by soft clay shales with a few thin bands of sandstone, all of which show the same curved strike with dips toward the center of the curve. About 250 yards west of the first ridge at Bear River City there is a second less prominent ridge of coal-bearing sandstone that seems also to have a curved strike parallel with the first. It is possible that these two ridges consist of identical strata duplicated by a fault or fold, but positive proof of this was not obtained.

From a point about one and a half miles north of Hilliard another ridge of Cretaceous sandstone dipping  $30^{\circ}$  to  $40^{\circ}$  east extends north and northwest for about two miles. The exact relations of this ridge at the intersection with those just described were obscured by surface debris, but it is evidently composed of the same series of beds that constitute the other ridges. The sandstone is underlain by a great thickness 1000 to 1500 feet—of fissile bluish and brownish shales not sufficiently exposed for accurate measurement.

Immediately west of Bear River City there is a prominent ridge the crest of which is formed by a hard brownish conglomerate trending north  $28^{\circ}$  east. It is nearly vertical and is continuously exposed for about four miles. All the strata immediately associated with this conglomerate and all those west of it have approximately the same strike. These strata are described\* in Professor Meek's section on Sulphur Creek, and as my first observations were made on the same section it is reproduced here in order that the new facts may be clearly connected with those already known. In copying the figure (section 1) the first three beds at the east end of the section are omitted, and names of the formations recognized are added beneath.

#### MEEK'S SECTION.

"No. 1. Black shale, only seen in the bottom of Sulphur Creek, thickness unknown.	
No. 2. Slope apparently occupied by clays, thickness perhaps 100 feet or more .....	100 ft.
No. 3. Soft light grayish sandstone, nearly vertical.....	90 ft.
No. 4. Covered space, probably occupied by clays, but showing some sandstone that may or may not be in place; perhaps room enough for 250 to 300 feet .....	300 ft.
No. 5. Two or three rather heavy beds of light yellowish gray sandstone, separated by clays, probably occupying some of the space included in division 4. Near the lower part two layers 15 to 18 inches each, of sandstone, containing <i>Ostrea soleniscus</i> , <i>Trapezium micronema</i> , etc. Altogether 90 to 100 feet or more .....	100 ft.
No. 6. Greenish and bluish gray sandy clays, with some dark shale at places .....	100 ft.
No. 7. Bed of good coal, said to be $7\frac{1}{2}$ feet in thickness..	$7\frac{1}{2}$ ft.
No. 8. Heavy massive bed of light colored sandstone, about 90 feet in thickness, standing nearly vertical, with some 3 to 5 feet of sandy clay between it and the coal of division 7 .....	95 ft.
No. 9. Gray sandy shales with alternations of sandstone and clay .....	255 ft.

\* Ann. Rept. U. S. Geol. Surv. Terr. for 1872, p. 451.

No. 10. Light gray sandstone .....	20 ft.
No. 11. Slope and unexposed space, perhaps 200 yards or more across.	
No. 12. Light gray sandstones and clays, including a bed of good coal, said to be 7½ feet in thickness; all dipping south-southeast 55° below horizon; and the sandstone above the coal containing many casts, <i>Inoceramus problematicus</i> , with a few casts of <i>Cardium</i> and undetermined univalves; altogether showing about .....	150 ft.
No. 13. A valley or depression showing no rocks, perhaps 150 yards across.	
No. 14. Ferruginous sandstone in thin layers, dipping northwest about 80° below horizon .....	40 ft.
No. 15. Bluish laminated clays with, at top (left or west side), a two-foot layer of sandstone, containing fragments of shells not seen in a condition to be determined, .....	125 ft.
No. 16. Clays and sandstone below (20 feet); gray and brown pebbly sandstone above (25 feet) .....	45 ft.
No. 17. Brownish and bluish clays, with some beds of white, greenish and brownish sandstones .....	115 ft.
No. 18. Hard gray conglomerate, standing nearly vertical, and forming crest of hill about 350 feet high .....	40 ft.
No. 19. Slope showing above some masses of conglomerate, like that of division 18, perhaps not in place, with, at places below this, some reddish clays; altogether space enough for 500 to 600 feet in thickness .....	600 ft.
No. 20. Greenish-white sandstone .....	40 ft.
No. 21. Brownish clays and sandy layers .....	60 ft.
No. 22. Brownish clays and beds of sandstone, the latter light gray below .....	110 ft.
No. 23. Whitish sandstone—forms crest of hill about 220 to 240 feet in height .....	40 ft.
No. 24. Conglomerate and some red clays .....	20 ft.
No. 25. Brownish and reddish clays with a few distantly separated thin beds and layers of gray sandstone, altogether 750 to 800 feet in thickness .....	800 ft.
No. 26. Gray sandstone in place, apparently connected with some masses (that may not be in place) so as to include space enough for 60 to 80 feet—forms crest of a hill ...	80 ft.
No. 27. A long space of perhaps 260 yards or more, with only a few low exposures of light-gray sandstone, showing a slight westward dip.	
No. 28. Numerous thin seams and layers of dark carbonaceous shales, with harder thin bands of various colored argillaceous, arenaceous and calcareous matter, including a few very thin streaks of coal; the whole being highly charged with vast numbers of fresh and brackish-water shells, such as species of <i>Unio</i> , <i>Corbicula</i> , <i>Corbula</i> , <i>Pyrgulifera</i> , <i>Viviparus</i> , <i>Melampus</i> , etc. Dip nearly east, about 75° below the horizon; thickness 175 to 200 feet exposed .....	200 ft.

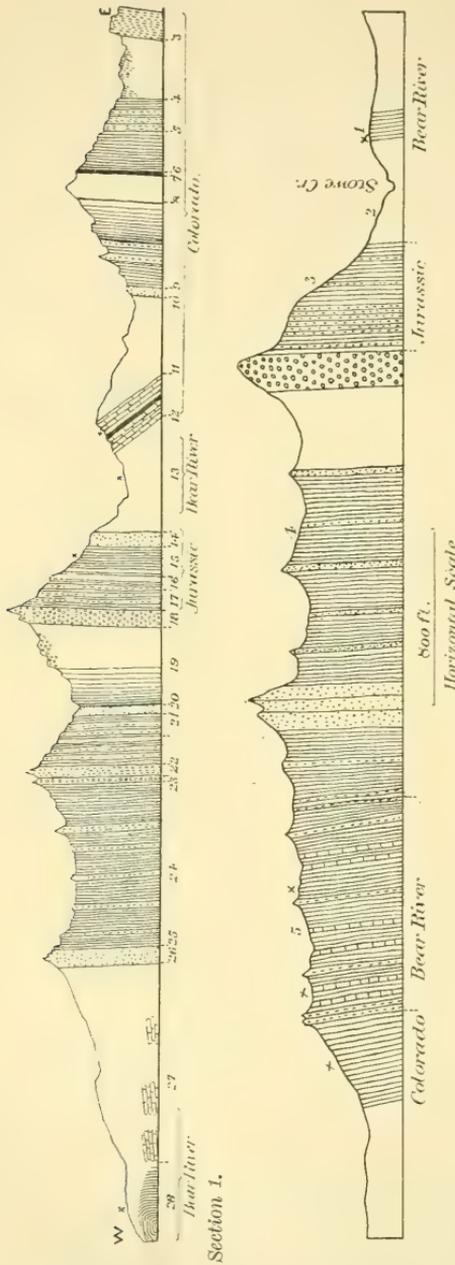


Fig. 2. Sections near Bear River City, Wyo. Section 1, on Sulphur Creek (after Meek). Section 2, on Stowe Creek. The important fossiliferous horizons are indicated by x.

that they must be later than the marine Cretaceous beds in the neighborhood. This circumstance and the uncertainty as to the exact age of the marine Cretaceous strata have had great influence in preventing a correct interpretation of facts observed.

It seems to have been assumed by most of the geologists who have visited this locality that the beds above enumerated are in their natural order of sequence beginning with the oldest, and this assumption was in accordance with all the facts then known. They found all the strata in the section, with a few exceptions that have been considered unimportant, practically conformable; that is they are nearly vertical and those at the east end contain well recognized Cretaceous fossils, while those at the west end, composing the Bear River formation, are filled with species that were originally described as Tertiary on account of their modern aspect and their resemblance to certain European Eocene forms. Later the strata were regarded as probably Cretaceous by Professor Meek and others, but their original reference to the Tertiary was tacitly accepted as proof

No recognizable fossils had been found in the broad space between No. 12 and No. 28, and the visible structural and topographic features gave no indication of the presence of folds or faults there. On careful search in this space it was found that the fossiliferous layer in No. 15 mentioned by Professor Meek contains characteristic Jurassic species and that No. 13 is in part occupied by fossiliferous Bear River shales, showing that between these two zones there is a fault the existence of which had not before been suspected.

In the space No. 13 several species of Bear River fossils were found on the surface and less than half a mile northeast along the strike the same forms were found in place in calcareous and argillaceous shale of which about 250 feet are exposed. The following forms were obtained:

- Pyrgulifera humerosa* Meek.
- Corbula pyriformis* Meek.
- Goniobasis chrysalis* Meek.
- Goniobasis chrysaloidea* White.
- Goniobasis macilenta* White.

These are all characteristic and easily recognizable Bear River forms, all of which occur in No. 28 of Meek's section. The zone was traced by means of small exposures and of fossils on the surface, north-northeast along the strike, to Stowe Creek, a distance of two miles.

500 or 600 feet west of these Bear River strata the fossiliferous layer in No. 15 mentioned by Professor Meek, yielded the following Jurassic species:

- Belemnites densus* M. and H.
- Trigonia quadrangularis* Hall and Whitf.
- Myacites (Pleuromya) weberensis* Meek?

Numerous examples of the first named species were found. It is one of the most common and characteristic forms of the Jurassic of the Rocky Mountain region. *Trigonia quadrangularis* is not so well known, but the type is from Jurassic strata near Como, Wyoming. The *Myacites* is abundant though not well preserved and there is some doubt as to the stratigraphic position of the type specimen which was referred to the Jurassic for paleontologic reasons. The evidence of the Jurassic age of this layer furnished by the first two species is, however, regarded as conclusive. The fossils were found for about half a mile along the strike. The other associated beds that are referred to the same age were so assigned because no reasons were found for separating them.

From No. 14 to No. 27 inclusive only the harder beds are exposed and the descriptions of the others are based on the character of the surface debris. It is evident, however, that none of these strata are duplicated as they would be if the

duplication of the Bear River shales had been caused by a simple fold. This part of the series and the overlying beds are more fully exposed in the section on Stowe Creek, which will be described. The beds in space No. 27 are very much disturbed and only slightly exposed. Besides the nearly horizontal outcrops of sandstone figured by Prof. Meek there are, a short distance east of the fossiliferous No. 28, two almost vertical bands of gray sandstone containing fragments of dicotyledonous leaves, while the outcrops 200 yards north show similar sandstone dipping  $45^{\circ}$  west. It will be seen on examining the corresponding part of the Stowe Creek section that this confused condition as well as the apparent fold in No. 28 are purely local, the only movement there indicated being a slight change in dip.

On the direct line of Meek's section there are no more exposures for a long distance because it passes into the valley of Sulphur Creek and thence down through the meadows on Bear River. But following the strike of No. 28 less than half a mile north-northeast it was found that the fossiliferous Bear River shales are succeeded westward by thin beds of gray sandstone (about 60 feet) and these by bluish and brownish fissile shales, of which about 1000 feet are exposed, containing numerous teleost fish scales. The strata are then covered for one-fourth of a mile or more to Millis Station where there is a tunnel on a nearly vertical bed of coal six feet thick. The associated beds are not exposed and the hills a short distance northwest are composed of horizontal Wasatch strata.

In the same way the Bear River shales were followed along the strike south-southwest for two miles from the line of the section and were there found to underlie the high hill on the east bank of Bear River. At this most southern exposure there is a covered space of about 500 feet in the meadows along Bear River. The hills on the west bank show some thin bands of sandstone followed by several hundred feet of bluish and brownish shales with teleost fish scales and crushed specimens of a *Prionocyclus* (perhaps *P. Woolgari*). These are evidently the same as the beds above mentioned lying west of the Bear River shales and belong to the lower part of the Colorado formation. A few hundred feet northwest of this locality there is an exposure of 145 feet of alternating sandstones, shales and carbonaceous layers with Colorado Cretaceous fossils. The dip is about  $80^{\circ}$  northwest, the same as that of the other beds just mentioned. On the uneven edges of this most westerly outcrop of the Cretaceous are the horizontal clays and sandstones of the Wasatch Tertiary. Several years ago Dr. White\* gave a list of species collected at this point and referred them to the Fox Hills group. All the identified forms also occur

\* 11th Ann. Rept. U. S. Geol. Surv. Terr., p. 248.

in the coal-bearing Cretaceous sandstones near the east end of Meek's section, which are now known to belong to the Colorado formation.\*

Two miles north of Sulphur creek another small stream, Stowe creek, has cut a deep valley across the upturned strata showing good exposures of most of them. The following detailed description will show that it supplements the Sulphur creek section, especially in the western half. The strata are all slightly overturned, dipping  $75^{\circ}$  to  $85^{\circ}$  east. The beds are numbered from east to west. (See section 2.)

## SECTION ON STOWE CREEK.

## 1. Bear River Formation.

Obscure exposures of dark shales with calcareous bands containing *Pyrgulifera humerosa*, *Corbula pyriformis*, *Goniobasis chrysalis*, etc.

2. Covered space about ..... 500 ft.

## 3. Jurassic?

Reddish shales and shaly sandstones. Dip  $85^{\circ}$  east... 100 ft.

Light bluish shales with some sandstones near base .... 120 ft.

Reddish shaly sandstone ..... 200 ft.

Shales and gray sandstones not well exposed ..... 100 ft.

Total ..... 520 ft.

## 4. Dakota?

Brown conglomerate of small pebbles. Dip  $85^{\circ}$  east.. 150 ft.

Covered in a valley ..... 250 ft.

Brown sandstone ..... 15 ft.

Reddish and bluish soft shales with some thin bands of sandstone mostly covered ..... 350 ft.

Brown sandstone..... 20 ft.

Variegated shales with thin beds of sandstone..... 425 ft.

Coarse gray sandstone ..... 200 ft.

Bluish and reddish shales ..... 100 ft.

\* The reference of all the coal-bearing Cretaceous sandstones of this neighborhood to the Colorado formation requires a word of explanation. There has been much discussion concerning the age of these beds and their equivalents at Coalville, Utah. A number of invertebrate species have been described from them, none of which excepting *Inoceramus problematicus* was known to occur in any of the members of the Meek and Hayden section east of the mountains. Lithologically they have some resemblance to the Montana (Fox Hills) formation, and they are underlain by beds of dark shales of the Colorado. For these reasons they have been most frequently referred to the Fox Hills, now called the Montana formation. My field work during the last two seasons has shown (1) that a large number of the species of this peculiar fauna occur in the Colorado formation, east of the mountains in southern Colorado, associated with the characteristic species of that formation; (2) that some of these characteristic species also occur in the Coalville beds. We must therefore conclude that the Colorado formation attained an unusual thickness along this western coast of the interior Cretaceous sea and that the local peculiarities of its fauna as well as the greater thickness and coarseness of the sediments are due to the proximity of the shore. These facts will be fully demonstrated in a paper now in preparation and they are mentioned here only because they have an important bearing on the age of the Bear River formation.

Coarse gray sandstone. Dip 85° east .....	6 ft.
Bluish and reddish shales .....	75 ft.
Total* .....	1591 ft.
5. Bear River Formation.	
Brown sandstone. Dip 75° east .....	20 ft.
Soft gray shales .....	25 ft.
Gray sandstone .....	10 ft.
Dark shales .....	60 ft.
Brown sandstone .....	10 ft.
Dark shales with calcareous bands containing numerous fossils— <i>Pyrgulifera humerosa</i> , <i>Corbula pyriformis</i> , <i>Unio belliplicatus</i> , etc. ....	250 ft.
Sandstone .....	10 ft.
Dark shales with thin bands of limestone, and sandstone and occasional carbonaceous seams; many Bear River fossils .....	400 ft.
Gray sandstone. Dip 75° east .....	10 ft.
Soft shales .....	25 ft.
Gray sandstone. Dip 75° east .....	20 ft.
Total .....	840 ft.
6. Colorado Formation.	
Bluish fissile shales with many fish scales and a few marine Cretaceous invertebrates, exposed about .....	500 ft.

The space for about half a mile west shows only a few small exposures of shales. At this point an opening has been made on a bed of coal six feet thick and dipping 75° east. This is doubtless the same coal bed as that which occurs at Millis station. The associated strata are concealed by soil and by debris from the horizontal Wasatch beds that cap the adjacent hills.

East and north of this section, in the area between the ridges indicated on the foregoing map, there is a valley in which there are no exposures excepting around its margin. On the east side, as has already been mentioned, the Cretaceous sandstones with a strong eastward dip are underlain by 1000 to 1500 feet of shales with fish scales, *Cardium pauperculum*, etc., that are the equivalent of the shales overlying (west of) the principal exposures of Bear River beds. It will be noticed that these shales do not appear in the section on Sulphur Creek between the eastern belt of the Bear River formation and No. 12. The latter which is evidently not in its normal posture, seems to have been thrust over on the shales thus concealing them. A short distance north of the section the divergent strike of the two formations gives ample room for the shales though they are not exposed.

\*It is probable that a large part of this member of the section belongs to the Bear River formation.

From the facts just given in detail the following deductions are made :

1. The latest strata embraced in Meek's section on Sulphur Creek are not those of the Bear River formation as he supposed but are the dark shales, No. 1, at the east end of that section which occupy a syncline between Hilliard and Bear River City.

2. Between Nos. 13 and 14 of Meek's section or perhaps within the space No. 13, a reversed strike fault along the axis of a sharp anticlinal fold has brought Jurassic strata in contact with the eastern belt of fossiliferous Bear River shales, concealing the intervening beds.

3. These recognized Jurassic strata are overlain by a considerable thickness of conglomerates, sandstones and shales of which the age is not known, though for stratigraphic reasons they are doubtfully referred to the Dakota.

4. The Bear River formation rests on the last mentioned beds and as just indicated is conformably overlain by the shales and sandstones of the Colorado Cretaceous.

It will be seen that the facts obtained at other localities tend to confirm these conclusions.

*The Area seven miles north of Evanston.*—From Evanston northward along the east bank of Bear river for five or six miles the hills consist of reddish brown conglomerates, sandstones and shales at the top underlain by lighter colored sandstones with shales and heavy beds of coal (the Almy mines), all dipping  $10^{\circ}$  to  $15^{\circ}$  southeast. Dr. White in his later writings refers all of these beds to the Wasatch while Mr. Emmons and others have regarded the coal as belonging to the Laramie. A short distance north-northwest of the most northerly of the Almy coal mines is a hill composed of the characteristic shales of the Bear River formation with very many fossils, including almost all the species found in that formation at Bear River City. The beds are exposed for a mile or more northward parallel with the course of the river. They have about the same, or in some places a less dip than the coal-bearing series, with which they have no other characteristic in common. The contact between the two formations is concealed in a valley where there is probably a fault. On the west slope of the hill, adjacent to the river valley, the Bear River shales are unconformably overlain by soft reddish brown sandstones and shales of the Wasatch Tertiary, dipping west, so that both the top and the bottom of the Bear River beds are effectually concealed.

It is worthy of note that about six miles north of this locality a high ridge of Carboniferous limestone is brought up by a fold the axis of which if prolonged would pass a little west of the Bear River exposure. The conditions observable in this area, however, throw comparatively little light upon the question of the taxonomic position of the Bear River formation.

All of the localities remaining to be considered are in the area which was examined by Dr. A. C. Peale in 1877, by whom collections of fossils were made from the Bear River strata at the most of them. His report\* on the region referred to was published in 1879 and his map of it accompanied the twelfth annual report of the Survey of the Territories which was not issued until 1882.

*Localities on Twin Creek and Ham's Fork.*—Thirty-five miles north of Evanston at Sage station, near the mouth of Twin creek, there is an abandoned mine on a thin bed of coal dipping about  $35^{\circ}$  northwest. Above the coal there is a considerable thickness of sandstones interstratified with argillaceous and siliceous shales none of which yielded any fossils. In a thin bed of sandstone, 15 or 20 feet below the coal *Modiola multilinigera*, *Barbatia coalvillensis* and a few other species of the Colorado Cretaceous were found. 400 or 500 feet east of (below) this there are exposures of sandstones and calcareous shales containing Bear River fossils, interstratified with thin seams of coal on some of which excavations have been made. A figure of the section and a list of the Bear River species collected here has been published† by Dr. Peale. He states that the fossils there enumerated came from above the coal. It is probable however, that one of the lower coal seams is referred to and that the bed in the Colorado formation was not then opened. On the south side of the creek less than half a mile from the coal mine there are obscure outcrops of a fossiliferous Tertiary limestone that also dips northwest, showing that it is involved in the folds and faults of the neighborhood.

On Ham's Fork there is a somewhat similar condition of things. This locality is about twenty-five miles east of the one last described and a mile east of Waterfall station. On the western border of the small area mapped as Jura-Trias by Dr. Peale there is a very small exposure of Bear River beds dipping  $45^{\circ}$  to  $70^{\circ}$  west. The fossils obtained include the following characteristic forms;

*Pyrgulifera humerosa.*

*Corbula pyriformis.*

*Corbicula durkeei.*

*Unio vetustus.*

*Unio belliplicatus.*

The apparent thickness of the calcareous shales containing these fossils, with the associated thin bands of sandstone, is 30 or 40 feet, and the length of the exposure is only about 200 feet. The contact with the underlying beds is not shown. They consist of reddish brown and purplish shales and beds of hard brown and gray sandstone with variable westward dips.

\* 11th Ann. Rept. U. S. Geol. Surv. Terr., pp. 511-646.

† Op. cit., p. 575 and Pl. LXVII.

On the west the Bear River formation is overlapped by a light-colored calcareous sandstone, interbedded with greenish clays and soft yellowish sandstones. The dip varies from  $10^{\circ}$  to  $20^{\circ}$  west and the total thickness seen is about 50 feet. The calcareous band contains *Goniobasis tenera*, *Unio haydeni*, *Viviparus paludinæformis* and other characteristic species of the Wasatch Tertiary. The few exposures in the space extending one half mile farther west shows that these Wasatch beds are folded in a gentle syncline beyond which the shales, sandstones and coal seams of the Colorado Cretaceous appear with dips varying from  $20^{\circ}$  to  $29^{\circ}$  west. The top of the exposed section is formed by the sandstones of Oyster Ridge, which are, in part at least, the equivalent of similar Cretaceous sandstones at Bear River City and at Coalville. It is believed that a large part of the Bear River formation and a considerable thickness of Colorado shales and sandstones are concealed beneath the folded Wasatch Tertiary beds above mentioned.

*The Valley of Smith's Fork.*—Smith's Fork empties into Bear River at Cokeville (formerly called Coketon) nearly twenty miles north of Twin Creek. The last three miles of its course is west, but above that for twenty miles it flows almost south. The stream was followed for that distance to the second great bend in its course where it approaches nearest to the head waters of Thomas' Fork. The narrow drainage area of this part of the stream is only from four to eight miles wide and lies between the Sublette range on the west and a nameless range, the southern continuation of the Salt River range, on the east. Nearly all the beds underlying this valley belong to the Bear River formation which has here a greater thickness than at any other locality visited. The strata are much folded, there being an anticlinal fold and two synclinals—one of which is replaced by a fault in the southern portion—between the two ranges and parallel with them.

A few detailed sections are given below to show the structure, and for comparison with the sections near Bear River City.

At Cokeville the Carboniferous limestones are brought up in a sharp broken fold forming prominent hills on both sides of Smith's Fork. The upper portion of the overlying strata that are doubtfully referred to the Triassic yielded a number of imperfectly preserved fossils belonging to the genera *Ariculopecten*, *Lingula*, *Camptonectes* (?) etc., that have not been specifically determined. They indicate that the strata containing them are certainly not later than the Jurassic and they are believed to belong to the "Meekoceras Beds" which have been referred to the Triassic. The beds immediately overlying are concealed by a fault which brings these Triassic (?) limestones in contact with the Bear River formation which rests on a

series of alternating sandstones, shales and conglomerates. Beneath the conglomerate there are reddish brown thin bedded sandstones and sandy shales forming the axis of an anticlinal fold. No fossils were found in the latter beds but they have a close resemblance to the strata in which Jurassic fossils were found near Bear River City, and they are separated from the Bear River formation by similar conglomerates and sandstones at both places.

## COKEVILLE SECTION.

From the mouth of Smith's Fork eastward.

1. Carboniferous.	
Blue limestone and shales in a sharp anticlinal fold . . .	1200 ft.
Thin bedded limestone and shales with some arenaceous layers . . . . .	600 ft.
Total . . . . .	1800 ft.
2. Triassic ?	
Red shales and sandstones not well exposed . . . . .	700 ft.
Blue, limestone with <i>Aviculopecten</i> , etc. Dip 70° east,	150 ft.
Total . . . . .	850 ft.
3. Bear River Formation.	
Covered about . . . . .	50 ft.
Dark shales with carbonaceous seams and calcareous layers containing numerous specimens of <i>Corbula pyriformis</i> , <i>Unio belliplicatus</i> and other Bear River species. Dip 60° west. This is seen in a tunnel that has been driven in search of coal.	
Mostly covered for a distance of 2250 feet. In this space there are some small exposures of shale and two or three bands of sandstone one of which contains <i>Ostrea</i> .	
Variegated shales and thin bands of sandstone. The west half contains <i>Pyrgulifera humerosa</i> , <i>Gonibasis macilenta</i> , etc., and several seams of coal on which some mining has been done. Dip 80° west.	
Thickness about . . . . .	700 ft.
Total thickness probably . . . . .	2500 ft.
4. Dakota ?	
Alternating beds of coarse gray and brown sandstone, and covered spaces that are probably underlain by shales . . . . .	
	1125 ft.
Brown pebbly conglomerate. Dip 80° west . . . . .	125 ft.
Total . . . . .	1250 ft.
5. Jurassic ?	
Greenish gray shales and shaly sandstones . . . . .	75 ft.
Reddish brown thin bedded sandstones with some sandy shales. Dip at top 75° west diminishing to 65° at the base. Estimated thickness to the river . . . . .	
	400 ft.
Total exposed . . . . .	475 ft.

The section here crosses Smith's Fork at the bend and the strata are concealed in the level river valley for a quarter of a mile. Then there are exposures of brown conglomerate and sandstone dipping about 50° east that are evidently the equivalents of the lower beds in No. 4. Still farther west along the

north side of Pine Creek there are characteristic exposures of the bluish and variegated Bear River shales, beyond which all the strata are covered for a mile or more to the range of hills that here forms the boundary between the Bear River and Green River drainage areas. The beds on the western flank of this range are the gray and blue calcareous shales that Dr. Peale referred to the Jurassic "Pentacrinus Beds."

The structure indicated by the dotted lines in the figure (Section 3) was seen in the continuation of this belt both north and south of the line of the section.

About twelve miles north of Cokeville a small stream, not named on the maps, cuts a deep gorge through the plateau on the east side of Smith's Fork and shows the general character of the underlying beds. The strike of the strata is generally very constant in this region, nearly parallel with the course of the river. This section therefore

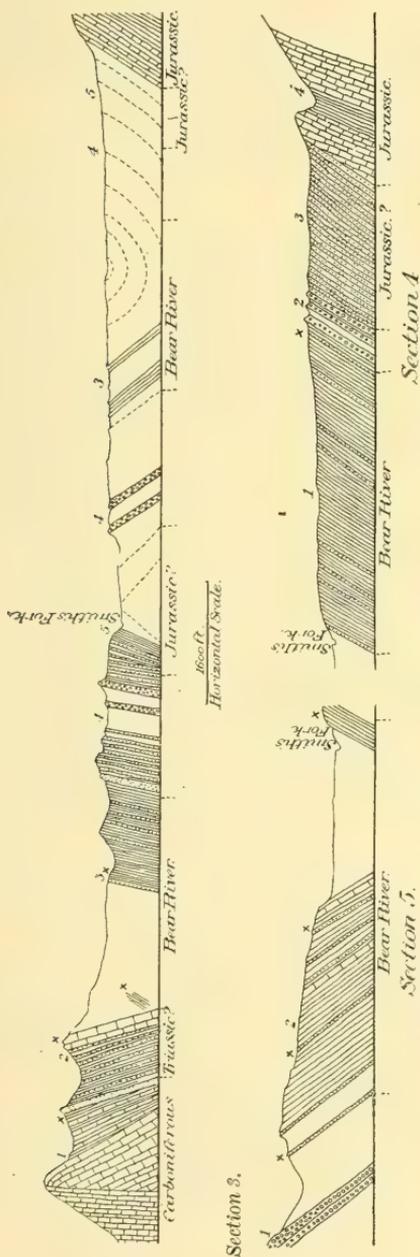


Fig. 3. Sections in the valley of Smith's Fork, Wyoming. Section 3, east side of Smith's Fork, 12 miles north of Cokeville. Section 4, west side of Smith's Fork, 17 miles north of Cokeville. Fossiliferous horizons are indicated by x.

supplements the preceding one as it shows the beds east of the synclinal fold.

Beginning at the river the following beds are exposed in descending order. (See Section 4).

SECTION ON THE EAST SIDE OF SMITH'S FORK.

1. Bear River formation.

Bluish argillaceous and calcareous shales with occasional thin beds of gray sandstone. Fossils are abundant especially in the upper half. There are also a few fossils (a small Gasteropod and nutlets of *Chara*) at the base. Dip  $55^{\circ}$  to  $60^{\circ}$  west. Thickness about..... 3000 ft.

2. Dakota?

Brown pebbly conglomerates and coarse sandstones alternating with covered spaces. Total thickness about..... 500 ft.

3. Jurassic?

A space nearly a mile wide that is mostly covered but the surface debris and numerous small exposures indicate that it is underlain by reddish brown sandstones and sandy shales. Dip  $55^{\circ}$  or  $60^{\circ}$  west. Thickness..... 3000 ft.

4. Jurassic.

Greenish gray laminated calcareous sandstone..... 100 ft.  
Blue and gray calcareous shales. Thickness undetermined.

No. 4 is the "Pentacrinus Beds" of Dr. Peale's general section\* of the Jura-Trias in this region.

Five miles farther north a part of the section on the west side of the stream was measured. The river is here in a synclinal valley as it was at the preceding section, but it cuts across the strata at a low angle so that near Cokeville it has passed west of the syncline and cuts through an anticlinal as we have seen. (See Section 5.)

SECTION ON WEST SIDE OF SMITH'S FORK.

1. Dakota?

Brown conglomerate and coarse sandstone, partly covered. It crops out on the crest and eastern slope of the divide between Smith's Fork and Thomas' Fork. Dip  $55^{\circ}$  east. Thickness..... 500 or 600 ft.

2. Bear River formation.

Covered. Farther north this space was seen to consist principally of shales with obscure Gasteropod casts near the base and with *Unio vestustus* and *Corbicula durkeei* at the top. Thickness..... 900 ft.

\* 11th Ann. Rept. U. S. Geol. Surv. Terr., p. 623.

Greenish sandstone weathering to a dark brown. It contains <i>Unio vestustus</i> , <i>Limnea (limnophysa) nitidula</i> and a few other fossils. Dip 55° east. Thickness .....	10 ft.
Covered .....	300 ft.
Gray sandstone containing a few dicotyledonous leaves* and Gasteropods .....	10 ft.
Bluish argillaceous and calcareous shales with some thin bands of sandstone. Bear River fossils are numerous in the calcareous layers. The dip seems to remain constant at 55° east to the river plain of Smith's Fork making a thickness of .....	2200 ft.
<b>Total</b> .....	<b>3420 ft.</b>

The level meadows of the river plain are about half a mile wide, and the east bank of the stream directly opposite is composed of Bear River strata dipping 60° west.

Three miles north of the last section the divide between Smith's Fork and Thomas' Fork is made up of fossiliferous Bear River shales and sandstones dipping east. The underlying sandstones and conglomerates (base of preceding section) are sharply folded in an anticlinal, west of which the highly fossiliferous Bear River beds again appear in a synclinal. Still farther west along Thomas' Fork the reddish brown thin bedded sandstones and sandy shales beneath the conglomerate are exposed.

*General Discussion of the Sections.*—The following table based on the detailed sections shows the relative positions of the different Cretaceous formations described and their correlation with the members of the complete upper Cretaceous section of the Northwest, in which the Colorado formation is the equivalent of the Fort Benton and Niobrara groups of the Meek and Hayden section and the Montana is the equivalent of the combined Fort Pierre and Fox Hills of the same section.

TERTIARY.	Wasatch.	Conglomerates, coarse sandstones and shales with coal at the base.
	Laramie.	Wanting, or included in the above.
	Montana.	Not positively identified.
CRETACEOUS.	Colorado.	Shales and coal-bearing sandstones. Thickness not less than 2500 ft.
	Bear River.	Very fossiliferous argillaceous and calcareous shale alternating with thin beds of sandstone.
	Dakota?	Conglomerates and coarse sandstones. Thickness of last two 2500 to 4000 ft.
JURASSIC.	Belemnites Beds.	Thin bedded sandstones and sandy shales.

\*The fragmentary plants collected from this formation have not yet been studied.

It has already been shown that the lower 400 or 500 feet of the sections near Bear River City is of Jurassic age. In the more northern areas beds of much greater thickness—not less than 3000 feet—of similar lithologic character and holding the same position relative to the overlying formations are believed to be of the same age, although no fossils were found in them. These beds rest conformably on easily recognizable calcareous shales and limestones from which *Pentacrinus asteriscus* and other characteristic Jurassic fossils have been obtained.

Above these beds comes a considerable thickness of conglomerates, coarse sandstones and shales separated from the preceding by great differences in the character of the sediments, and closely associated with the Bear River formation throughout the entire region, though at a few localities they are not exposed. The conglomerate at the base is a very irregular deposit, varying within short distances from a brown or gray cross-bedded sandstone to a conglomerate composed of pebbles two inches or more in diameter. The general character, however, remains constant and the bed is easily recognized. In the sections I have called this formation the Dakota?? and have assigned to it in each case all the non-fossiliferous beds above the base of the conglomerate and below the recognized Bear River beds. It is evident that a portion if not all of the strata in these sections between the Jurassic and the Colorado Cretaceous must be the equivalent of the Dakota formation, but the division here made is simply one of convenience.

Of the 3000 to 3500 feet of strata assigned to the Bear River formation at the more northern localities at least 2500 feet contain identified fossils characteristic of the formation. The 900 feet at the base is not usually fossiliferous but it contains nutlets of *Chara* and small Gasteropods indicating that it is of fresh-water origin, and there seems to be no reason for separating it from the overlying beds. The lithologic character of the Bear River formation is very constant throughout the whole region, as the detailed sections have shown. Its thickness increases northward as far as my examination extended. There is not so great a difference in this respect, however, as the arbitrary division of my sections would indicate, for it is probable that near Bear River City enough should be transferred from the Dakota? to the Bear River formation to make the thickness of the latter nearly 2000 ft.

The Colorado formation as it occurs at Bear River City, resting immediately on the Bear River beds, has been sufficiently described. It was not found north of Twin Creek.

The Montana formation was not positively identified at any of the localities studied. Possibly a part of the shales be-

tween Hilliard and Bear River City should be referred to it and it may occur in the upper portion of Oyster Ridge and west of that ridge near Ham's Fork.

The true Laramie does not occur in the region under discussion, unless the coal-bearing series north of Evanston and its equivalent west of Ham's Fork belong to that formation. It has already been stated that the Evanston coal should probably be referred to the Wasatch.

*Corroborative Facts.*—(1) The reports of Dr. A. C. Peale and Prof. O. H. St. John\* show that this formation extends northward beyond Snake River to latitude  $43^{\circ} 45'$  and covers considerable areas. Both these geologists state in their reports that they did not find Cretaceous fossils beneath the Laramie, that is, the Bear River formation. At the few localities where they found undoubted marine Cretaceous its stratigraphic relation to the "Laramie" was not determined.

(2) Prof. St. John found it impracticable to separate the post-Jurassic formations of his district, and he frequently speaks of the Laramie, meaning the Bear River strata, as conformable with the Jurassic.

(3) In the Smith's Fork region Dr. Peale mapped a narrow band between the Jurassic and the "Laramie" as Cretaceous, but he did this only because there is a considerable thickness of non-fossiliferous beds (the "Jurassic" of my sections) overlying the recognized Jurassic and beneath the Bear River formation which was then regarded as Laramie.

(4) The fauna of the Bear River formation is unique. Of the more than thirty species now known in it not one has been found in the true Laramie nor in any of the other fresh-water formations of the West.

These facts were all perplexing as long as the Bear River formation was placed at the top of the Cretaceous, or in the Tertiary, but they become significant and are much more easily explained when it is known that its true position is near the base of the upper Cretaceous and separated from the Laramie by several thousand feet of marine strata.

In conclusion it should be stated that my grateful acknowledgments are due to Dr. C. A. White whose previous investigations had led him to believe that the Bear River formation is older than the Laramie. He accompanied me to the typical localities and identified for me the various points mentioned in previous reports. His suggestions and advice have also aided me greatly in the preparation of this paper.

\* 11th Ann. Rept. U. S. Geol. Sur. Terr., pp. 363, etc.; 12th Ann. Rept. Pt. 1, p. 188, etc.; see also sections on plates 4, 7 and 9 and the maps accompanying the latter report.

ART. XV.—*The Iron Ores of the Marquette District of Michigan*; by C. R. VAN HISE.

BEFORE considering the subject of this article, it is well to recall the general views held by the late Prof. Irving as to the Lake Superior ore-bearing formations, and those of the writer as to the position and genesis of the ores of the Penokee district. Prof. Irving maintained that the ores, jaspers and associated rocks are derived directly or indirectly by the alteration and silicification of an original lean iron-bearing carbonate.\* A detailed study of the Penokee-Gogebic district led the writer to the following conclusions:† First, the original rock of the iron-bearing formation was a lean cherty carbonate of iron, magnesium and calcium; second, the various phases of rock now found in this formation, such as chert, jasper, magnetite-actinolite schists and ore-bodies, are all produced from this original carbonate by various alterations, the processes involved in which are described in detail; third, the ore deposits occur in bodies which all reach the surface of the earth, which have a longitudinal pitch and are roughly triangular in cross-section. One of the lower sides of each triangle is bounded by an impervious dike-rock, the other by an impervious slate-formation; fourth, the ores in their present positions are concentrates produced by downward percolating waters which carried iron carbonate to the apices of the troughs, where it was precipitated by oxygen brought by waters coming more directly from the surface. At the same time silica was removed.

At the close of the description of the Penokee ores, attention was called to the fact that in certain respects the occurrence of the Marquette ores are analogous; but at that time the study of the latter had not extended far enough to give anything more than a general statement that it was probable that the same principles of concentration are applicable to the ore-deposits of both regions. Since that time a systematic investigation of the entire Marquette district has been undertaken, and while the study of the iron-bearing formation is far from complete, certain results have been reached, to set forth which is the object of the present paper.

\* Origin of the Ferruginous Schists and Iron Ores of the Lake Superior region, R. D. Irving: this Journal, III, xxxii, pp. 255-272, 1886.

† The Iron Ores of the Penokee-Gogebic Series of Michigan and Wisconsin, C. R. Van Hise: this Journal, III, xxxvii, pp. 32-48, 1889; The Penokee Iron-bearing Series of Michigan and Wisconsin, by R. D. Irving and C. R. Van Hise: Tenth Annual Report of the Director of the U. S. Geological Survey, 1888-89, pp. 341-507.

In much of the field work upon which this article is based, I was in company with Prof. Raphael Pumpelly. The common conclusions reached at this time are consequent upon our joint observations. To Mr. James R. Thompson, Mining Engineer of the Lake Superior mine, I am indebted for detailed observations upon the forms and relations, and for plats of many of the ore-deposits of the Ishpeming-Negaunee area. From these plats several of the figures are taken.

*Two ore-bearing formations.*—The ore-deposits of the Marquette district occur in two formations. It has been recently recognized that these formations belong to different series, separated by a great unconformity, and therefore that one of the two is much older than the other.\* The superior of these is here called the Upper Marquette series, the inferior the Lower Marquette series. The known ore-deposits in the upper series are much less important than those in the lower, and unless expressly stated the Lower Marquette series is always referred to.†

*Character of Lower Marquette ore-bearing formation.*—The ore-deposits of the Lower Marquette series all occur in or are associated with a single formation, known as the ore-bearing formation.

The non-fragmental character of the quartz and partly individualized silica associated with the ore-bearing formations of the Lake Superior region has been insisted upon in papers already published. The part of the Marquette iron-bearing formation containing the majority of the ore-bodies consists normally of bands of nearly pure silica, alternating with bands composed chiefly of oxides of iron, although frequently bearing more or less silica. The alternating layers are generally not more than an inch in thickness and are more frequently in the neighborhood of half an inch. A single layer, if followed for some distance, is usually found to gradually narrow and die out or to have a rounded oval termination. Sometimes the belts of quartz are so short as to be no more than tolerably long ovals. When the quartz is free from oxide of iron it has a white color and is usually called chert, although the microscope shows that the silica is wholly individualized. When the exteriors of the quartz granules are stained with hematite, or particles of hematite are included within them, giving the siliceous bands a red color, the material is called jasper. It is a general rule that near the top of the forma-

\* An Attempt to harmonize some apparently conflicting Views of Lake Superior Stratigraphy, C. R. Van Hise: this Journal, III, xli, pp. 117-137, 1891.

† For the equivalents of the Upper and Lower Marquette series in other parts of the Lake Superior region, see paper cited.

tion the silica is all or nearly all jasperized. In passing to lower horizons less and less of it is jasperized, until in the lower parts of the formation the siliceous bands are white. In the cases in which the jasperization is incomplete, it usually affects the outer parts of the bands and progresses inward. Frequently all stages may be seen between completely jasperized bands and those in which the jasperization has begun to affect only an outer film of the layers. It sometimes happens that above a band of paint-rock or soap-rock the silica is all jasperized, while below it is the white chert. It follows from the foregoing that we have associated with many of the ore-bodies, either banded ore and chert or banded ore and jasper.

The remaining important variety of rock associated with the ore is magnetite-actinolite schist. Where magnetite is the prominent oxide of iron, actinolite or grünerite\* is almost always present. In this phase of material the iron is mainly concentrated into layers, giving the rock a banded appearance the same as with the ferruginous cherts and jaspers.

Recent study has shown that iron carbonate is also an important constituent of the ore-bearing formation. Messrs. W. S. Bayley and W. N. Merriam have most frequently found this material at places where the formation dips under a greenstone. In one case iron carbonate occurs abundantly in the deeper workings of a mine. Transitions are seen between the unaltered carbonate and those phases of the formation in which the carbonate is partly or wholly oxidized to limonite, hematite or magnetite.

It is believed that the cherty carbonate of iron, as first advocated by Irving, is the original source of the various forms of ferruginous rocks occurring in the ore-bearing formation. However, it is not the purpose of the present paper to consider in detail the processes by which the many kinds of rocks were produced. This part of the subject for another district has already been somewhat fully treated.†

*Associated formations.*—In considering the character, position and genesis of the ore-deposits, it is necessary to take into account two associated formations: the overlying conglomerate and quartzite of the Upper Marquette series, and the eruptives.

The eruptives occur in bosses and in dikes. They were originally diabases, but frequently have passed over into diorites, and these again have further altered. In the northeast part of the great ore-producing township of Marquette county, T. 47 N., R. 27 W., is a large area of greenstone. This area

\* Notes on Michigan Minerals, A. C. Lane, H. F. Keller and F. F. Sharpless: this Journal, III, xlii, 505-508, 1892.

† Tenth Annual Report, U. S. G. S., pp. 393-408.

is almost encircled by a series of mines, which lie contiguous to the outer border or in the valleys between outlying bluffs. In many cases the greenstone in nearing the ore formation grades into a laminated rock, which has undergone profound alteration as a result of leaching and shearing. Thus changed, it is known as soap-rock, or when stained with iron oxide, as paint-rock. Numerous sections and diamond drill holes have so frequently shown all gradations between the massive diorite and the schistose soapstone and paint rocks as to leave no doubt whatever of their actual continuity. Beside the large masses of greenstone within or associated with the iron-bearing formation are numerous dikes of the same material. These sometimes run nearly parallel to the lamination of the ore-formation, but more frequently cut across it at a greater or lesser angle. These dikes are usually altered throughout, so that in general they have not been recognized as intrusive rocks. Like the altered parts of the greenstone bosses, they are called soap-rock or paint-rock. That they are really igneous is shown by their structural relations, and by the fact that occasionally they are traced to and found to be offshoots from the larger masses of greenstone. These soapstones, as indicated by their name, have a greasy feel, are very soft, have frequently a mottled gray and white color, although often they are deeply stained with red oxide of iron. In chemical and mineral composition these soapstones differ greatly from the original diabases. They have lost nearly all of their alkalis and very often are now largely a hydrated silicate of magnesium and aluminium.

The formation overlying the ore-deposits belongs to the Upper Marquette series and is, as has been said, a quartzite-conglomerate, the material of which is very largely derived from the immediately subjacent formation. The heavily conglomeratic part in some cases is but a few feet in thickness, in others is hundreds of feet thick. The detritus of the quartzite-conglomerate is nearly like the material of the underlying formation, except that within the former no large fragments of pure ore have been observed. This conglomerate suggests that the ore-formation was in approximately its present condition before the deposition of the Upper Marquette series.

*General structure of district.*—Before dealing with the ore-deposits it is necessary to speak of the general structure of the Marquette district. This can best be appreciated by examining Brooks' geological map.\* The Republic tongue is a simple synclinal, the sides of which are nearly vertical, showing that the formation has been sharply folded upon itself. The

\* Atlas accompanying the Geology of Michigan, Pl. 3.

southwest end of this trough, where the Republic mine is located, has a pitch to the northwest of  $40^{\circ}$  or  $50^{\circ}$ . At the west end of the Marquette district proper the mines, such as the Michigamme, Spurr, Champion, etc., are upon the sides of a great synclinal, which, however, is probably a synclinorium. In the great mining center of T. 47 N., R. 27 W., already referred to, where are the towns of Ishpeming and Negaunee, the formation has been folded into a series of rolls, which have variable pitches, as a consequence of which there are here several iron ranges approximately parallel. The mines, as in the more simply folded part of the district, are frequently at the sides of the synclinals, which, as already said, are generally flanked by diorite ridges. Whether the upwelling of the eruptives was the cause of the folding, or whether as the folding occurred fracture took place in the brittle ore-formation of which the intruding rock took advantage, it is yet too early to discuss.

*Classification of Lower Marquette ore-deposits.*—The known ore-bodies, with reference to their position, may be divided into the following classes: (1) deposits at the contact of the quartzite-conglomerate and the ore-bearing formation; (2) deposits resting upon soap-rock which grades into massive diorite; (3) deposits resting upon dikes of soap-rock which follow along or cut across the ore-bearing formation; (4) deposits interbedded in the jasper or chert. (See fig. 1, p. 123, generalized section of ore-formation in which ore in its more important relations is represented by cross-hatching.)

(1.) *Deposits at the contact of the quartzite-conglomerate and the ore-bearing formation.*—The ores occupying this position are generally hard and either specular or magnetic. It is to be remembered that the adjacent rock of the underlying ore-bearing formation is usually banded ore and jasper, although occasionally it is magnetite-actinolite schist. Because of the constant association of the hard ores with the red form of silica this material is sometimes called "specular jasper." One of the largest known deposits of the first class is that at Republic, and this locality, because of its magnificent exposures, is particularly favorable for study. While the main bodies of ore occur at the contact horizon, the mine maps show a constant tendency to form offshoots, a part of the ore following the banding of the jasper formation, which dips at a steeper inclination than the contact plane. (Fig. 2, p. 123). A body may continue in considerable force for some depth, but when it gets far from the contact plane, it is apt to die out. At and below the place where the branch strikes off the main deposit may become somewhat narrower, but in passing downward it often gains its full magnitude, and then a second shoot may start back from the contact plane into the underlying jasper.

Of course the entire contact horizon of the quartzite and ore formation is not occupied by ore-bodies as represented in the generalized figure. The deposits occur at places along the contact where sharp subordinate folding has occurred, or where the jasper formation is broken by cross joints, or where a soapstone dike cuts the contact plane forming a trough; or, finally, by a combination of two or more of these phenomena. The last is well illustrated by the position of the great deposit of the Republic, which is at the southeast corner of the horse-shoe, where the curve, instead of being gentle, is abrupt, causing the jasper formation to become sharply plicated and often fractured (fig. 3), and where there are numerous dikes of soap-rock which usually form one of the boundaries of the ore-deposits. The mining engineer remarked that the ore-deposits cannot live long when they become separated from the soapstone. Upon the east side of the Republic horse-shoe the ore-bodies are in chimney-like forms which often continue for a considerable depth and which are often usually rather sharply separated from the banded ore and jasper adjacent. (Fig. 4). However, here, as at the great deposits, the boundaries are generally found at fractures or flexures.

A detailed examination was made of the manner in which the change occurs between the jasper and the ore. While, as remarked, the ore often terminates somewhat abruptly, it also frequently grades into the jasper. In following a jasper band toward the ore it was found that instead of remaining solid it becomes porous and frequently contains considerable cavities. These spaces in the transition zone are lined with crystalline ore. In passing on toward the ore-deposit more and more of the silica is found to have been removed and the ore has replaced it to a corresponding degree. An examination at many localities led to the conclusion that the transition from the banded ore and jasper to the ore takes place as a consequence of the removal of silica and the substitution of iron oxide. Often in these cases the fine-grained part of the ore is that of the original rock, while the coarser material is the secondary infiltration.

The above details as to the occurrence of the hard ore at Republic are typical of this class in the remainder of the district. In the Ishpeming-Negaunee area, for instance, the ore often terminates along a slip or joint crack. Also the ore-bodies are likely to be found where the folding or crushing of the jasper has been severe, and especially where these phenomena are accompanied by soap-rock.

The ore-bodies between the ore formation and overlying quartzite are not always wholly in the jasper, but often extend upward to a greater or less degree into the quartzite-conglomerate, and some deposits wholly occupy the horizon of the

recomposed rocks. It is reasonable to suppose that a thin stratum of the conglomerate overlying the richer part of the iron-bearing formation may have been nearly, if not quite as heavy in its iron content as the formation from which it was derived. In these cases a part of the iron of the ore-deposit at least is a direct mechanical detritus and differs therefore in its genesis from the remainder of the ores; but all have alike been affected by a secondary concentration; for the process of replacement has affected the siliceous detritus in the same way that it has the laminated jasper in the original formation. When the ore-bodies partly occupy the place of the quartzite-conglomerate and partly that of the ore-formation proper, as a consequence of the secondary concentration, these two formations, although of widely different geological age, have been welded together. This is well shown at the Kloman mine.

(2.) *Deposits resting upon soap-rock which grades into massive diorite.*—Here are to be placed many of the deposits of soft ore and some of the hard ores. The masses of soap-rock may follow somewhat closely the lamination of the ore-formation or they may cut across it. In either case the deposit follows along the contact plane, the impervious soap-rock always being below the iron ore and above it the fractured and porous jasper or chert (see fig. 1, p. 123). Not infrequently a mass of soap-rock or diorite forms a synclinal trough in which the ore body rests, when the maximum thickness of the ore is likely to be at the lower part of the synclinal (fig. 5). Sometimes a small dike of soap-rock or paint rock shoots off from the large body and cuts into the ore (fig. 6). At other times the soap-rock bulges into the ore as though it had been bent into sharp corrugations. That the soapstone upon which the ores rest, actually grades into diorite is shown by many drill holes at the Lake Superior mine and very clearly at the Salisbury mine, as well as at other localities.

In some cases the first and second classes of deposits approach close to each other and might be mistaken for one continuous deposit of the same character, the two occupying opposite sides of a synclinal. This is shown by fig. 7, which shows upon one side of the synclinal the following section: diorite grading upward into soapstone, ore, jasper, quartzite-conglomerate. Upon the other side of the synclinal the section is: jasper, ore and quartzite-conglomerate.

(3.) *Deposits resting upon dikes of soap rock which follow along or cut across the ore-bearing formation.*—The ores here belonging, like those of the second class, are usually soft. They may occur upon one side only of a dike rock, or, when it is vertical or nearly so, upon both sides. When two dikes are not far distant from each other the whole or part of the

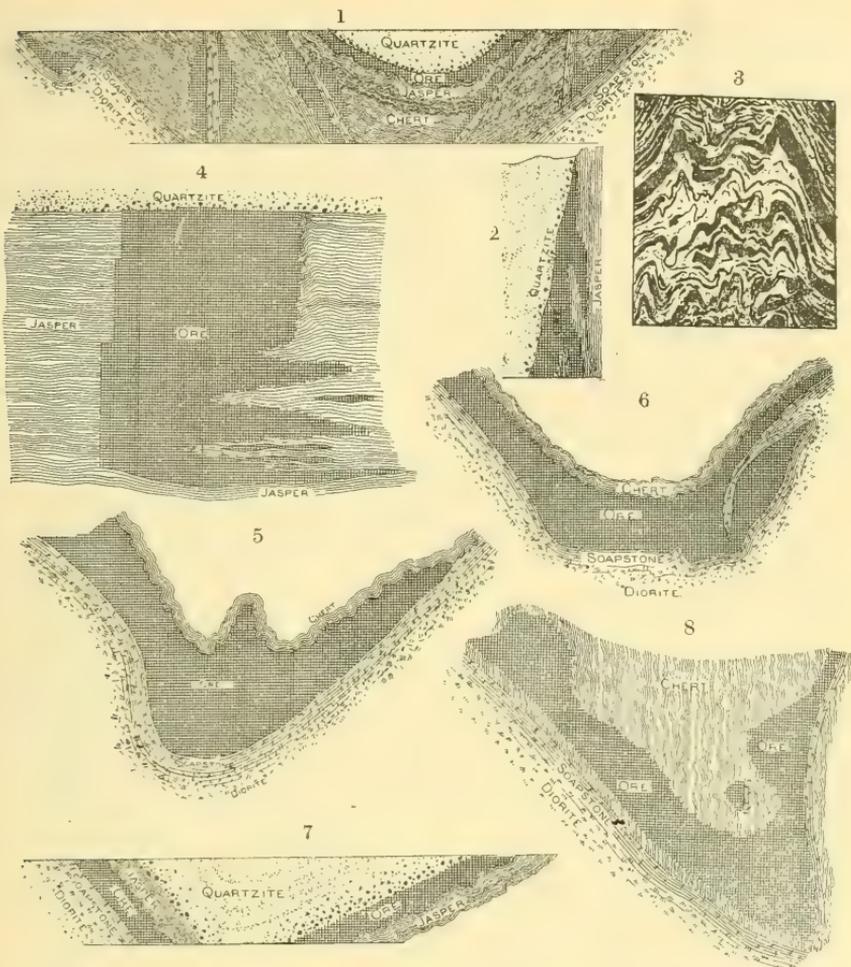


FIG. 1. Generalized section, showing relation of ore-deposits of Lower Marquette series to associated formations.

FIG. 2. Diagram showing tendency of an ore-deposit at contact of Lower and Upper Marquette series, to send offshoots into the jasper parallel to its lamination.

FIG. 3. Sharply plicated jasper (black belts) and ore (white areas), showing shattering of the jasper and concentration of the ore. The ore is proportionally greater where the folding has been the sharpest. Drawn from photograph.

FIG. 4. Horizontal section of ore-deposit on east side of Republic horse-shoe. Left side of ore bounded by a cross-joint; right side is bounded in part by a sharp flexure passing into a joint and in part grades into the lean banded jasper and ore.

FIG. 5. Vertical section of an ore-body, bounded below by soapstone grading into diorite, and above by ferruginous chert; change from ore to chert not so sharp as drawn.

FIG. 6. Another section of the same deposit shown in Fig. 5, but here is seen an offshoot of soapstone from the main mass.

FIG. 7. The ore upon left side rests upon soapstone grading into diorite and is not at the contact plane of the Upper and Lower Marquette; ore at right side is at this contact plane and rests upon jasper. The two combined have a synclinal appearance.

FIG. 8. At the left the ore rests upon the soapstone grading into diorite; at the right it is upon one side of a dike-rock. The dike is an offshoot of the diorite. At the contact of the two a trough is formed in which the ore-body becomes of large size. Figs. 5, 6, 8 from mine plats furnished by Mr. Thompson.

space between may be occupied by ore. When a dike is alone and has a flat dip the ore is always on the upper side, that is in such cases the dike rock is always the foot-wall of the deposit. (See fig. 1.)

A dike carrying ore may unite with a large mass of soap-stone varying to diorite, which also carries ore, when a trough will be formed and the deposit is here apt to become large. In this case we have a union of the second and third classes of deposits. At the locality shown in fig. 8 the soap-rock grades into diorite and dips south about  $45^{\circ}$ , constituting the main foot-wall. Standing vertical and striking  $20^{\circ}$  or  $30^{\circ}$  away from the foot-wall is a dike of paint-rock or soap-rock cutting across the formation. Resting upon both are ore-deposits, and by their union at the apex of a trough formed by the junction of the two the ore-body is of large size.

(4.) *Deposits interbedded in the jasper or chert.*—No deposits of this class of large size are known, for unless below is a soap-rock (when it would fall into a previous class) no impervious stratum is present upon which the ore can collect, unless (and this does not often occur) a layer of the ore-bearing formation itself locally loses porosity.

*The ore-deposits secondary concentrations.*—The ore-bodies of the second, third and fourth classes, that is all that lie wholly within the ore-bearing formation, are usually soft, and they may occur at almost any horizon within the iron-bearing formation. Being for the most part at some distance from the contact between the quartzite-conglomerate and ore-formation they are commonly within the ferruginous chert rather than in the banded ore and jasper.

The foregoing descriptions show how intimate is the connection between the ore-bodies and the paint or soap rocks. Mr. Thompson says this connection has become so evident to the miners, and they have such confidence that this material is a favorable indication, that it is called by them "the mother of the ore."

The ore-deposits in longitudinal sections are not horizontal, but generally have a pitch, which in the Ishpeming-Negaunee area is usually to the west and often amounts to as much as  $20^{\circ}$  or  $30^{\circ}$ . Consequently the ore-bodies represented in horizontal cross-section are found at different depths in following them longitudinally. This principle of pitch is equally applicable whether the underlying formation is jasper or soap-rock, whether the ore is in sheets, lenses or troughs.

While the ore-deposits of the Lower Marquette series have a greater variety of form and relations than do those of the Penokee district, it is evident that the conditions governing their formation are much the same. In both districts the

material immediately underlying the ore is relatively impervious to water. In the cases of these deposits which rest upon soap-rock this lack of porosity is nearly complete. Many of the ore-bodies are in troughs in the Lower Marquette series, as are nearly all in the Penokee district. The ore-bodies in both in longitudinal section have a pitch. In both the many phases of material found in the ore-bearing formation are nearly the same, and in both is found plentiful residual iron carbonate. It is therefore thought that the explanation of the origin of the ores in the Penokee district is applicable, with few modifications, to those of the Marquette district, although the larger number of the deposits of the latter belong to an older series.

The forms, attitudes and relations of the ore-deposits render it evident that they are not eruptives. No eruptive would be found in such strange shapes and relations. It is equally certain that these irregular masses of ore are not produced directly by sedimentation. All the facts bear toward the conclusion that the ore is a secondary concentration produced by the action of downward percolating water. When the facts are examined in detail, it is seen that the ore-deposits occur at places where circulating waters are sure to be concentrated. The soap-rock accommodates itself to folding without fracture, and while probably allowing more or less water to pass through, acts as a practically impervious stratum along which water is deflected when it once comes in contact with it. It is a common opinion among miners that a few inches of soap-rock is more effective in keeping out water than many feet of the iron-bearing formation. On the other hand, the brittle siliceous ore-bearing formation has been fractured by the folding to which it has been subjected so that where these processes have been extreme water passes through it like a sieve. That the tilted bodies of diorite or soap-rock, especially when in a pitching synclinal or forming a pitching trough by the union of a dike and a mass of diorite, must have guided downward-flowing waters is self-evident. The pitch common to other deposits is also evidence in these cases of laterally deflected downward-moving waters and indicates a wholly or partly impervious substratum even when its character has not yet been ascertained. It is also plain that the contact plane between the quartzite-conglomerate and the ore-bearing formation, that is, the plane of unconformity between the Upper and Lower Marquette series, must have been a great horizon for downward-flowing waters.

If it is true that the whole of the iron-bearing formation was originally a lean cherty carbonate of iron, with perhaps some calcium, and magnesium, or if we go no farther back than the ferruginous cherts and jaspers, it is then concluded

that in order to produce the ore, two things must have occurred: first, the concentration of iron oxide in the places where are found the ore-bodies; and second, the removal of silica from these places.

*Time at which concentration occurred.*—The final concentration of the Lower Marquette ores occurring at the contact of the Upper and Lower Marquette series must have taken place later than Upper Marquette time. This is indicated by the fact that while these ores are so frequently found at the contact plane the fragments of the overlying conglomerate are almost wholly of the lean chert or jasper, or magnetite-actinolite schist, and include few of the rich hard ore which if present ought to have yielded fragments. This not only shows that the final concentration had not occurred, but that the cherty carbonate (if the assumption be correct that the ore-formation was originally of this material) at the surface had been decomposed before Upper Marquette time. These conglomerates therefore give us an indication of the early character of a part of the ore-bearing formation from which the ore-bodies were later derived. The position of these ore-bodies at the contact plane of the Upper and Lower Marquette series is also evidence that they have been here concentrated subsequent to Upper Marquette time; for it is exceedingly improbable that erosion so generally stopped at a horizon rich in ore, a material which is softer than jasper and would therefore be more rapidly cut out. Further, this contact is not at a certain plane of the ore-bearing formation, but here is at a higher horizon and there at a lower one. Bearing in the same direction, although perhaps not strongly, is the occasional welding of the quartzite-conglomerate and ore-bearing formation already mentioned.

The relations of the ore-bodies within the ore-formation to the diorites and dike-rocks give evidence that the concentration of this ore has occurred subsequently to the intrusion of these rocks. It is certain that some of these eruptives are intrusives later than the Upper Marquette series, since they cut across the overlying quartzite. Others of them appear to have yielded fragments to the Upper Marquette series and therefore antedate these rocks. Finally if the ore bodies had become concentrated before the Upper Marquette folding and erosion, their invariable positions above the impervious formations would be inexplicable. The folding would perhaps have as often left them below as above these formations. Taking all the facts together, it is highly probable that the concentration of all the ores occurred during and later than the folding and erosion subsequent to Upper Marquette time.

*Manner of ore-concentration.*—Surface waters bearing oxygen passing downward through the Upper Marquette series or

the iron-bearing formation of the Lower Marquette series would decompose the iron carbonates with which they came in contact and thus become carbonated. These carbonated waters would then be capable of taking other iron carbonate into solution. What proportion of the original iron carbonate still remained in the ore-bearing formation at the beginning of concentration is uncertain, but since it is still found in places sheltered from percolating waters, such as the deeper workings of one of the mines and under diorite masses, it is probable that the quantity was very considerable. The oxides or carbonates of iron may also have been taken into solution by organic acids. These downward-moving waters would pass through the iron-bearing formation until they came in contact with an impervious substance or else, if passing through the Upper Marquette series, they reached the contact plane between the two series along which they would travel. It is possible that the ore which formed along the contact horizon was contributed in part by the ferruginous materials of the Upper Marquette series, although it is probable that the greater part of the ore here found came from material of the ore-bearing formation now removed by erosion. After the ore-bearing formation had been leached for a long time, it became as it is now found, very porous along the soap-rock and along the contact plane of the Upper and Lower Marquette series. Here would be carried other oxygen-bearing waters more directly from the surface. The union of these two currents would precipitate the iron oxide. The abundant waters traversing these ore-bearing localities would also slowly dissolve the silica. That this interchange actually does occur is known of the localities in which a detailed examination has been made, as for instance at Republic. It is probable that in the ore-deposits associated with the soap-rocks the removal of silica is due in part to them. Originally diabases, they must have contained alkalis, while analyses of them show at present an almost entire absence of these elements. The alkaline waters produced by their alteration would thus furnish a menstruum capable of taking the silica into solution. This desilicification of the iron-bearing formation by alkaline waters was many years ago suggested by Brooks,\* for a part of the Marquette district. Rominger† not only made the same suggestion in reference to the Jackson mine, but further held that the siliceous matter removed, was replaced by oxide of iron carried by water solutions.

The percolating waters which carried material along the readiest paths to form the ore-bodies, and which removed the silica also helped to jasperize the ore bearing formation, i. e. it charged the white silica with oxide of iron and thus reddened it, although it cannot yet be certainly stated to what

\* *Geol. of Michigan*, vol. i, p. 134.

† *Geol. of Michigan*, vol. iv, p. 75.

degree this process had already gone before Upper Marquette time. Whatever the time at which the work was done, the process seems to have been as follows: The upper part of the ore formation was traversed by solutions more extensively than the deeper lying portions. It naturally follows that the ferruginous material was in part deposited about and through the minute particles of silica, reddening them and changing the material from white chert to red jasper. In some places this jasperization has extended deeper than in others and, as already said, it sometimes abruptly stops at an impervious mass of soap-rock. Prof. Pumpelly suggests that before the secondary concentration which formed the ore-bodies, the bands of silica of the ore-formation were white and perhaps in a partly amorphous condition; that at the time of this concentration a partial recrystallization of the silica occurred, affording an opportunity for the ferruginous impregnation so characteristic of the jaspers. A microscopical examination shows that while most of the silica of the entire formation is now individualized, much of the iron oxide of the jaspers is concentrated about the particles of quartz, and that numerous minute flecks also occur within their interiors, thus giving support to Prof. Pumpelly's suggestion.

One or two questions remain to be considered: First, why the ore is so frequently hard and specular along the contact horizon or in the jasper and is usually soft within the ferruginous chert. Second, why the magnetites when present occur at the contact horizon.

An examination of the jasper associated with the hard ores shows that crystallized hematite and magnetite often occur in cavities formed by the removal of the silica. In such geodal cavities these materials have been deposited in a granular crystalline condition. In the continuation of the process the silica was wholly removed and its place taken by the crystalline hematite and magnetite. The adjacent jasper also shows that numerous cracks and fissures have been filled with hematite or magnetite. The manner in which these veins of coarser crystallized material frequently cut across the finer grained substance which represent the iron oxides present before the concentration, shows conclusively that they are secondary infiltrations. The formation of the coarsely crystalline hematite and magnetite thus appears to be connected with the abundance of iron-bearing solutions along the contact plane.

Oftentimes also the hard ores are of the brilliant micaceous or specular variety. In a hand specimen composed of rapidly alternating layers of ore and silica, where the folding has been severe, micaceous ore is often found between the rigid bands of quartz. Along these ferruginous zones is seen all the evidence of slickensides, and the micaceous character of the ore is seen to be due to the shearing to which it has been subjected.

Now the micaceous ore from the large deposits, as first suggested by Prof. Pumpelly, gives the same evidence of shearing. When it is remembered that in the folding of thick formations accommodations and re-adjustments must occur, it is natural to suppose that this re-adjustment has more largely taken place at the contact between the Upper and Lower Marquette series than at any other one horizon, for this is emphatically the plane of weakness. Thus would be explained the finely laminated micaceous variety of ore. It is not impossible that the heat and pressure caused by the shearing along the contact plane would be sufficient to change soft ore into micaceous hematite, but to the writer it appears more probable that these ores represent sheared specular hematite and magnetite. Since the final concentrations of the ores occurred during and subsequent to the folding of the series, it is necessary to believe that this shearing was a contemporaneous process, or else that after it occurred residual silica was replaced by iron oxide and that this metasomatic change did not affect the prior lamination of the original ore. Doubtless both explanations are applicable in varying degrees at different places.

That it is easy to reduce hematite to magnetite is well known, and it is probable that the production of the granular infiltrated variety of this ore is due to the reducing character of some of the solutions which have passed down along the great contact plane of percolation where the magnetites are extensively found. This reducing power could readily be imparted by organic acids. That some kind of reducing agent has been present is indicated by the veins of pyrite which are frequently associated with the magnetic ores.

It is supposed that the magnetite of the magnetite-actinolite schists is due to the direct oxidation of an original carbonate of iron. This is known to be true of the Penokee and Animikie magnetites and also of the magnetite of the Lower Marquette series in the deeper workings of one of the mines. When iron carbonate is decomposed in the presence of an excess of oxygen the sesquioxide is of course formed; but if it is supposed that an insufficient amount of oxygen was present, as is quite probable, from three molecules of iron carbonate would be produced one molecule of magnetite and three of carbon dioxide, if only a single atom of oxygen was available.

*Ores of the Upper Marquette series.*—The ore-deposits of the Upper Marquette series, so far as studied, show that the original material was an iron carbonate and that the ores are secondary concentrates resting upon impervious formations. Sometimes this impervious formation is a black slate; at other times it is an intrusive basic eruptive; and at still others it is a surface volcanic. As a consequence of folding, or by the junction of two of these basal formations, and of concentra-

tions, the ores occupy troughs or the sides of synclinals. That the ore is a concentrate from an original impure iron-bearing carbonate is easily shown. Wholly unaltered carbonate, often accompanied by organic matter, is abundant, and all stages of the change into the soft hematites and limonites of the Upper Marquette series are seen.

*Ores of other districts.*—In the Menominee district the ores, as in the Marquette district, occur in two formations, one of which belongs to the Lower Menominee, correlated with the Lower Marquette series, while the other belongs to the Upper Menominee, correlated with the Upper Marquette series. The Upper Menominee is more important as an ore-producer than the Upper Marquette. A detailed study has been made of only a small number of the mines, but a general study has covered nearly the entire district. So far as work has gone, while there will be some modifications of detail, the principles have been found thus far to hold that the ores are secondary concentrations upon impervious formations, and are particularly likely to be of large size when these are folded or two combine to form pitching troughs. Also, as in the Marquette district, the basement impervious formations are often igneous and not infrequently are surface volcanics. At other times, and especially in the Upper Menominee series, the impervious stratum is a detrital slate. As typical instances of the Menominee mines may be mentioned the following: At the Armenia the ore-body is at the bottom and upon the sides of a synclinal trough, pitching at an angle of about  $45^{\circ}$ . Below the ore is an impervious black slate. At the Mansfield mine the ore-body nearly vertical laterally but pitching longitudinally, has impervious slates upon each side, one of which is clearly a volcanic rock. The ore of the Hemlock mine rests upon an impervious stratum consisting of surface volcanic material.

The ores of the Vermilion Lake district have been studied by us only in a general way, but so far as our investigation has gone all the facts bear toward the conclusion that the principles here hold which are applicable to the other iron-bearing districts of the Lake Superior region. It is true that Prof. N. H. Winchell and H. V. Winchell\* have proposed a chemical theory for the origin of the rocks of the iron-bearing formation which does not derive it from a lean iron-bearing carbonate; but even if this theory be accepted (and I do not hold it), it is applicable to the ore-bearing formation rather than to the ore-deposits. The descriptions and figures of the mines published by the late Prof. Alex. Winchell and by Prof. N. H. Winchell, seem to me to be wholly in harmony with our own observations, and to indicate that the Vermilion Lake ores are sec-

\* The Iron Ores of Minnesota, N. H. and H. V. Winchell: Bulletin No. 6, Geol. and Nat. Hist. Survey of Minn., Appendix A, pp. 391-399.

ondary concentrates which usually rest upon impervious formations.\*

As instances among the mines figured by these authors may be mentioned the following: The ore of the Ely mine is found between impervious schists, the layers of which are inclined. At the Stone mine the ore in its upper workings is in two bodies, each of which rests upon green schists. In its deeper workings these are found to come together and make a solid mass of ore. The ore grades above into the jasper, which is like a great horse separating the upper parts of the deposit. In short, the relations so far as principles are concerned, are much the same as shown in figure 8, taken from a deposit in the Marquette district. At the Chandler mine the ore has its greatest length along and rests upon as a foot-wall, a great mass of greenstone. The upper boundary of the ore is irregular and grades into mixed ore and jasper. It is said of the Ely that the "ore is quite open to the action of percolating water," and that the material shows the effects of crushing and folding. The schists associated with the ores in the Vermilion district are regarded by the Professors Winchell as well as by us as of igneous origin.†

The facts given by these writers then seem to show that the ore is a secondary concentration, instead of that the "ore and jasper" are "of similar and contemporaneous origin." Indeed in the report upon the Vermilion ores, published soon after returning from the field, Prof. N. H. Winchell held, although this position was later abandoned, that the iron ores are later than the siliceous jasper and probably produced by metasomatic change.

It is fully recognized that the explanation above given for the ores of the Lake Superior districts in which mining is now being done, is not wholly if at all applicable to the titaniferous magnetites of northeastern Minnesota associated with the great gabbro flows near the base of the Keweenaw series. In the interstices of these magnetic ores are olivine, augite, feldspar, and often secondary quartz, the whole having a completely crystalline interlocking structure; in other words, they are no more than a very magnetic gabbro. Since these ores occur as basal horizons of the great gabbro flows, it has always seemed to me that this class of deposit is of direct igneous origin. In the crystallization of basic rocks, magnetite is one of the early minerals to separate, and in the immense masses of gabbro, before the magma has solidified the crystals of magnetite have slowly settled by virtue of their superior specific gravity to the

\* Fifteenth Ann. Rept. Geol. and Nat. Hist. Survey of Minn. for the year 1886, pp. 24, 25, 221, 235, 255. Bulletin No. 6, Geol. and Nat. Hist. Survey of Minn., pp. 63-67.

† Fifteenth Ann. Rep. Minn., pp. 231, 245, 246; Minn. Survey Bull. vi, pp. 64, 394, 398, 399.

base of the flow, forming thick layers of magnetite. The residual magma has crystallized as the interstitial minerals, and thus we have the titaniferous magnetites of the gabbros. A recent petrographical study by Dr. W. S. Bayley has shown that a part of the magnetite is secondary. As these ores are associated with abundant secondary quartz it is not impossible that much of the magnetite has been brought to its present position after the solidification of the rock.

*General.*—It is evident that the ores of the Upper Marquette series, like those of the Lower, were concentrated during and subsequent to the folding and erosion which affected both. Thus while the ore bearing formation of the Lower Marquette series is far older than that of the Upper Marquette, and had undergone great changes before the latter was deposited, the local concentration of the iron into workable deposits occurred simultaneously as a consequence of the same great causes. This statement also applies, so far as present knowledge goes, to the two iron-bearing series of the Menominee district. The Penokee series is equivalent to the Upper Marquette and Upper Menominee. The equivalency of the Animikie and the Penokee series and their simultaneous tilting into monoclines on opposite sides of the Lake Superior synclinal has been shown in another place.\* It is also shown that this tilting, and consequently the concentration of the ores, occurred subsequently to Keweenawan time. It was suggested that the basic intrusives of the Penokee series upon which the ore-deposits rest are of Keweenawan age. Is it not probable that many of the basic intrusives of like character in the Marquette and Menominee districts are products of the same period?

It appears then probable that the local concentration of the iron ores into workable bodies did not generally begin before Upper Huronian time, while in certain districts it did not begin until much later. That the process has yet ended we have no evidence. The ores of the Lake Superior region occurring in two geological series are remarkably alike. This likeness is plainly due to their similar genesis.

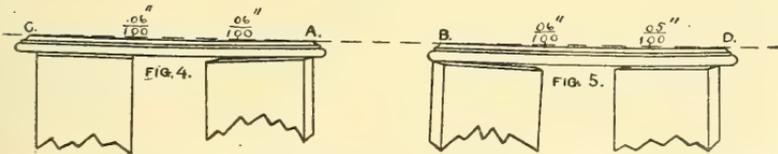
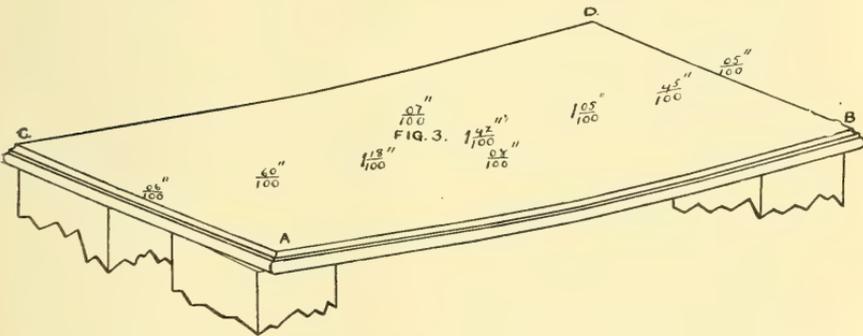
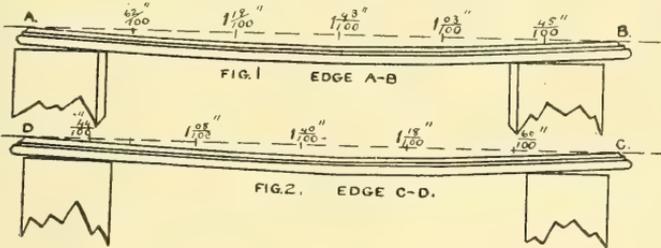
This paper must be considered as an account of the progress of an investigation rather than a complete exposition. While it is possible that a further study will make necessary a modification of certain minor points, it is believed that the principle of secondary concentration along great channels of downward percolating waters, and particularly at places where these waters are converged by tilted impervious formations is nearly if not quite of universal applicability to the workable ore-deposits of the Lake Superior region.

United States Geological Survey,  
Lake Superior Division, Madison, Wis., December, 1891.

\* Tenth Ann. Rept. U. S. Geol. Survey for 1888-89, pp. 402-408, 458-460.

ART. XVI.—An Illustration of the Flexibility of Limestone; by ARTHUR WINSLOW.

THE adjoining cut illustrates an interesting case of the flexing of a limestone slab under moderate stress, applied for a long time. The slab is of white, crystalline limestone or inferior marble and is one of a number in the State lot of the cemetery of Jefferson City, Missouri. Others are seen there



Sketch showing deflection of a limestone slab, due to its weight. Scale 1 inch = 2 feet. Stone erected to memory of Tyrrel P. Bruton, Cemetery, Jefferson City, Mo.

NOTES.—The dimensions of the slab are 6 ft. x 3 ft. x 2 in. It was put in place in the year 1866. The measurements were made August, 1890. The deflections are expressed in inches.

in the same conditions, though the flexing in these has not proceeded so far. It is probable that, in the one illustrated, the extreme condition, without fracture, has already been reached,

if it is not passed, as hair-like lines of incipient fracture are already observable on the lower side of the slab, near its center, running transversely to the length. The slab in question has been in place about 25 years, and the supporting corner posts have settled in such a way that the bearing of the slab upon them is generally only along one edge or along a part of one edge. The carefully made drawing from which the cut is prepared shows all details so well that further description will be unnecessary.

The measurements for this drawing were made by the writer assisted by Mr. A. E. Woodward,\* late assistant geologist of the Missouri Geological Survey, and the drawing was prepared by the latter. The deflections were determined by stretching a fine wire tightly across the block from edge to edge, and then measuring the space between the wire and the slab at any desired point with the aid of a pair of dividers. The length of the slab, it will be noticed, is 6 ft., the breadth 3 ft., and the thickness 2 inches. The distance lengthwise, between supports, is about 4 ft., and crosswise between 1 and 2 ft. The sag at the center of the slab, along the lines A-B and C-D, is nearly  $1\frac{1}{2}$  inches, beneath the two ends, or about  $\frac{1}{10}$  of the total length, or about  $\frac{1}{3\frac{1}{2}}$  of the distance between the supports. Assuming the curve to be the arc of a circle, the radius of the circle would be about 37 ft.; or, in other words, a long slab of such marble 2 inches thick, could, under continued stress for a period of twenty-five years, be bent to the form of a circle less than 80 ft. in diameter.

A more detailed study of the measurements yields other facts of interest. Thus an extreme sensitiveness to stress is indicated by the transverse flexing between points of support close together; this is shown by the sections along the lines A-C and B-D. Further, it will be noticed that, along the sections A-B and C-D, the measurements indicate convex undulation between the center of the slab and the points B and D, due to a recurving downwards of the end of the slab, which projects beyond the point of support. At the other end, however, the support is nearer the end of the slab, and here the curvature is continuously concave.

\*Died September, 1891.

ART. XVII.—*The Separation of Iron, Manganese and Calcium by the Acetate and Bromine Methods*; by R. B. RIGGS.

HAVING in hand the analysis of a series of samples containing iron, manganese and calcium in large amounts, it seemed advisable to test the two analytical methods involved, namely, the separation of iron from manganese by precipitating it as a basic acetate, and the separation of manganese from calcium by means of bromine. The object was not so much to test the accuracy of the acetate process as to determine the conditions favorable or otherwise to its successful use. In the case of the manganese-calcium separation on the contrary, the value of the method was in question, for where either or both constituents are present in quantities its accuracy has been doubted.

For convenience and accuracy standardized solutions of the three substances were used. Piano wire was the basis of the ferric chloride solution. This was dissolved in hydrochloric acid and oxidized by means of nitric acid. The nitric acid was in turn expelled by repeated evaporations with hydrochloric acid. Last traces of ferrous iron were oxidized by bromine. The value of this solution was found by means of a standard\* permanganate solution.

Weight of FeCl <sub>3</sub> solution taken. gram.	Weight of Fe found. gram.	Weight of Fe in 100 grams of solution. gram.	Mean.
(1.) 20.32	0.14957	0.7378	0.7382
(2.) 20.335	0.15017	0.7385	
(3.) 20.30	0.14957	0.7383	

For the manganese chloride solution, manganese dioxide was the starting point. This was digested with nitric acid, dissolved in hydrochloric acid and nitric acid—twice evaporated to dryness and filtered—treated three times by the basic acetate process (each time allowing a considerable precipitation of manganese), and recovered from solution each time by a bromine precipitation. The last precipitate was dissolved in hydrochloric acid and the excess of acid expelled by evaporation. This solution was standardized by determining the manganese as pyrophosphate.

Weight of MnCl <sub>2</sub> solution taken gram.	Weight of Mn <sub>2</sub> P <sub>2</sub> O <sub>7</sub> found. gram.	Weight of MnO in 100 grams of solution. gram.	Mean.
(4.) 9.98	0.1346	0.6743	0.6739
(5.) 10.095	0.1360	0.6735	

\* The permanganate solution was standardized with the same wire so that the results are relatively correct.

The solution of calcium chloride was prepared from calcium carbonate purified by repeated precipitations, as carbonate, by means of ammonium carbonate. It was free from iron, alumina and alkalis.

	Weight of CaCl <sub>2</sub> solution taken. gram.	Weight of CaO found. gram.	Weight of CaO in 100 grams of solution. gram.	Mean.
(6.)	20·094	0·1133	0·5638	} 0·5633
(7.)	20·18	0·1136	0·5632	
(8.)	20·19	0·1135	0·5630	

My experiments began with analyses of solutions containing known quantities of the three substances. From this they grew and though the order may be the reverse of a logical one it had best be followed in giving the results.

In the first and second series the quantities of iron and calcium were constant, the manganese was variable. In a third series, containing only manganese and calcium, the proportions of each were varied.

The general mode of operating was the following:

The solutions, containing, in the first and second series, the equivalents of about 0·2 grams of iron and 0·17 grams of calcium oxide and quantities of manganese oxide varying from 0·03 to 0·2 grams, were diluted to 350–400<sup>c.c.</sup> To secure the usual conditions of analysis, and because ammonium salts tend to hold manganese in solution, 10<sup>c.c.</sup> of hydrochloric acid were added. The cold solution was neutralized with ammonia containing ammonium carbonate. The precipitate that might be formed was dissolved with as little as possible hydrochloric acid and 5 grams of ammonium acetate\* added.

For the precipitation of the iron and the conversion of the salts of the other elements into acetates, this is an unnecessary excess and because of its possible reducing action on the iron, such an excess should in general be avoided. But, preliminary experiments having been made, it was believed that with proper care the reduction of the iron might be avoided. To further test this opinion and because of the influence of † ammonium acetate in holding manganese salts in solution, this excess was added.

Two acetate precipitations were made. The iron was thrown down a third time with ammonia. In but two cases (Nos. 14 and 17) did the third filtrate contain manganese. In making this separation care was taken not to digest the iron precipi-

\* The ammonium acetate was prepared by neutralizing ammonia with acetic acid and an amount taken which would be equal to about 5 gr. of the salt.

† Experiments seemed to show that the influence of ammonium acetate in holding manganese salts in solution, though the solution be ammoniacal, is somewhat greater than that of the chloride of ammonium.

tate too vigorously nor too long and as a result there was in no case any appreciable reduction.

The filtrates from iron, being united, were evaporated to 400–500<sup>c.c.</sup>, 10<sup>c.c.</sup> of ammonia, followed by 250–350<sup>c.c.</sup> of bromine water, were added to the hot solution, which was then heated on the water bath until the precipitate gathered leaving a clear colorless supernatant liquid. If digested over a direct flame the separation may be hastened.

The success of this precipitation depends largely on treating the solution hot. If bromine be added to a cold solution the oxidation is slow and often less complete. The addition of bromine to the solution already made ammoniacal seems preferable to a reversal of the order as it insures a more uniform oxidation.

Three bromine separations were made, the manganese precipitate being dissolved in hydrochloric and sulphurous acids. In no case did the third filtrate show calcium. The first and second filtrates from manganese were united. The volume was reduced to 300–400<sup>c.c.</sup> and the calcium was thrown down as oxalate and weighed as oxide.

The manganese was weighed as pyrophosphate. The iron was determined by the standard solution of permanganate.

The following are the results.

	Weight of Fe taken. gram.	Weight of Fe found. gram.	Weight of CaO taken. gram.	Weight of CaO found. gram.	Weight of MnO taken. gram.	Weight of MnO found. gram.
( 9.)	0·2254	0·2251	0·1699	0·1690	0·0341	0·0355
(10.)	0·2248	0·2251	0·1700	0·1687	0·0680	0·0689
(11.)	0·2252	0·2248	0·1700	0·1696	0·1092	0·1094
(12.)	0·2251	0·2251	0·1700	0·1705	0·1500	0·1501
(13.)	0·2254	0·2253	0·1702	0·1697	0·2043	0·2053

Error in weight of	Fe gram.	CaO gram.	MnO gram.
( 9.)	0·0003 —	0·0009 —	0·0014 +
(10.)	0·0003 +	0·0013 —	0·0009 +
(11.)	0·0004 —	0·0004 —	0·0002 +
(12.)	0·0000	0·0005 +	0·0001 +
(13.)	0·0001 —	0·0005 —	0·0010 +

Experience tells us, that in dealing with such precipitates as those of iron and manganese, repeated precipitation is necessary. In analyzing this necessity and determining its limitations a series of partial separations was made, and the quantities of manganese and calcium in each of the several respective filtrates was determined. The iron, of which about 0·22 grams was added in each case, was undetermined.

	Weight of Fe taken. grm.	Weight of MnO taken. grm.	Weight of MnO found in				Total. grm.	Error. grm.
			1st filtrate from Fe. grm.	2d filtrate. grm.	3d filtrate. grm.			
(14.)	0·2248	0·3341	0·0342	0·0005	none	0·0347	0·0005 +	
(15.)	0·2248	0·0678	0·0681	0·0006	trace	0·0687	0·0006 +	
(16.)	0·2250	0·1088	0·1073	0·0013	none	0·1086	0·0002 —	
(17.)	0·2252	0·1500	0·1477	0·0024	none	0·1501	0·0001 +	
(18.)	0·2253	0·2042	0·2003	0·0034	trace	0·2037	0·0005 —	

	Weight of CaO taken grm.	Weight of CaO found in				Total. grm.	Error. grm.
		1st Fe filtrate.		2d Fe filtrate.			
		1st Mn filtrate. grm.	2d Mn filtrate. grm.	grm.			
(14.)	0·1700	0·1650	0·0025	0·0020	0·1695	0·0005 —	
(15.)	0·1700	0·1640	0·0044	0·0010	0·1694	0·0006 —	
(16.)	0·1702	0·1611	0·0074	0·0013	0·1698	0·0004 —	
(17.)	0·1700	0·1640	0·0038	0·0016	0·1694	0·0006 —	
(18.)	0·1701	0·1614	0·0059	0·0023	0·1696	0·0005 —	

In separating calcium from manganese in the first filtrate from iron three precipitations were made. In no case did the third filtrate contain enough calcium to show.

From the above analyses the necessity of two precipitations in separating manganese from iron and calcium from iron and manganese is evident. More than that seem superfluous.

In general the amount of manganese found in the second filtrate from iron is proportional to its total quantity. It frequently happens however that in neutralizing the solution, preparatory to the acetate separation, the manganese is precipitated and partially oxidized, in which case its resolution is impracticable. This oxidation is probably due rather to the action of the air than to any after effect of acetic acid. In separating manganese and calcium the completeness of a single separation seemed to depend, if anything was to be inferred from the above analyses, as well on the nature of the manganese precipitate as on its quantity.

It will be noticed that the manganese errors, with but one exception (16) are positive and the calcium errors, with one exception (12), are negative. This is to be anticipated. The positive error in the case of manganese comes from the use of a non-volatile precipitant. The negative error of calcium is probably owing to the fact that the oxalate is not absolutely insoluble.

The indications being that two precipitations are necessary, where the calcium and manganese are either or both present in quantities, a series of separations was made varying both

constituents. That the conditions of the previous analyses might be approximately kept, 5 grams of ammonium chloride and 10 grams of ammonium acetate were added in each case. Only the calcium of the first manganese filtrate was determined.

	Weight of MnO taken. gram.	Weight of CaO taken. gram.	Weight of CaO found in 1st filtrate. gram.	Loss. gram.
(19.)	0.2042	0.1702	0.1639	0.0063
(20.)	0.1020	0.1705	0.1638	0.0077
(21.)	0.0508	0.1702	0.1662	0.0042
(22.)	0.0207	0.1702	0.1682	0.0018
(23.)	0.2039	0.0848	0.0779	0.0069
(24.)	0.1020	0.0849	0.0831	0.0018
(25.)	0.0516	0.0855	lost	----
(26.)	0.0204	0.0846	0.0833	0.0013
(27.)	0.2037	0.0423	0.0399	0.0024
(28.)	0.1023	0.0427	0.0421	0.0006
(29.)	0.0512	0.0424	0.0415	0.0009
(30.)	0.0203	0.0428	0.0421	0.0007
(31.)	0.2037	0.0171	0.0141	0.0030
(32.)	0.1023	0.0173	0.0158	0.0015
(33.)	0.0509	0.0170	0.0167	0.0003
(34.)	0.0207	0.0171	0.0162	0.0009

These results indicate that the amount of calcium, carried down with the manganese, depends largely on the relative quantities of manganese and calcium. However this may be it is evident that where the amounts of each are not less than 0.02 grams a double precipitation of manganese should be made.

Having introduced such large quantities of ammonium salts into the solutions the question of effect on the oxalate precipitate was raised. Attention has been called to the negative calcium error. Is this due simply to the solubility of the oxalate or is it the sum of large positive\* and larger negative errors?

In answer to this suggestion a number of calcium determinations were made, in which the previous conditions, as to quantity of ammonium salts and volume of solution, were observed.

\* The source of positive error would be the reagents and glass ware. The operations, excepting the precipitation of manganese by bromine, were carried on in platinum. The ammonium hydrate and sulphurous acid were freshly prepared. The other reagents were carefully tested.

	Weight of CaO taken. gram.	Weight of CaO found. gram.	Error. gram.
(35.)	0·1136	0·1131	0·0005—
(36.)	0·1138	0·1135	0·0003—
(37.)	0·1136	0·1136	0·0000
(38.)	0·1139	0·1137	0·0002—
(39.)	0·1136	0·1132	0·0004—
(40.)	0·1138	0·1133	0·0005—

The solutions 300<sup>c.c.</sup> contained approximately 5 grams of the chloride, 5 grams of the acetate and 10 grams of the bromide of ammonium. The inference is that their influence in restraining the oxalate precipitation is slight.

Summary: In precipitating iron as basic acetate it is probably better to avoid a great excess of the acetate. A considerable excess need not however interfere with the separation. While an acetate solution favors the reduction of iron, with care this reduction may be avoided. The precipitate should not be digested too vigorously nor too long.

In neutralizing the solution, preparatory to the acetate separation, a slight precipitate of manganese, due to oxidation, is almost always formed. This influences more or less markedly the completeness of a single separation. It cannot be wholly avoided, though the effect of the presence of ammonium salts, in holding manganese salts in solution, is probably beneficial. While the manganese remains in solution oxidation cannot take place.

In precipitating manganese from an ammoniacal solution by means of bromine the presence of acetates is desirable. The oxidation is more rapid, hence more complete than in a solution free from acetates. Bromine water should be added to the hot ammoniacal solution. If the solution be cold the oxidation is slow and in the end often incomplete. The addition of bromine to the solution already made ammoniacal seems preferable to a reversal of this order as it insures a more uniform oxidation.

Where either the calcium or the manganese is in excess of 0·02 grams two precipitations are necessary.

In conclusion it may be said that, in the hands of a careful analyst, both methods are, according to present standards accurate.

Chemical Laboratory, Trinity College,  
Hartford, Nov., 1891.

ART. XVIII.—*The Central Massachusetts Moraine*,\* by  
RALPH S. TARR.†

UPON the plains of the Central States the ice of the last glacial period has registered, with distinctness, the various halts in its recession. The record of the ice retreat in this region has been worked out in admirable detail by the glacialists in charge of this work. Rapid retreats, temporary halts and slight readvances are here indicated by the glacial deposits.

The disappearance of the ice from New England must have been marked by very nearly the same history, but the detailed record of this retreat has not yet been studied. This is due in part to the fact that until recently no systematic studies of the glacial deposits of New England have been undertaken, but chiefly to the fact that the record left by the ice, as it melted away, is obscure. This obscurity is the result of the topographic diversity of the region. Upon a plain a slight moraine becomes a marked topographic feature, but amid the hilly district of New England its importance is masked by the more striking undulations and reliefs. In addition to this the very fact of the diversified topography has made the minor moraines actually less distinct and hence more difficult to study than would have been the case on a level country. The ice margin must have conformed in a measure to the topography, and hence the deposits must have varied in distribution with the variations in altitude and relief. Not only was their distribution so influenced but also their character. The rapid water currents rendered possible in a hilly country swept away portions and modified others.

For several years Prof. N. S. Shaler has been conducting detailed studies of the glacial deposits of Massachusetts and the neighboring states and eventually, if his plans are carried out, the record of the ice retreat in this region will be definitely known. As an assistant in this work during several summers it was my fortune to find and trace out, in part, a distinct morainal band in Central Massachusetts, marking a temporary halt in the recession of the glacier, and it is this that I shall briefly describe.

On the islands off the southern coast of New England a well defined terminal moraine has long been known and well de-

\* Published by permission of the Director of the United States Geological Survey.

† I am indebted to Prof. J. D. Dana and Mr. Warren Upham for valuable suggestions which have aided in the preparation of this paper as well as to Prof. N. S. Shaler, under whose direction the field work, upon which these results are based, was done.

scribed by various observers. It seems to be established that this moraine marks the point of the glacier for the greater part of its long stand upon this part of the continent. Patches of morainal matter have been noticed and described from various parts of New England, by Mr. Upham and others, but no continuous lines of moraine have been traced for any considerable distance. Some of these morainal patches have been supposed to mark local glaciers remaining upon the higher lands after the main ice mass had disappeared.

A singular morainal area was described by Prof. Shaler in the Ninth Annual Report of the U. S. Geological Survey, as occurring at Cape Ann on Massachusetts Bay. As an assistant in this work my attention was called to this deposit several years ago and its boundary within the area was traced with considerable accuracy. At that time it was not known that this bit of moraine was connected in any way with any other, but subsequent studies of the glacial deposits have pointed to a somewhat continuous moraine from Cape Ann nearly to the Connecticut River. Beyond the Connecticut morainal deposits have not been identified with certainty, excepting in some of the larger stream valleys; and the connection of these apparently isolated moraines with the Central Massachusetts moraine has not been definitely established.

The Cape Ann moraine has been fully described by Prof. Shaler,\* with numerous illustrations from photographs. In general it occupies a large part of the island of Cape Ann and of the mainland to the west and southwest. On the island it covers the major part of the interior, but is rarely found in perfect development below the one hundred foot contour line, this part of the island being chiefly bare bed rock as if wave-swept. The morainal boundary is roughly circular, with an average diameter of not more than four miles. It is completely separated from the moraine on the mainland to the westward by the inlet or "reach" of "Squam River," but above the one hundred foot contour line it begins again occupying a wooded strip, with a width of from one to four or five miles, in the towns of Manchester, Essex and Gloucester. Farther still to the west the moraine becomes narrower but is distinctly traceable in the vicinity of Chebacco Pond, Wenham, and farther west to the extreme boundary of the Salem sheet of the Massachusetts topographical atlas.

This band of moraine is twenty miles long, and the width varies from a few hundred yards west of Wenham to four or five miles east of that town. The average width is not less than a mile. From the western part of the Salem street to

\* Ninth Annual Report U. S. Geol. Survey, pp. 529-611.

Ayer Junction, a distance of twenty-four miles I have had no opportunity for studying the surface geology, but just southeast of Ayer Junction distinct morainal deposits are found and a quite continuous band of moraine extends from here westward to the Connecticut river, passing south of Winchendon, Royalston, Orange and Turner's Falls. This line of moraine is fifty miles long and thus from Cape Ann to the Connecticut, a distance of ninety-four miles, moraine has been found in seventy miles, the remaining twenty-four not having been examined.

To briefly describe the Cape Ann moraine it may be said that the essential features are sharp peaks and hummocks of drift, completely enclosed kettle-holes of unstratified drift, and a surface thickly strewn with boulders chiefly of granite locally derived. While the entire surface is boulder strewn, the most excessive development of bowldery deposits is in trains, or parallel bands extending a little north of east at right angles to the direction of glacial motion. There are several square miles of such bowldery places on Cape Ann where the boulders are literally piled one upon another with rarely any soil showing. A better development of the "bear-den" moraine would be difficult to find. Parallel with these bowlder lines are ridges of drift and the corresponding valleys.

While the material composing the moraine is considerably less clayey than ordinary till it is, with rare exception, an unstratified deposit quite closely resembling till. A few patches of stratified drift and a single serpent kame occur on the island.

On the mainland west of Cape Ann much the same character marks the moraine, except that boulders are less numerous, as long as the moraine rests on the granite. Where it is found upon the metamorphic rocks as in Wenham and westward the boulders decrease perceptibly in abundance and size, the deposits are more sandy and they merge more commonly into stratified deposits. At the same time the distinctly "shoved" moraine narrows. These facts are undoubtedly to be referred in part to the change in character of supply, but chiefly to the more moderate relief which permitted the deposition of sand and gravel deposits. Some of the morainal peaks are partly buried beneath such deposits.

In the region between Ayer Junction and the Connecticut River the morainal accumulations are quite puzzling. The country is hilly and deeply scored by both east and west and north and south valleys. The result has been a complicated distribution of the morainal deposits which renders exact statements concerning the detailed history of their formation quite

impossible at present. The distribution is in more or less continuous patches; but distinct lines of moraine cannot be traced for any considerable distance, their continuity being interrupted by the irregularity of the topography. As the result of this we find a series of scalloped, serrated lines in the general moraine. These lines and the entire moraine are sometimes broken, yet the general continuity of the deposit is undoubted, for the breaks are rarely a mile in length.

A vacillating condition at this place is indicated by the great width of the morainal deposits. The moraine-covered tract is often eight or ten miles in width and isolated patches of "shoved" moraine are found both to the north and south of this.

The central Massachusetts moraine is typically developed at Winchendon, Gardner, and south of Athol and Orange on the Winchendon and Warwick sheets of the Massachusetts topographical map. A detailed description of the moraine on the various sheets will be found in Prof. Shaler's forthcoming monograph on the Surface Geology of Massachusetts. It presents all the features of a typical "shoved" moraine, being rough in outline and boulder strewn, having hummocks and kettles of unstratified drift and being associated with stratified drift both of contemporaneous and subsequent origin. This stratified drift is of the sand plain, esker and valley drift types. In places the morainal hummocks are made up of roughly stratified layers of till and gravel, they are at times partly and even entirely covered by stratified drift of the overwash type, and sand plains are not uncommonly found amid the morainal peaks and kettles. No distinct frontal apron exists, for the diversity of the topography would not admit of such well defined level deposits.

These observations prove that the ice halted in its retreat from New England at about the line occupied by this moraine. The halt was not of sufficient duration to permit of the formation of a strikingly well defined moraine yet it was long enough for the formation of a well defined morainal band. The varying width in the central part of the State points to some vacillation in the ice front at this place, though this does not seem to have been the case in the eastern part of the moraine near the coast line.

One of the striking features of the central Massachusetts moraine is its east and west course, since its linear extension is in general direction slightly diagonal to the glacial striæ. This is particularly the case in its sea coast end where it can be traced continuously for a score of miles nearly due west, whereas the striæ point usually N. 25 W. or even more. Even

in the interior the moraine does not swerve to the southwest showing that the highlands of the northern central part of the State and of New Hampshire exercised little influence upon the ice front. It may be said, however, that the glacial striæ in this part of the State point nearly north and south, the southeasterly trend near the sea coast being very likely due to the influence of the easterly sloping coast border.

Since this moraine has not been traced west of the Connecticut nothing can be definitely said with regard to its westerly continuation. It seems probable, as suggested to me by Prof. Dana, that the influence of the very marked highland region of the Berkshire Hills in Western Massachusetts must have caused a southward extension of the ice margin west of the Connecticut. In the region about Pittsfield and North Adams, particularly in the larger valleys, there are patches of bowldery, hummocky, partially stratified drift which seem to be morainal in character. No attempt can be made to correlate these with the central moraine at this time.

It is hardly probable that between the Long Island moraines and that of central Massachusetts the recession of the ice was so uniform and rapid that no sign of its retreat was left and the facts in the field seem to show that this was not the case. My studies have been in the main in isolated districts in Massachusetts, Connecticut and Vermont, so that aside from the moraine just described it is not possible for me to state definitely that other bands of moraine exist. Still, both south and north of this moraine, I have found isolated patches of true shoved moraine, though nowhere has it been found to have the well marked development noticed in that of central Massachusetts. Such deposits have been noticed in the vicinity of Worcester, Mass., in southeastern Massachusetts, Waterbury, Connecticut and southern Vermont, and other observers have described moraine in New Hampshire.

None of these deposits have been studied in detail and with a view to their relation to one another, but without doubt, when they are so studied it will be found that the history of the disappearance of the ice sheet from New England was, like the ice of the upper Mississippi valley, one of numerous halts and slight readvances, though the records left will be found to be much less distinct in New England than in the west.

ART. XIX.—*Proofs that the Holyoke and Deerfield Trap Sheets are Contemporaneous Flows and not later intrusions*; by BEN K. EMERSON.

IN the concluding paragraph of his most interesting article on the Trap Rocks about New Haven,\* Professor Dana is inclined to make the results he has reached regarding the traps and sandstones of the New Haven region general for those of the whole Connecticut Valley.

He concludes that these traps are subsequent to and intrusive in the sandstones and not “poured out in one, two or more horizontal sheets, separated, and overlaid horizontally by beds of sandstone.” The essential point in this contention, if I understand aright, is that the traps associated with the Triassic sandstones are all newer than these sandstones.

The following is presented as an abstract of the proofs that all the main trap sheets in Massachusetts are contemporaneous flows, and easily distinguished from the smaller intrusive masses.

1. At the upper surface of the Deerfield bed of trap east of the mouth of Fall River opposite to Turner’s Falls, a perfect ropy surface of flow is exposed and the soft red shale folds round the curved surfaces and into the deep grooves in a way only possible by a surface flow. The red sand can be picked out of open steam holes on the surface, as the bed is strongly vesicular at surface. At the base it is here aphanitic and the sandstone is baked into a black hornstone-like mass.

2. At the base of the same bed several miles south in the north edge of Greenfield, the cliff has been cleared at the City’s Stone Crushing Works and a very remarkable section is exposed (fig. 1). The dip is east, and in the westward facing cliff the heavy trap bed, *T*, rests on soft unbaked sandstone, *S*, and is vesicular and coarsely brecciated for about 12 to 16 feet. The lower portion of this agglomerate, *T*<sub>s</sub>, is cemented by a red sand which penetrates the fissures between the breccia blocks for six or eight feet up from the base and is now hardened to red sandstone, which is continuous below with the sandstone on which the trap rests, while an aphanitic non-vesicular trap is continued down between the coarse porous blocks, *T*<sub>t</sub>, from the unbrecciated mass above to fill the fissures down to the point reached by the sand.

\* This Jour., xlii, p. 110.

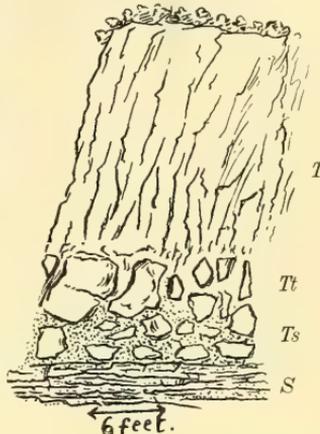
The explanation of this, I believe to be, that like an unrolling carpet the slaggy surface of the flow was underrolled on a submerged or muddy bottom and the mud was forced up into the fissures by the weight of the 200 feet of trap, and met in the cracks by the still liquid trap from above.

3. The Holyoke sheet from its east end to the Connecticut River bakes the sandstone on which it rests and has rarely large long steam pores running up from the base six inches or a foot, caused by the moisture in the subjacent sandstone, and it is highly vesicular and without any trace of baking at its upper surface.

Between the Connecticut and Westfield rivers (fourteen miles), the *base* of the sheet is often very vesicular and kneaded full of dove-colored limestone, as if limestone and trap had been plastic at the same time. In thin sections the fine grained limestone can be seen penetrating the steam holes with a distinct flow structure, but the boundaries are sharp between trap and sandstone. The trap is here perhaps 300 feet thick, but has not baked the subjacent arkose at all. At one place where the railroad between Westfield and Holyoke cuts the south line of the latter place a broad area of the *upper surface* of the sheet is filled in the same way with the same limestone to a depth of 8 or 10 feet. This latter rock is not in place in the rocks cut through by the trap, either at the surface or in the many artesian borings I have studied, down to 3500 feet in depth. I explain the above structure also by the underrolling of the surface of the sheet as above. A limited amount of calcareous mud was washed onto the submerged surface of the advancing sheet (which was superficially solidified) and blended more or less with this surface which by the continued advance of the mass became in part underrolled, thus protecting the sand below from baking, and bringing the highly vesicular trap loaded with limestone to the base of the bed.

4. At the Delaney's Quarry by the railroad on the north line of Holyoke the extremely irregular surface of the trap which rises and falls twenty feet in the quarry and is warty and ropy in the extreme, is closely fitted by the dark mud at first deposited, and the sandy layers immediately above undulate in and

1. Trap Section, Greenfield.



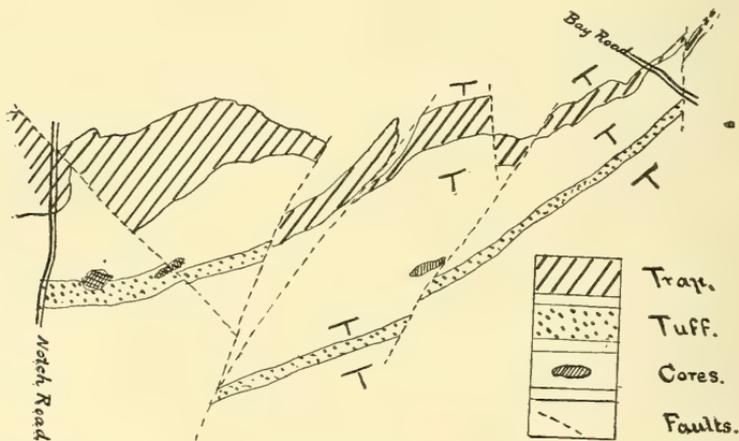
T, Trap; Tt, Trap agglomerate with trap cement; Ts, Trap agglomerate with sand cement; S, Sandstone.

out of the depressions and slowly obliterate them, and all without marked induration. The trap immediately beneath is the finest amygdaloid. This is a portion of the posterior sheet.

5. The Holyoke sheet is covered by arkose and this by a thick bed of trap tuff and agglomerate whose outcrop stretches parallel to, and a mile south of, the main Holyoke sheet from its east end to Holyoke town, about eighteen miles.

I have cut many thin sections from all parts of this bed, and the diabase of which it is composed is not in any way to be distinguished from that of the main trap sheets here discussed. This makes certain the eruption of a great amount of trap during the deposition of the sandstones, and accords with the supposition that the closely associated Holyoke sheet was also contemporaneous with the sandstones. Fig. 2 gives a sketch

2.



of the east end of the Holyoke range and shows that the trap sheet and the tuffa bed have been faulted together and that the main trap sheet must have found its present place in the sandstones below the tuffa before the epoch of disturbance which caused this faulting, while the latter cores show generally a distinct connection with these faults.

Except the Holyoke and Deerfield beds, and the "posterior" trap sheet running across Holyoke town and Agawam, all the trap given on the small map recently published by me\* is intrusive but is in small amount, and is in every way contrasted with the large beds discussed above. The intrusive trap sends out dikes in the sandstone in all ways. The smallest cores or dikes do much more baking than the thick beds because they have passed as hot lava through the sandstone while the beds have run as scoria-encased flows on the sands.

\* Bulletin of the Geological Society of America, vol. ii, pp. 451-456, pl. 17.

## SCIENTIFIC INTELLIGENCE.

## I. CHEMISTRY AND PHYSICS.

1. *On the Gravi-volumeter.*—An instrument by means of which the mass of a given gas is given directly from a single reading of its volume, has been devised by JAPP, who has called it a gravi-volumeter. It is a modification of the gas volumeter of Lunge. The apparatus consists of two gas burettes, each of 50<sup>cc</sup> capacity, provided with obliquely bored taps. One of these, A, has a three-way tap, and is used as the gas measuring tube; the other, B, has only a single tap and serves as the regulator tube. Both tubes are moistened internally, in order to saturate the gases they contain with aqueous vapor, and both are connected by means of stout flexible tubing and a T piece with the same movable reservoir of mercury. In calculating the “gravi-volumetric values” of the different gases to be measured, the 25<sup>cc</sup> division of the regulator tube is taken as the starting point. In the case of nitrogen, for example, the volume to which 25<sup>cc</sup> of standard-dry nitrogen must be brought in order that 1<sup>cc</sup> may correspond with one milligram of the gas, is calculated. Since the mass of 25<sup>cc</sup> of nitrogen is  $0.001256 \times 25 = 0.0314$  gram, or 31.4 milligrams, this mass must be brought to 31.4<sup>cc</sup>. The division 31.4 on the regulator tube is therefore marked N<sub>2</sub>. Similar points are determined for other gases and marked O<sub>2</sub>, CO<sub>2</sub>, etc. The barometer and thermometer are now read, the volume which 25<sup>cc</sup> of standard-dry air would occupy at this pressure and temperature is calculated, and this volume of air is admitted into the regulator tube. Suppose it is desired to ascertain the mass of a quantity of nitrogen contained in the measuring tube. It is necessary only to raise or lower the mercury reservoir until the mercury in the regulator tube stands at the nitrogen mark, 31.4, this regulator tube being adjusted so that the mercury level in it and in the measuring tube is the same. Under these conditions each cubic centimeter of nitrogen in the measuring tube has the mass of one milligram; so that the reading of the gas volume in cubic centimeters and tenths gives at once the mass of the gas in milligrams and tenths. By bringing the mercury in the regulator tube to the proper level, the mass of any other gas may be read in a similar manner. If it be brought to the 25 mark, the gas or mixture of gases will have the volume it would occupy in the standard-dry state and the apparatus acts as a gas-volumeter.—*J. Chem. Soc.*, lix, 894, November, 1891. G. F. B.

2. *On the Element Fluorine.*—An extended memoir upon the element fluorine has been published by MOISSAN, giving the results of his more recent researches upon this substance. An excellent resumé of this paper has been given in English by Tutton. For preparing the fluorine the platinum U-tube employed in the later experiments was much larger and had a

capacity of 160<sup>cc</sup>. It was immersed during electrolysis in boiling methyl chloride, giving a temperature of  $-23^{\circ}$ . In this tube a mixture of 100<sup>cc</sup> hydrofluoric acid and 20 grams  $\text{HKF}_2$  was contained; and this under the action of 26 to 28 Bunsen cells arranged in series, evolved four liters of pure fluorine per hour. The gas as evolved was first conducted through a platinum spiral placed in a bath of boiling methyl chloride and maintained at about  $-50^{\circ}$ , for the purpose of condensing the accompanying hydrogen fluoride, which boils at  $19.5^{\circ}$ . It was then passed through platinum tubes filled with fragments of fused sodium fluoride, by which the last traces of the hydrogen fluoride were removed. At the beginning of the electrolysis the fluorine attacks the positive electrode, which is of pure platinum, producing  $\text{PtF}_4$ . This apparently unites with the potassium fluoride to form  $(\text{KF})_2\text{PtF}_4$ ; and it is only when the liquid contains this double salt that the electrolysis proceeds regularly. Pure fluorine possesses an odor resembling that of a mixture of hypochlorous acid and nitrogen peroxide; though this odor is masked by that of the ozone formed by its action upon moist air. In a thickness of one meter it has a greenish yellow color, paler and more yellow than that of chlorine; but its spectrum shows no absorption bands. Its spark spectrum shows 13 bright lines in the red between  $\lambda = 0.744^{\mu}$  and  $0.623^{\mu}$ . Its density, as the result of many experiments, appears to be 1.265, the theoretical value being 1.316. It is not liquefied at  $-95^{\circ}$  at the ordinary atmospheric pressure. Fluorine combines with hydrogen with explosion, even in the dark and at a temperature of  $-23^{\circ}$ . With oxygen, on the other hand, it does not unite even at  $500^{\circ}$ . When fluorine acts on water a peculiar odor is noticed, which soon passes into that of ozone and which the author thinks may be due to an oxide of fluorine. Many other reactions are given in Moissan's paper.—*Ann. Chem. Phys.*, VI, xxiv, 224, Oct., 1891; *Nature*, xlv, 622, Oct., 1891.

G. F. B.

3. *On the commercial production of Ozone.*—In a recent lecture by FRÖLICH he has given an account of the experiments which have been made in the laboratory of Siemens and Halske in Berlin for the commercial production of ozone. The original Siemens ozonizing tube consisted of two concentric glass cylinders, the inner one coated interiorly and the outer one exteriorly with metal; these two coatings being supplied with an alternating current of high potential, while oxygen was made to traverse the annular space between them. It now appears that only one dielectric is necessary, mica, celluloid, porcelain and the like being available as well as glass, and the ozone-tube having either a metal tube within and a metal-coated non-conducting tube without, or a metal tube without while the inner tube is made of the non-conducting material and lined with metal. The metals to be used are of course those which are not attacked by ozone, such as platinum, tin or aluminum. Cold water flows through the inner tube, and through the annular space pure dry air. Several such

tubes may be combined into one system and worked with alternating currents; though for single tubes a continuous current with an interrupter is best. The apparatus now at work in the above laboratory yields 2.4 milligrams of ozone per second. Experiments are in progress looking to the production of a supply of compressed ozone for technical uses; this having already been done on the small scale under a pressure of nine atmospheres. One use specially dwelt upon by the lecturer is that for the disinfection and sterilization of water.—*Nature*, xlv, 39, November, 1891.

G. F. B.

4. *On Free Hydroxylamine*.—Free hydroxylamine  $\text{NH}_2\text{OH}$ , has at last been isolated by LOBRY DEBRUYN. For this purpose he heated about a hundred grams of hydroxylamine hydrochlorate dissolved in 600<sup>cc</sup> of warm methyl alcohol, with such a quantity of sodium, also dissolved in methyl alcohol, as was necessary to leave the hydrochlorate in slight excess. After removing the sodium chloride by decantation and the methyl alcohol by distillation at 160–200<sup>mm</sup> pressure, the residue was treated with anhydrous ether to completely precipitate the last traces of the sodium chloride. The liquid separated into two layers, the upper one being the ether, containing about 5 per cent of hydroxylamine, and the lower containing over 50 per cent, besides the remainder of the methyl alcohol. On subjecting this lower layer to fractionation under 60<sup>mm</sup> pressure, three products were obtained, one containing 27 per cent of hydroxylamine, one 60 per cent, and the third crystallizing in the ice cold receiver in long needles and being pure hydroxylamine,  $\text{NH}_2\text{OH}$ . It is very hygroscopic and fuses at 33°, the liquid having a remarkable power of dissolving metallic salts. It is without odor and is heavier than water. It explodes violently when heated to 80–100°. It is only slightly soluble in liquid carbon compounds such as chloroform, benzene, carbon disulphide and the like. It readily attacks cork and cellulose. The pure crystals are very stable. Bromine and iodine act upon free hydroxylamine, the former with violence.—*Recueil des travaux chimiques des Pays Bas*, x, 101, 1891; *Nature*, xlv, 20, November, 1891.

G. F. B.

5. *On Iron Carbonyls*.—MOND and LÄNGER have continued their researches upon the volatile compound of iron and carbonyl discovered by them in the first half of the present year.\* For its preparation, they now prepare first finely divided iron by heating ferrous oxalate in a current of hydrogen, boiling the resulting product in water, and again heating the iron in a current of hydrogen. The hydrogen after cooling is displaced by carbon monoxide and the tube is closed at one end the other being connected to the source of supply of the carbonyl, this gas being slowly absorbed by the iron. After twenty-four hours, the iron-carbonyl is distilled off, the receiving tube being cooled to –20°, and the operation is repeated. The yield is small, only one gram being obtained from 100 grams of iron. As thus ob-

\* See this Journal, III, xlii, 424, November, 1891.

tained iron-carbonyl is a somewhat viscous liquid of a pale yellow color. Its specific gravity at  $18^{\circ}$  is 1.4664. Under a pressure of 749<sup>mm</sup> it distills without decomposition at  $102.8^{\circ}$ ; and it solidifies below  $-21^{\circ}$  yielding a mass of yellowish needle-shaped crystals. On exposure to the air it is slowly decomposed, yielding ferric hydrate. At  $180^{\circ}$  it is decomposed into iron and carbonyl. Its vapor-density is 6.4 to 6.5; corresponding to the formula  $\text{Fe}(\text{CO})_5$ , which requires 6.7, while  $\text{Fe}(\text{CO})_4$ , requires 5.7. Hence the authors propose for it the name ferro-pentacarbonyl. It is isomeric with ferrous croconate  $\text{C}_3\text{FeO}_5$ . When exposed to the light for several hours in a sealed tube this substance yields tabular gold-colored crystals, which when dry have a metallic luster and resemble flakes of gold. On analysis figures were obtained agreeing with the formula  $\text{Fe}_2(\text{CO})_7$ , diferro-heptacarbonyl.—*J. Chem. Soc.*, lix, 1096, December, 1891. G. F. B.

6. *On the Presence of Iron-Carbonyl in Water Gas.*—In the course of some experiments upon a water-gas containing about 40 per cent of carbon monoxide, ROSCOE and SCUDDER noticed that the magnesia combs placed over the flame of the burning water gas became rapidly coated with iron oxide which materially decreased the illuminating power. Steatite burners were found to be stained with iron oxide in the same manner. When allowed to accumulate, the deposit took a coralloid, tuberous form, quite different from that assumed by particles mechanically transported. Suspecting the formation of iron-carbonyl, they compressed the water-gas in iron cylinders to eight atmospheres and allowed it to stand for a week. The gas, which usually burned with a blue non-luminous flame now burned with an intense yellow one and deposited upon the magnesia comb held in it large quantities of iron oxide. On depressing the lid of a porcelain crucible upon the flame a black stain of metallic iron was obtained; and on passing it through a heated tube a mirror of this metal was produced. Thirty liters of the compressed gas gave 32 milligrams of metallic iron when heated in a tube in this way. A plug of cotton wool placed between the heated portion of the tube and the burner received 40 milligrams of iron, in addition. On cooling the gas a liquid condensed having the properties of iron-carbonyl. Ordinary coal gas compressed in iron cylinders has been found to deposit iron upon the lime cylinders used in lantern projection.—*Nature*, xlv, 36, November, 1891. G. F. B.

7. *An Introduction to Chemical Theory.* By ALEXANDER SCOTT, M.A., D. Sc. 12mo, pp. viii, 266. London and Edinburgh, 1891. (Adam and Charles Black).—The object of this excellent little book is to supplement those chemical text books which "are occupied too fully by the mere enumeration of facts and descriptions of experiments, to the exclusion of the more philosophical parts of the subject." The mode of treatment is original, the chapters on the "Constitution of Matter," on "Atomic and molecular Weights," on "Classification of the Elements," on "Abnormal

Vapor Densities and Dissociation," on "Thermo-chemistry" and on "Chemical change" being especially satisfactory. We cordially commend the book to those students who desire to acquaint themselves with the modern philosophy of chemistry.

G. F. B.

8. *Experiments arranged for Students in General Chemistry.*—By EDGAR F. SMITH and HARRY F. KELLER. 2d. Ed. Enlarged. 8vo, pp. 60. Philadelphia, 1891 (P. Blakston, Son & Co.). "This little work," say the authors in their preface, "is designed for beginners in chemistry." It describes carefully and precisely such experiments as the student can make himself, illustrated with cuts of the apparatus needed. It appears to us admirably adapted to its purpose.

G. F. B.

9. *A Text-book of Elementary Chemistry.* By GEORGE F. BARKER, M.D. 2nd Edition, 1891. (John P. Morton & Co., Louisville, Ky.) There are not a few among our teachers of chemistry who believe that in schools of applied science and medicine, where chemistry is taught as a collateral subject, and in required courses in colleges, where but a limited time can be allowed for the acquisition of the principles and facts of this science, the inductive method of instruction is impracticable, and it is partly because of this belief and partly because Dr. Barker's work was admirably arranged, its statements were clear, accurate and concise, and the system of nomenclature and notation adopted were judiciously chosen from among the many then competing for recognition, that the first edition of his *Elementary Chemistry* owed the gratifying success which it achieved and has maintained since its publication in 1871.

This approval has made it seem undesirable in preparing a second edition to alter materially the general plan of the book other than results from the adoption of Mendeléeff's periodic law as the basis of its classification of the elements and for the arrangement of the descriptive part of the book; the use of the laws of thermo-chemistry in the elucidation of chemical phenomena and in tracing the connection between matter-changes and energy-changes; and the substitution of the word mass for weight in the terms "atomic weight" and "molecular weight" by which greater precision of statement is effected and the terminology of chemistry is brought into entire accord with that of the rest of the physical domain. Besides this the book has undergone a thorough revision; the newer discoveries in physical chemistry, such as the liquefaction and solidification of the gases and the many other physical constants being recorded from the data of the most recent experiments. Notwithstanding the considerable amount of new matter added, the size of the book has not been materially increased, as in the author's judgment a text-book should contain no more matter than the student may be required to master.

C. E. M.

10. *Low Temperatures.*—Professor PICTET has established in Berlin a laboratory for work with low temperatures. In order

to avoid the great pressure required in handling the highly evaporative substances of lowest boiling point which serve to produce extreme cold, it is necessary to divide the difference of temperature into several stages. Each stage is fitted with especial apparatus consisting of an air pump worked by steam, which drains off the vapors of the liquid from the refrigerator, and forces them into a condenser where, reduced to the liquid state, they are again offered for evaporation in the refrigerator. Thus the liquid, without leakage, passes through a continuous circuit, and the operations can be carried on for any length of time. The liquid made use of for the first stage is a mixture of sulphurous acid and a small percentage of carbonic acid and is called "Liquide Pictet." It is condensed at a pressure of two atmospheres in a special tube cooled by running water. Oxide of nitrogen is the liquid chosen for the second stage. Its vapors are condensed in the same way, at a pressure about five or six times as great in a tube maintained at about  $-80^{\circ}\text{C}$ . by the action of the first circuit. As a medium for a third stage in which continuous circulation has not yet been attempted, atmospheric air is employed, which passes into the liquid state at a pressure of about 75 atmospheres, provided the condenser is kept at  $-135^{\circ}$  by the first two circuits. The evaporation of the liquefied air causes the thermometer to fall below  $-200^{\circ}$ . A remarkable difference has been noted in the radiation of heat by Prof. Pictet. Material considered a non-conductor of heat does not appear to affect much the passage of heat into a body cooled down below  $-100^{\circ}$ . In Professor Pictet's words the slow oscillations of matter, which constitute the lowest degrees of heat, pass more readily through the obstructions of a so-called non-conductor, than those corresponding to a higher temperature, just as the less intense undulations of red light are better able to penetrate clouds of dust than those of the blue. The quantity of heat which hourly floods a cylinder 1250<sup>mm</sup> high by 210<sup>mm</sup> wide (the size of the refrigerator) at  $-80^{\circ}$ , is no less than 600 calories, and no packing will keep it out. At a lower temperature, the radiation being even greater, the power of the machinery intended to draw off still more heat would have to be enormous. The lowest temperature Prof. Pictet judges to be attainable is about  $-255^{\circ}$ . In order to measure the elasticity of mercury, Prof. Paalzon had the metal cast and frozen in the shape of a tuning fork. Professor Pictet by freezing chloroform has refined it so that it becomes a stable substance.—*Nature*, Nov. 12, 1891.

J. T.

11. *Vibrations of Strings*.—MENZEL and RAPS have studied this subject by the aid of photography. The light of an electric lamp is thrown by means of a slit and a combination of lenses upon the vibrating wire or string. The image of the slit is at right angles to the string. A chronograph cylinder is placed behind the vibrating string. This cylinder is covered with sensitive paper. When the string is at rest and the cylinder revolves, a dark band is photographed on the paper with a white

line passing through its middle, caused by the shadow of the string when it crosses the slit. When the string vibrates this shadow draws, so to speak, the vibration of the string on the sensitive paper. A large number of results accompany the paper. The effect of bowing the string near the nodes, is discussed.—*Ann. der Physik und Chemie*, No. 12, 1891, pp. 623–641. J. T.

12. *The Telephone as an optical instrument for current measurement*.—M. WIEN affixes a stylus to the diaphragm of a telephone. This stylus touches a mirror which is fastened to a flexible arm, which in turn is clamped in an adjustable support. The mirror holder is tuned carefully to the note of the diaphragm and the latter is also tuned to the note of the alternating current which is employed. The instrument readily shows  $3 \cdot 10^{-7}$  amperes.—*Ann. der Physik und Chemie*, No. 12, 1891, pp. 681–688. J. T.

13. *Solubility of Glass*.—F. KOHLRAUSCH has completed an exhaustive paper on this subject. Among the large number of results obtained by him, it is noted that glass containing silicic acid, boracic acid, alkali without chalk, show little solubility. Borax glass without silicic acid is enormously soluble.—*Ann. der Physik und Chemie*, No. 12, 1891, pp. 577–622. J. T.

14. *An Introduction to the Mathematical Theory of Electricity and Magnetism*; by W. T. A. EMTAGE. 228 pp., Oxford, 1891.—This little volume gives an excellent introduction on the mathematical side to the subjects of Electricity and Magnetism, and will be very useful to the student who does not wish to plunge at once into one of the larger treatises. The method of presentation and the statement of definitions are very clear and systematic.

## II. GEOLOGY AND MINERALOGY.

1. *Tenth Annual Report of the U. S. Geological Survey, 1888–89*.—J. W. POWELL, Director. In this Report, the report of the Director and the Administrative reports of the Heads of Divisions, occupying 252 pages, are followed by three memoirs of great value, entitled: General account of the freshwater morasses of the United States, with a description of the Dismal Swamp district of Virginia and North Carolina, by Prof. N. S. SHALER, with plates VI to XIX; The Penokee Iron-bearing series of Michigan and Wisconsin, by R. D. IRVING and C. R. VAN HISE, with plates XX to XLVII; and The Fauna of the Lower Cambrian or Olenellus Zone, by C. D. WALCOTT, with plates XLVII to XCVIII.—A second volume of 123 pages constituting Part II. of the Report, is devoted to the subject of the Irrigation Survey.

Professor Shaler treats of the formation of morasses, and the conditions favorable to it in climate, vegetation and position, and enters into the history, geological structure and economic value of the region of the Dismal Swamp, illustrating the subject with many sections and fine plates. The paper by Professors Irving and Van Hise describes with fulness the rocks and structure of

the Penokee belt of iron-bearing and other beds, lying in Wisconsin, next south of the Keweenaw series. It is made the basis by them, along with the Keweenaw, of the pre-Cambrian division of rocks called "Algonkian;" but in the closing paragraph, it is stated, after remarks on the use of the term Huronian, that the Penokee series is properly Huronian, if the latter term is restricted to such water-deposited rocks as are proved to lie unconformably on a system of older crystalline rocks which are distinctively Archæan. The evidence of unconformability in the case of the Penokee series appears to have been worked out with great care. Many plates of rock slices, maps and stratigraphic sections, illustrate the paper. Mr. Walcott's memoir has been noticed in the last volume of this Journal.

In the course of the Administrative Reports, Professor Shaler states (p. 19) that he has discovered that the reefs of living coral on the east coast of Florida have not their limit at Cape Florida, as has been hitherto supposed, but extend many miles north; that a distinct reef continues probably 10 or 12 miles beyond Jupiter Inlet.

Mr. Arnold Hague reports (p. 134) the discovery of a new hot spring area, on the east side of the Yellowstone near the head of Wapiti Creek. He also states (p. 135) that orpiment and realgar have been found coating siliceous sinter in the Norris Basin, Yellowstone Park. Mr. G. F. Becker attributes (p. 142) the exterior form of the great granite domes of the Yosemite to exfoliation on a gigantic scale.

The U. S. Geological Survey has also issued many new Bulletins. No. 68, Earthquakes in California, by J. E. Keeler; No. 69, A Classified and Annotated Bibliography of Fossil Insects, S. H. Scudder; 71, Index to the known fossil insects, including Myriapods and Arachnids, idem; 72, Altitudes between Lake Superior and the Rocky Mountains, W. Upham; 73, the viscosity of Solids, C. Barus; 75, Record of N. A. Geology for 1887 to '89, N. H. Darton; 76, Altitudes in the U. S., 2nd. ed., H. Gannett; 77, Texan Permian and its Mesozoic type of fossils, C. A. White; 79, a late volcanic eruption in Northern California and its peculiar lava; J. S. Diller; 80, Correlation Papers, Devonian and Carboniferous, H. S. Williams; 81, Correlation Papers, Cambrian, C. D. Walcott; 82, Correlation Papers, Cretaceous, C. A. White; 91, Record of N. A. Geology for 1890, N. H. Darton.

2. *Stratigraphy of the Bituminous Coal Field of Pennsylvania, Ohio and West Virginia*; by ISRAEL C. WHITE. Washington, 1891. Bulletin No. 65 of the U. S. Geological Survey.—This admirable memoir by Prof. White deserves more than the passing notice usually assigned to such papers. It is an attempt to correlate the groups and individual coal beds, which is so far successful as to challenge respect from all who have spent much labor within the area discussed. This bulletin is no mere compilation of old work done by Prof. White and others; it is an actual revision of all that has been done, a great part of the

region having been re-examined. Prof. White deals with the Coal Measures only, of which, in accordance with the Pennsylvania classification, he recognizes five groups, beginning with the Pottsville Conglomerate, XII, and ending with the Permo-Carboniferous, XVI. Each of these groups is the subject of a chapter, of which the first part gives a large number of measured sections to prove the relations of the group, while the second part describes in detail the variations of the several strata. Much of the material is wholly new, nearly all of that relating to West Virginia being published now for the first time. The gathering together of the salient facts from the Pennsylvania reports was a serious labor, for which we should be deeply grateful. Prof. White has been generous in recognition of his fellow-laborers, sometimes overlooking his own work and assigning credit where no credit is due.

J. J. S.

3. *Age of the Plants of the American Trias.*—MR. LESTER F. WARD, in a review of the plants of the American Trias, (Bull. Geol. Soc. Amer., iii, 23, 1891) arrives at the conclusion that present knowledge fixes the horizon of the formation "at the summit of the Triassic system;" and also that the beds of Europe, "which seem to be most nearly identical so far as the plants are concerned, are those of Lunz in Austria and of Neue Welt near Basle in Switzerland," which are referred "by the best European geologists to the Upper Keuper."

A paragraph on page 25 of the Bulletin of the Geological Society (page 3 of Mr. Ward's article) needs some correction. It reads: "Second, the New Jersey and Pennsylvania area, extending from the Hudson River to the Potomac. I have not used the term 'Palisade area,' which was employed by Professor Dana, because he makes this to include also the Triassic deposits of Virginia and even to embrace the Richmond coal-field."

Prof. Dana is not aware that he ever made the Palisade area to include "the Triassic deposits of Virginia" of which there are several, or "even the Richmond Coal-Field." In the last edition of his Manual, on page 404, it is stated that the Palisade area extends from New York to Orange County, Virginia. [The same extension is given it in the colored geological map published in the 5th Annual Report of the U. S. Geological Survey (1885), as well as in earlier maps.] The termination in Orange County is nearly 50 miles northwest of the Richmond area. On the next page the Manual, describing the Triassic areas severally, states again the same limits, and makes the Palisade area No. 4, and the area near Richmond No. 5. The first edition of the Manual (1862) gives the same numbering of the areas and the same limits to the Palisade area.

4. *Chalk and flints at the Solomon Islands.*—Prof. LIVERSIDGE describes (Australian Association, 1890) chalk from Ulawa Island of the Solomon group, containing Foraminifera, but not so abundantly as a similar chalk described by him in 1877, from New Ireland. With the chalk were flints closely resembling those of

England; all were rolled specimens. Nothing organic was detected in the flint. He cites from Dr. Guppy's letters of 1883 that the flints of Ugi, another island of the group, are found in the soil. The prevailing rock of the island is an earthy foraminiferous limestone, and no flints were found in it.

5. *Paramelaconite and Footeite*.—Dr. G. A. KOENIG has recently described two new copper minerals which occur closely associated with each other upon a mass of cuprite and limonite. They were obtained by A. E. Foote from the Copper Queen mine at Bisbee, Arizona.

PARAMELACONITE occurs in steep pyramidal crystals (A, fig. 1.) terminated by the basal plane, the pyramidal faces are strongly striated; from the measured angle,  $001 \wedge 111 = 58^\circ 50'$ , the vertical axis  $c = 1.6643$  is calculated. The hardness is 5, sp. gravity 5.833. Color purplish black, on the fracture pitch black. An analysis gave: CuO 100.58,  $Fe_2O_3$  0.64 = 101.32, which is interpreted as: CuO 87.66,  $Cu_2O$  11.70,  $Fe_2O_3$  0.64 = 100. It is hence essentially CuO, like melaconite and tenorite, but is distinct in crystallization, and a relation in form to octahedrite is suggested.

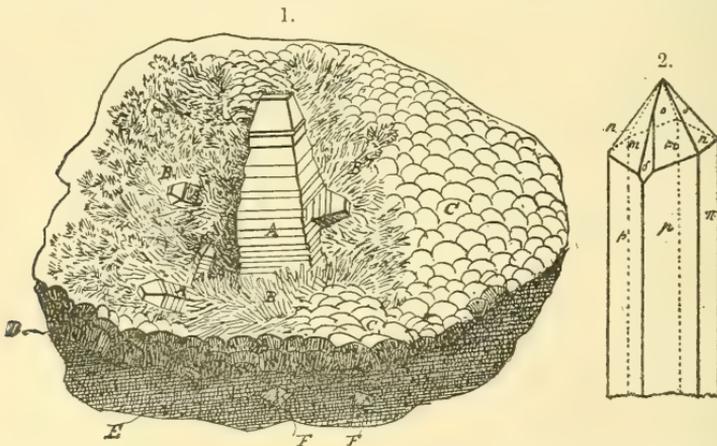


FIG. 1.—Paramelaconite (A) with acicular crystals (B) of Footeite, upon mammillary limonite (C, D); this passes into a granular mixture of limonite and cuprite (E), inclosing native copper (F). FIG. 2.—Footeite. Figures from Koenig's paper.

FOOTEITE occurs in minute prismatic crystals referred to the monoclinic system (fig. 2); they are terminated by a pyramid and two domes; the prismatic angle is  $49^\circ$  and  $131^\circ$ . The color is deep blue. An approximate analysis on 0.0165 gr. gave: CuO 63.7,  $CuCl_2$  13.5,  $H_2O$  22.8 = 100. The calculated formula is  $8Cu(OH)_2 \cdot CuCl_2 + 4H_2O$ ; this brings it somewhat near tallingite which, however, contains about twice as much chlorine.—*Proc. Acad. Nat. Sci. Philad.*, 284-291, 1891.

6. *Notes on the Genus Acidaspis*; (2) *Note on Coronura aspectans* Conrad (sp.), the *Asaphus diurus* Green; (3) *Observations on the Terataspis grandis* Hall, the largest known Trilobite;

by J. M. CLARKE. From Rept. State Geologist N. Y. for 1890, pp. 13, 3 pl.; 7, 1 pl.; 6, 1 pl. 1891.—These critical observations on *Acidaspis*, *Coronura*, and *Terataspis*, give important supplemental information to the previous knowledge of these forms. *Ceratocephala*, a name proposed by Warder in 1838, was the first distinctive term applied to any member of the well-defined group currently known as *Acidaspis*, and is taken as the leading genus. The author arranges the species in the following subgeneric groups: *Odontopleura* Emmrich, 1839, *Acidaspis* Murchison, 1839, *Ceratocephala* Warder, *sensu stricto*, 1838, *Dicranurus* Conrad, 1841, *Selenopeltis* Corda, 1847, *Ancyropyge* Clarke, 1891.

The fortunate discovery of an entire specimen of *Coronura aspectans* Conrad (sp.), terminates a long series of synonymical uncertainties. It gives a remarkable confirmation to the conclusion reached in vol. vii, Pal. N. Y., based upon fragmentary evidence, that the eye described by Conrad and the pygidia described by Hall and Meek belong to a single species. The author, moreover, considers this as included in an earlier name, the *Asaphus diurus* Green.

The restoration of a specimen of *Terataspis grandis* Hall, based on a large cephalon and on comparisons with other portions, gives a length of twenty inches. It consequently represents the largest individual trilobite known. The species had a highly differentiated defensive armor, which with its great size made it one of the dominant Paleozoic invertebrates. C. E. B.

7. *Cretaceous fossils of Syria*.—R. P. Whitfield describes and figures a number of Syrian species in the Bulletin of the American Museum of Natural History for December, 1891.

8. *Annual Report of the Geological Survey of Arkansas for 1890*. Vol. II, *The Igneous Rocks of Arkansas*, by J. FRANCIS WILLIAMS, 457 pp., 8vo, 1891. John C. Branner, State Geologist.—This country affords no more interesting series of igneous rocks than the elæolite-syenites and related rocks of Arkansas, which Dr. Williams discusses with admirable thoroughness in this volume. It is at the same time a nearly new field, for though the many rare and interesting minerals, particularly of the Magnet Cove region, have been long known and often described, but little has been published in regard to the nature and occurrence of the rocks with which they are associated. Four regions are enumerated, in which these rocks occur: (1) that of Pulaski county or Fourche Mountain; (2) of Saline County; (3) of Magnet Cove and (4) the Potash Sulphur Springs. The Fourche Mountain rocks which are largely used for building purposes, include the "blue granite" here named *pulaskite*, a rock with trachytic structure consisting of orthoclase, biotite, hornblende with but little augite, elæolite, sodalite, etc.; also the "gray granite," or elæolite-syenite; further a variety of dike rocks; there are also certain augitic rocks to one of which—a kind of monchiquite (Rosenbusch)—the name *fourchite* is given, while a sub-group under this is called ouachitite. The most varied and interesting of the regions named is

that widely known by the name of Magnet Cove, where there is an extensive development of rocks of the *elæolite-syenite* type and with them certain remarkable *leucititic dike* rocks of very high interest. These contain large crystals, sometimes nearly an inch across, of *pseudoleucite* crystals now entirely altered to a mixture of *orthoclase* and *elæolite*, also *elæolite*, *orthoclase*, *ægirite*, *pyroxene*, *biotite*, etc. The author discusses these rare types of rocks with great fulness and also the various contact rocks and contact minerals of the whole region. The latter include those of the *quartz* and *sandstone*, as *brookite*, *rutile*, etc., also those of the *calcite*, including *perovskite*, *vesuvianite*, *monticellite* and others.

This volume of Dr. Williams is a model of careful, thorough work, honorable alike to the author and to the State, and its varied contents have been hardly more than hinted at in this notice. It gains an additional and melancholy interest from the fact that it was the chief and last work of its lamented author, who did not live to see it in complete form; it is stated that the disease which so abruptly closed his labors was contracted during the work in the field which is here recorded.

### III. BOTANY AND ZOOLOGY.

1. *On specific Assimilation in Umbelliferæ*.—M. GÉNEAU DE LAMARLIÈRE (*Comptes rendus*, July 27th, 1891), recounts the results of interesting experiments on leaves, conducted in the Biological Laboratory at Fontainebleau, under the direction of M. Gaston Bonnier. The Order *Umbelliferæ* presents good material for the comparison of the amount of assimilation in different leaves of the same area. The activity of assimilation in dissected leaves is appreciably greater than from the same surface of leaf in a single segment. This difference is uniformly correlated with the minute structure: dissected leaves in this order have two or more layers of palisade-parenchyma; while simple leaves and those having large segments possess only a single layer of parenchyma. In the case of linear divisions, the parenchyma is continued around the marginal nerve and tends to invade the lower face. The following table indicates the wide difference which exists in the amount of assimilative activity. The species first mentioned, *Angelica silvestris*, has large segments: the species compared with it has in each case smaller divisions of the leaves, but these are thicker.

		c.c.		c.c.		c.c.		
I.	{	<i>Angelica silvestris</i>	1.	{ 0.102	2.	{ 0.112	3.	{ 0.140
		<i>Libanotis montana</i>		{ 0.159		{ 0.166		{ 0.240
II.	{	<i>Angelica silvestris</i>	4.	{ 0.087	5.	{ 0.091	6.	{ 0.110
		<i>Peucedanum Oreoselinum</i>		{ 0.286		{ 0.241		{ 0.240
III.	{	<i>Angelica silvestris</i>	7.	{ 0.068	8.	{ 0.076	9.	{ 0.084
		<i>Peucedanum Parisiense</i>		{ 0.232		{ 0.252		{ 0.380

The numbers denote the amount of carbonic acid (expressed in cubic centimeters) absorbed in one hour.

G. L. G.

2. *Effects of certain poisons on the germination of seeds.*  
 CH. CORNEVIN (Comptes rendus, Aug. 3, 1891).—The author investigated the effect of a toxic extract of certain seeds upon the germination of the seeds of that species. For this series, Saponine, which abounds in *Agrostemma Githago*, and Cytisine, in the seeds of *Cytisus Laburnum*, were made to act for from six to forty-eight hours on the seeds of the respective plants, by the side of unpoisoned seeds used for control. These poisons did not hinder the progress of germination.

A second series was designed to determine the effects of poisons originating in some other part of the plant on the germination of seeds of that species. Nicotine from tobacco, and opium from the poppy were employed. Seeds of tobacco immersed in a solution of nicotine, 1 : 150, were retarded for 48 hours in their germination. On the other hand, opium appeared to hasten the germination of the seeds of the poppy, but further examination showed that the complex substance should be studied with reference to its constituents. Three alkaloids hastened the germination, namely, narcotine, codeine, and narceine; while two had no effect, morphine and thebaine; and one retarded the process, papaverine.

G. L. G.

3. *Proofs of land-communication between Europe and America during the "modern" age of the earth.*—M. ÉMILE BLANCHARD (Comptes rendus, July 20, 1891), cites numerous examples of organisms common to the two continents, and appeals to these as proofs that the continents were formerly united together in a line drawn from Scotland through Iceland to Greenland. The plants which he enumerates are certain Anemones, *Cruciferae*, Violets, Stellarias, numerous *Rosaceae*, especially *Spiræas* and *Potentillas*. Further, are to be mentioned many *Saxifrages*, *Epilobiums*, and *Caprifoliaceae*. *Scrophulariaceae*, *Labiatae*, *Borraginaceae*, and *Gentianaceae*, among herbs: Alders, Willows, and Junipers, and the Yew, among aborescent forms. It will be observed that M. Blanchard carries his list much beyond the ordinary limits of the boreal species common to both continents. There is nothing particularly new in the view expressed, but the illustrations are many and to the point. Besides the species of plants, he mentions a large number of insects, fishes, and quadrupeds, which exist in specific identity on both sides of the Atlantic.

G. L. G.

4. *Comparative Anatomy of Plants.*—AD. CHATIN, in presenting to the French Academy the last fascicle of his history of Phanerogamous Parasites, calls attention to the date of the beginning of his researches. The original Thesis was propounded in 1840, and the present work, based thereon, was begun in 1854. The parts have been issued at intervals ever since, and have maintained throughout a definite character of their own. A work covering so long a period, and developed under the diverse influences of different phases of scientific thought must always possess a peculiar historical interest. The author began his work when

there could not be said to be anything like a comparative histology, in our sense of the term, and it has been continued through years which have given to us, on every hand, contributions in every department of the subject. We can imagine, therefore, the satisfaction which the author takes now in noting the general results obtained by himself and by others who have worked in the same field, in establishing a comparative histology for technical and morphological ends. Even if the author did not inaugurate the movement, he has participated in it from the very outset.

G. L. G.

5. M. LUCIEN DANIEL (Comptes rendus, Sept. 21, 1891), sums up the results of his experiments on root-grafting as follows:— (1) we can often obtain grafts on the roots of closely allied plants. (2) The graft may succeed without bringing the generative layers in contact. (3) Sometimes we can graft a plant on the root of another belonging to an entirely different family; *Saponaria* on an *Onagracea*, for example. (4) The lack of success in most cases can be explained by the obstacle which the membranes of the graft present to the passage of nutritive matters. G. L. G.

6. Two communications in recent numbers of Comptes rendus, are of considerable interest to vegetable physiologists, but of greater importance to Horticulture. LECHARTIER (Oct. 12, 1891), shows that the leaves of artichokes which turn yellow and then darker, fading away and wilting, towards the close of the season, yield up their food to the ripening parts in a very steady manner. HENRI BECQUEREL (Oct. 19, 1891), gives the results of his examination of soil temperatures during the winter of 1890–91.

7. BOURQUELOT (Comptes rendus, Nov. 23, 1891), has examined the different parts of *Boletus edulis* and *aurantiacus*, with reference to the distribution of the nutritive matters therein contained. These fungi agree in this; they contain most of their food in the forms trehalose and glucose, mostly the former, in the stalk, and rim, and not in the so-called tubes. The foot or stalk contains about twice as much as the rim. G. L. G.

8. *Die natürlichen Pflanzenfamilien*.—This admirable treatise by ENGLER and PRANTL, which has been often mentioned in this Journal, has now proceeded as far as Numbers 68 and 69. The typography is as good as at the outset, and the illustrations as excellent and abundant. The disorder attending the method of publication by detached numbers is likewise as great as at first, and leaves much to be desired. There seems to be no reason why a work of this high character should be marred by defects observable in cheap subscription books. There is, however, little doubt that the completed treatise will be, in every way, one worth waiting for. G. L. G.

9. *Work of Lobworms in bringing Sand to the Surface*.—Prof. CHARLES DAVISON, of Birmingham, England, in a paper published in the Geological Magazine of November, 1891, gives the results of his observations on the work of the Lobworms in the "Holy Island Sands," between Holy Island and the opposite

coast of Northumberland. His method of investigation was like that of Darwin on earthworms. His results show that while the earthworms studied by Darwin brought to the surface in four cases 14.58, 18.12, 7.56 and 15.1 tons per acre annually, the Lobworms bring up 136 times this amount in the same time. In his six trials he obtained per acre 901, 3146, 3147, 449, 396, 329 tons per acre. The average is 47,237 cubic feet annually per acre; which corresponds, after drying and pressing, to a layer 13 inches thick. The Lobworms burrow to a depth of 12 to 24 inches; and taking the higher figure, "the layer of sand in which they live must on an average pass through their bodies once in 22 months." Fresh sand is being continually placed by them within the wearing action of the sea. The surface over which they occur is inclined; and at the touch of the water, the casting sinks down and swells out at the base, more of it flowing down the slope than up. It thus loses its vermiform appearance and is changed to a low mound elongated downward or completely flattened out.

#### IV. ASTRONOMY AND TERRESTRIAL PHYSICS.

1. *Periodic Variation of Latitude.*—The observations of Dr. Küstner at the Berlin Observatory, published in 1888, indicated the surprising phenomenon of the variation of the geographical latitude of Berlin, to the extent of nearly, if not quite, half a second. This announcement was received by astronomers with considerable hesitation, and only the known accuracy of the methods of the Berlin Observatory, together with the established high reputation of the observer, secured for it the careful attention which its apparent improbability might otherwise have prevented. Various explanations were suggested: among them some possible difference between the atmospheric refraction north and south of the zenith: also, since the variation seemed to be an annual one, some influence connected with the changes of the seasons: also some imaginable systematic errors in the declinations of the stars employed, varying with their right-ascensions.

The International Geodetic Association deputed Prof. Helmert, director of its Central Bureau, to arrange for concurrent action by various observatories for investigating the nature of the variations in question, a plan which was effectively carried out. An elaborate collection and discussion of more than 5000 latitude determinations was presented by Dr. Albrecht to the Association. The simultaneous observations at Prague and Potsdam gave results in perfect conformity with those made at Berlin, and it soon became manifest that the phenomenon was no local one, but that all the latitude-determinations at the several places gave accordant indications of simultaneous fluctuations in 1889 exceeding the half of a second. Later the hypothesis that the period of the variation was annual was disposed of by evidence that the various latitudes determined in 1890 were in general

smaller by about  $0''.2$  than those observed at the same season in 1889.

The well-known theoretical period of ten months, originally deduced by Euler, had been shown successively by Peters, Nyrén and Newcomb, after careful comparison of various series of observations, to manifest little or no trace of real existence. The supposed secular changes, on which Fergola, supported by Schiaparelli, had based propositions for further investigation, had similarly been shown by Prof. Hall to be questionable. Later, Radau and Helmert published researches, in which it was pointed out that, an epicyclical combination of the ten-months' period with one of several years' duration, commensurable with it, would give a resultant inequality of the latitude having a period of from eleven to fifteen months, and the particular character of which would depend on the coefficients assumed.

The observed variations of latitude might of course be explained by a change either in the position of the zenith or in that of the pole. To decide this question, as well as to confirm or disprove the assumption that the observed motion is common to the whole globe, the Geodetic Association equipped and sent out an expedition to establish a station at Honolulu, a point differing by about  $180^\circ$  in longitude from the region in which the German observations had already been made. The observer, Dr. Marcuse, was instructed to make continual determinations of the latitude, by Talcott's method, for a full year. And, that the determinations might be fully confirmed, the U. S. Coast and Geodetic Survey was invited also to send an observer, with another instrument, to the same place,—an invitation which an appropriation from the Bache fund of the National Academy enabled the Superintendent to accept. Accordingly he deputed Mr. Preston, an experienced assistant of the Survey, to make these independent determinations. Meanwhile the observations in Europe, were continued, and with mutually confirmatory results. Moreover Dr. Nyrén brought to the Astronomical Congress at Munich, in August last, a series of latitude-determinations made at Pulkowa, which exhibited variations closely parallel to those simultaneously made at the German observatories.

The original observations of Dr. Marcuse at Honolulu were sent to the Central Bureau at Berlin, in monthly installments, and were computed there. At the close of September last, three months' observations had been fully computed, and the result found that, while the changes were entirely accordant in magnitude with the European ones, they were in the opposite direction. This might at first be supposed to imply an actual tilting of the earth's axis, corresponding to a change in position of the celestial pole. But this appears not to be the case, for, although the distance between the zenith and the pole is thus seen to have diminished in one place, while it increased at the other, on the opposite side of the earth, the interpretation mentioned is excluded by the important fact that identical stars were employed for the

determinations at both places, and the observations therefore made at times differing by twelve hours. The inevitable inference is that the changes observed are not in the position of the celestial pole, but in that of the zenith; in short, that the phenomenon is not one of nutation, strictly speaking, but rather a change in the position of the terrestrial pole, affecting the geographical latitude of the point of observation.

In Nos. 248-251 of the *Astronomical Journal* are a series of articles by Dr. S. C. Chandler, giving the result of his later investigations of this periodical variation. In 1884, '85 he had made a series of determinations of the latitude of Cambridge, with his then newly invented instrument, the *Almucantar*. These showed a curious progression in the values obtained for the latitude, to which he called attention in the *Astronomische Nachrichten* as early as May, 1885. A continuation of the observations confirmed the phenomenon, and a new discussion of the whole, with this fuller material, has given almost identical results; and showed both a maximum and a minimum, as well as a period of about fourteen months. The further discussion of this, and various other series of observations in which similar unexplained anomalies had been found, led him to the general result that the earth's axis of figure is revolving around that of rotation, from west to east in a period of 427 days; so that one pole revolves about the other in a circle, the radius of which is about thirty feet.

After discussing various series of observations suitable for the purpose, Chandler has arrived at the conclusion that the adoption of this hypothesis affords the true solution of various discordances which have long perplexed astronomers. Incidentally he points out, as a probable result of the incorporation of this new anomaly in the latitude, that the value of the constant of aberration, now commonly employed in preference to Struve's, is likely to prove too large; and that Struve's value is nearer the truth. By a comparative discussion of simultaneous observations made at Melbourne, Leyden, Pulkowa and Washington, he demonstrates that the phenomenon is not simply local or regional, but is terrestrial. He furthermore shows that Bradley's zenith-sector observations, which originally led to the discovery of aberration and nutation, also reveal the effect of the periodic latitude-variation with remarkable distinctness, and finds that these, as also various other series, indicate that the period has, in general, been lengthening since the last century. But he infers that, so far as can be recognized at present, the lengthening of the period has not proceeded according to any regular law, but appears to a certain extent capricious; and moreover that there is some relation between the amplitude and the period of the variation.

In No. 251 of the same *Journal* Prof. Newcomb points out that the 427-day period is perfectly consistent with dynamic laws, since we may suppose the deviation from Euler's theoretic value to be due to imperfect rigidity of the earth and to the fluidity of

the ocean; the joint effect of these tending to produce an approach of the two poles and a lengthening of the period of rotation. He thinks that the modulus of the earth's elasticity, deducible from Chandler's period will probably prove consistent with that which Sir Wm. Thomson indicates as requisite, in order to account for tidal phenomena.

B. A. G.

2. *Astronomy and Astro-Physics*, January, 1892. Editors: WM. W. PAYNE, Goodsell Observatory, Northfield, Minn., and GEORGE E. HALE, Kenwood Astro-physical Observatory, Chicago. —This new Journal is in part a continuation of the well known *Sidereal Messenger*, but with this is coupled a new department devoted particularly to spectroscopy and astro-physics. The first number, containing a variety of valuable and well illustrated papers, gives a highly favorable impression of this new periodical and promises much for its success in the future.

## V. MISCELLANEOUS SCIENTIFIC INTELLIGENCE.

1. *Essays upon Heredity and kindred Biological Problems* by DR. AUGUST WEISSMANN, Prof. Univ. Freiburg in Breisgau. Edited by E. B. POULTON, M.A., F.R.S., S. SCHÖNLAND, Ph.D., and A. E. SHIPLEY, M.A., F.L.S. Vol. I, 472 pp., 8vo. Oxford, 1891 (in New York, Macmillan & Co.).—The second edition of the English translation of Prof. Weissmann's remarkable essays is in course of publication and the first volume has just been issued. It contains the essays on the Duration of Life; on Heredity; on Life and Death; on the Continuity of the germ-plasm as the foundation of a theory of Heredity; on the number of polar bodies, and their significance in Heredity; on the supposed Botanical proofs of the transmission of acquired characters; on the supposed transmission of mutilations. The second volume will consist of four additional essays with a preface by Prof. Weissmann.

2. *Ostwald's Klassiker der exakten Wissenschaften*. (Wm. Engelmann, Leipzig).—The volumes of this series last issued include:

No. 25. Unterredungen und mathematische Demonstrationen über zwei neue Wissenszweige, die Mechanik und die Fallgesetze betreffend von Galileo Galilei. Fünfter und Sechster Tag (1838).

No. 26. Über die Constitution der organischen Säuren von Justus Liebig (1838).

No. 27. Untersuchungen über die Kakodyreihe von Robert Bunsen (1837–1843).

No. 28. Über die Asymmetrie bei natürlich vorkommenden organischen Verbindungen von L. Pasteur (1860).

No. 29. Über das Gesetz nach welchem die Einwirkung der Säuren auf den Rohrzucker stattfindet von Ludwig Wilhelmy (1850).

No. 30. Abriss eines Lehrganges der theoretischen Chemie vorgetragen an der K. Universität Genua von S. Cannizzaro (1858).

3. *Minerals: A monthly magazine*. Vol. I, No. 2, New York, Jan. 1892 (published by the Goldthwaites).—The first number of this new magazine has recently appeared and presents in its 30 pages a number of short articles and notes upon a variety of topics interesting to the collector of minerals.

4. *Modern American Methods of Copper Smelting*, by EDWARD DYER PETERS, Jr. Second Edition, revised and enlarged. 398 pp., 8vo. New York, 1891. (The Scientific Publishing Co.).—The first edition of this valuable work appeared some four years since and was at that time noticed in this Journal (xxxv, 88). In the second edition now issued, the work is thoroughly revised, with the addition of considerable new matter which should make it still more widely useful.

## OBITUARY.

Dr. JOSEPH LOVERING, for many years Professor of Mathematics and Natural Philosophy at Harvard University, died on the 18th of January at the age of seventy-eight. He was born in Charlestown, Mass., Dec. 25, 1813. In 1836, three years after his graduation at Harvard, he was appointed tutor of mathematics and physics at that institution, and two years later he began the duties of his professorship; this position he held until his death, although some three years since he was relieved from active labor. In addition to his college work, he gave nine courses of twelve lectures each, before the Lowell Institute, and other briefer courses before the Smithsonian Institution, the Peabody Institute of Baltimore and at other points. From 1867-76, he was connected with the U. S. Coast Survey, and had charge of the computations for determining by cable trans-atlantic longitudes. He was elected a member of the National Academy of Sciences in 1873, and in 1879 he received the degree of LL.D. from Harvard. For nearly twenty years he was the permanent secretary of the American Association, and in this latter capacity, edited fifteen volumes of the proceedings of the association. In 1873 he was made its president; his presidential address upon the Mathematical and Physical state of the Physical Sciences, is published in vol. viii, (1874) of this Journal. Several of his physical papers have appeared in this Journal, and many others, a partial record of an active life, are to be found in the publications of the American Academy of Arts and Sciences and elsewhere. He leaves a widow, two sons and two daughters.

WILLIAM P. RUST, who for a number of years was in the employ of the U. S. Geological Survey as a collector, was taken suddenly ill while engaged in his work at the celebrated Trilobite locality, near his home at Trenton Falls, N. Y., and died a few days thereafter (on the 17th day of October,) 1891, aged 65 years. Mr. Rust was connected with the work of Mr. Charles D. Walcott upwards of twenty years, and collected large series of fossils under his direction. He also made large collections of Trenton fossils that are now in the Museum of Comparative Zoology, Cambridge, Mass., the New York State Museum, the Museum of Cornell University and in the National Museum. His skill in working out the trilobites and other fossils from the Trenton and the Chazy-Calcareous limestones in New York and

Vermont has given to the collections made by him a value that places him amongst the contributors to the advancement of American paleontology.

C. D. W.

SIR ANDREW CROMBIE RAMSAY, Director-General of the Geological Survey of Great Britain from 1871 to the close of 1881, died on the 9th of December, 1891. His various geological investigations gave him high rank among geologists, and brought him many honors. He was elected President of the Geological Society in 1862, and President of the British Association in 1880, and was knighted in 1881, when, on account of the condition of his health, he resigned his connection with the Geological Survey. As a biographical notice in *Nature* by his successor in the Survey writes, "the news of his death will carry regret into the hearts of many men of science all over the world." The notice, in its closing paragraph, portrays, as follows, a side of his character not well known in America.

"There was in Sir Andrew Ramsay such simplicity and frankness that men of the most diverse natures were attracted to him, and as they came to know him more intimately, the gaiety and kindheartedness of his disposition attached them to him in the closest friendship. Fond of literature, and glad to relieve the pressure of his scientific work by excursions into the literary field, he had acquired a range of knowledge and of taste which gave a special interest to his conversation. Now and then he found time to write an article for the *Saturday Review* in which this literary side of his nature would find scope for its exercise. But the daily grind of the official treadmill left him all too little time for such diversions. His death removes from our midst one of the foremost geologists of our day, and from the friends who knew him in his prime, a large-hearted, lovable man, whose memory they will cherish till they too pass away.

DR. FERDINAND VON RÖMER, Professor of Geology and Paleontology in the University of Breslau, and long an able and active laborer in these departments, died at Breslau, on the 14th of December, in his seventy-fourth year. He made an honorable record for himself in American science by his excellent memoirs on the paleontology of Texas and Tennessee: *Die Kreidebildungen von Texas und ihre organischen Einschlüsse*, 1852, and *Die Silurische Fauna des westlichen Tennessee*, 1860, each about 100 pages in quarto, with descriptions of a large number of species and admirable figures on many plates.

Dr. Römer's Jubilee as Professor was to have been celebrated on the 10th of next May.

# LITTELL'S LIVING AGE.



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## Three and a Quarter Thousand

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[THIRD SERIES.]

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ART. XX.—*Mt. St. Elias and its Glaciers*;\* by ISRAEL C. RUSSELL. With a map, Plate IV.

THE National Geographic Society, in connection with the U. S. Geological Survey, has sent two exploring parties to Mt. St. Elias, Alaska. The first in the summer season of 1890, and the second a year later. The object of these expeditions was to explore the region about Mt. St. Elias, and learn as much as possible of its geography and geology, and if practicable to climb the mountain itself, which is thought to be the highest summit on the North American continent.

I had charge of each expedition, and it is my object to give here a brief account of the country explored.

The southern shore of Alaska is probably as wild and inhospitable as any coast in the world. Lofty mountains, snow-clad throughout the year, rise almost directly from the ocean, and send down not only scores but hundreds of glaciers to sea-level. From Cross sound to Kayak island, a distance of 300 miles, there is only one break in the iron-bound coast, in which ships can take refuge, that is Yakutat bay, fifty miles east of Mt. St. Elias. On the east side of Yakutat bay near its entrance, there is an Indian village, a mission and a trading-station. This is the nearest human habitation to Mt. St. Elias, and was the basis from which we began our explorations.

\* Abstract of a lecture before the Geological Society of America, at Columbus, Ohio, Dec. 29, 1891.

*Expedition of 1890.\**

In 1890, I left the Mission at Yakutat, early in June, with eight companions, and proceeded by boat to near the head of Yakutat bay, where our tramp toward the interior began. We worked our way slowly northwestward towards Mt. St. Elias for fifty miles across mountain spurs and over glaciers. More than nine-tenths of the journey was over rough ice or on the névés from which the glaciers flow. We reached an elevation of 7500 feet on the north side of Mt. St. Elias, but were caught in the early winter storms and forced to retreat.

During this journey we became acquainted especially with the great névé fields on the mountains, and explored a large part of the northern border of the great Piedmont glacier, which is of the nature of a vast lake of ice, formed by the union and expansion of several large Alpine ice streams on the plain intervening between the mountains and the sea. This veritable *Mer de glace* is known as the Malaspina glacier. It was thus named by the Superintendent of the U. S. Coast Survey several years since, in honor of Don Alejandro Malaspina, an Italian explorer in the service of Spain, who visited the southern coast of Alaska in 1792. The Malaspina is the most interesting of all the glaciers in the St. Elias region, and will be briefly described a few pages in advance.

*Expedition of 1891.*

Early in June of the present year, I returned to the St. Elias region, and after calling at the Mission at Yakutat, landed at what is known as Icy bay, fifty miles west of Yakutat bay, and there began again the study of the geography and geology of the region to which I wish to direct attention.

With five camp hands for companions, I crossed the Malaspina glacier to the Chaix hills, and from there went up the Agassiz and Newton glaciers. Our highest camp was in the snow in the great amphitheater in which the Newton glacier rises, between Mt. Newton and Mt. St. Elias, and at an elevation of 8000 feet. We occupied it for twelve days, and during that time owing to clouds and snow storms, were able to make but one advance. On the day we did advance, we climbed to the divide between Mt. Newton and Mt. St. Elias and from there ascended the north slope of the great pyramid forming the summit of Mt. St. Elias, until we reached an elevation a little over 14,500 feet above the sea.

From the divide and while climbing the slope above it, we had an unobstructed view of the vast unexplored region

\* A popular account of this expedition appeared in the National Geographic Magazine for May 1891.

north of the St. Elias range. The day was unusually beautiful and a strange land, which had never before been seen by man, lay spread out like a map beneath our feet. Having previously crossed the mountain system of which the St. Elias range forms a part, some 200 miles east of Mt. St. Elias, and traversed the country to the northward, I expected on reaching the divide between Mt. Newton and Mt. St. Elias, to behold a similar region. I pictured to myself a comparatively low forested land, interspersed with lakes, and divided by streams, and perhaps giving some signs of human occupation. But I was entirely mistaken. What did meet my astonished gaze was a vast snow-covered region, limitless in its expanse, through which hundreds and probably thousands of barren, angular mountain peaks project. There was not a stream, not a lake, and not a vestige of vegetation in sight. A more desolate or a more utterly lifeless land one never beheld. Vast, smooth, snow surfaces, without crevasses or breaks, stretched away to seemingly limitless distances, diversified only by jagged and angular mountain peaks. The general elevation of the snow surface is about 8,000 feet, while the mountain peaks which pierce it are from ten to twelve thousand feet or more, in altitude above the sea. To the north I could see every detail in the forbidding landscape for miles and miles. The most distant peaks in that direction were forty or fifty miles away. To the southeast was Mt. Fairweather, sharply defined against the sky, although 200 miles distant. About an equal distance to the northwest are two prominent mountain ranges, the highest peaks of which appeared to be as lofty as Mt. Fairweather. These are in the vicinity of Mt. Wrangell, but no volcanic vapor could be seen about them. Whether any one of them was Mt. Wrangell or not I was not able to decide.

The view to the north called to mind the pictures that explorers give of the borders of the great Greenland ice sheet, where many rocky islands, known as *nunataks*, alone break the monotony of the boundless sea of ice. The region before me was a land of nunataks.

If those of my readers who are familiar with the Great Basin of the Far West, will fancy the most desolate portion of that arid region buried beneath a thousand feet of snow and ice, leaving only the southern slopes of the most rugged peaks exposed, they will have a mental picture of the land of desolation north of Mt. St. Elias.

Owing to long continued stormy weather, we were forced to abandon the hope of reaching the summit of Mt. St. Elias and returned to Icy bay.

On reaching the flat lands along the ocean, near the mouth of the Yahtse, we measured a base line three miles long and

obtained the necessary measurements of angles for determining the height of Mt. St. Elias and of a few of its neighbors. Computations based on these measurements, show that Mt. St. Elias has an elevation of 18,100 feet, plus or minus a probable error of less than 100 feet.

From Icy bay we tramped eastward along the coast to the head of Yakutat bay, and thus became familiar with the outer border of the Malaspina glacier. After reaching the head of Yakutat bay we explored the continuation of the same inlet, known as Disenchantment bay. The entrance to the inner bay was discovered by Malaspina in 1791, while searching for a passage between the Pacific and the Atlantic. At first the opening in the mountains at the head of Yakutat bay, gave hope that the long-looked for "Northwest Passage" had been found, but on entering it Malaspina learned his mistake and as an indication of his disappointment, named the inlet "Puerto del Desengaño," which has been changed by English writers, to "Disenchantment bay."

When Disenchantment bay was discovered, the Hubbard and Dalton glaciers had a greater extension than at present and uniting at Haenke island, blocked the inlet from shore to shore with a wall of ice similar to that now formed by the Hubbard glacier.

Disenchantment bay was next visited by Capt. Puget of Vancouver's expedition, in 1794, and was found to be blocked by ice, as had been described by Malaspina.

This is the last report we have of the condition of the ice in the bay, until our visit in 1890. When the Revenue Steamer *Corwin* called for us at the close of the season, we steamed up the bay past Haenke island, to within half a mile of the ice cliffs of the Hubbard glacier, and then turned back without exploring its eastern extension. It is reported that two prospectors in their search for gold visited the eastern arm of the bay a few years since, but of this excursion there is no record.

In the fall of 1891, I again visited the bay and with two companions explored its entire extent. We found it to be prolonged nearly due east from the Hubbard glacier for about ten miles, with a width of about three miles. From near the east end of this arm, beginning at what I have called Cape Enchantment, there is another arm, looking like a broad, placid river, from two to three miles wide, which runs south for over twenty miles, and extending beyond the mountains, expands into a circular lake-like water-body in the flat lands between the mountains and the sea. A partial survey of this southern portion of the bay was made, but stormy weather coming on, all instrumental work had to be abandoned.

Disenchantment bay is surrounded on all sides by magnificent mountains. In grandeur of scenery, it is second to none of the wild fiords of southern Alaska. It resembles Lynn canal, which is familiar to many Alaskan tourists, but is narrower, more like a river, and the bold, snow-covered, and ice-scored mountains are nearer at hand. The precipitous shores bordering the east and west arm are bare of vegetation, and the southern arm is also desolate, except at the extreme southern end, where the bases of the mountains are forested. Its shores throughout, up to an elevation of over a thousand feet, bear evidences of recent glaciation. An interesting feature in which the southern arm differs from the other portions of the inlet, is furnished by conspicuous gravel terraces, which score its sides in even, horizontal lines up to a height of about 150 feet. These terraces sweep about the bluffs of gravel enclosing the lake-like expansion at the south, showing that the water-body which made them did not find an outlet in that direction. As the entrance of the bay was blocked with ice when visited by Malaspina and Puget, it seems reasonable to suppose that the water-body in the southern arm owed its existence to the ice dam thus formed. The terraces are therefore about 100 years old. The numerous small stream-channels which cross them, show what has been accomplished in the way of subaërial degradation in a century.

#### *Geology.*

Concerning the geology of the St. Elias region our knowledge is very imperfect. Owing to the great extent of glaciers and snow-fields, opportunities for studying the formations beneath are exceedingly rare.

All of the rocks about Yakutat and Disenchantment bays, with the exception of a few intrusions of diorite and certain thin beds of limestone, are brown sandstone and dark shales. The dip of these strata is almost invariably to the northeast. Their thickness is great, but has never been even approximately estimated, owing to the fact that they have apparently, been crushed and overthrust on a grand scale. These beds constitute a well-defined formation, which has been named the Yakutat system. North and west of the area occupied by the Yakutat system, and for several reasons thought to be older, there is a series of shales, limestones and conglomerates, that have been named the Pinnacle system, on account of their appearance in a long line of cliffs at Pinnacle pass. In the cliffs at Pinnacle pass there is a bed of bowlders, which was observed in 1890, but its true character was not fully recognized until the following year. It was then found that what

is probably an extension of the same bed, increases very greatly in thickness toward the west and forms the Samovar, Chaix, and probably the Robinson hills. These hills are formed of sandy shale, filled with both angular and rounded stones and boulders which represent a great variety of rocks. This terrane is a morainal deposit, and was formed in the ocean from the debris of glaciers which broke off in bergs. In the Chaix hills this deposit is over 4000 feet thick and is composed of conformable brown and gray strata, dipping northward at an angle of about ten degrees.

The topographic form of Chaix hills shows that they have been formed by a monoclinal uplift, of very recent date. Although composed of soft beds, they have not been deeply dissected by erosion. This conclusion as to the recency of the uplift to which they owe their prominence, is fully sustained by the fossils with which some of the beds are charged. All of the shells obtained are of species still living in the adjacent ocean.

North of the principal outcrops of the Pinnacle system are sandstones and shales that are lithologically undistinguishable from the characteristic rocks of the Yakutat system. These dip under the crystalline rocks forming the Augusta and St. Elias ranges, and form the actual bases of the mountains. From such facts as have been observed, I have ventured the hypothesis that the schists have been overthrust on to the sandstones and shales, and hence that the uplifting of the mountains is an event of very recent date. This conclusion was reached during the expedition of 1890, and was tested the following year, but without succeeding in fully demonstrating it, or finding evidence which would militate strongly against it. It must stand, therefore, as an interesting hypothesis, which awaits additional study.

The cliffs in which the rocks of the Pinnacle system are exposed at Pinnacle pass and in the Samovar, Chaix and Robinson hills, are monoclinal uplifts, due to the elevation of one side—in these cases always the north side—of faults. The Augusta and St. Elias ranges are also monoclinal uplifts. Nothing of the nature of anticlinal or synclinal folds was observed in the region explored. The prevailing and characteristic structure is monoclinal and very similar to the Great Basin type. The ranges including those immediately north of Mt. St. Elias have steep escarpments on one side and a gentle slope corresponding approximately with the dip of the strata, in the opposite direction. The ranges are short and in general trend northeast and southwest. Their steepest slopes are toward the southeast.

After the uplift of the mountains, glaciers seem to have taken immediate possession and to have protected the rocks from ordinary stream erosion. It is an interesting fact demonstrated to my own satisfaction at least, that the present ice drainage is consequent on the orographic structure. The glaciers in many instances follow the courses of faults, and ice falls occur in so many instances when the glaciers cross fault scarps, that their presence may be predicted from such a distance that only the general orographic structure is distinguishable.

#### *Glaciers.*

Although the St. Elias region is full of novelty and interest to the geographer and geologist, its chief attractions are for the glacialist.

The lower limit of perennial snow or the "snow line," is at an elevation of about 2000 feet above the sea. Above that elevation all of the mountains excepting the most precipitous cliffs are loaded with snow throughout the year. This snow forms the reservoirs from which flow hundreds of glaciers of the Alpine type. Some of these, as the Seward glacier for example, are fully fifty miles long and over three miles broad at the narrowest point. They are veritable rivers of ice which slowly drain away the snow that accumulates on the mountains. Besides the great ice-rivers there are very many secondary and tertiary glaciers, which do not form well defined streams. Some of these are of the same type as the small ice bodies that still linger in the cirques of the High Sierra of California, and illustrate the fact that the term "glacier" has a wide range so far as the size of the ice bodies to which it is applied, is concerned.

The glaciers of the Alpine type which flow southward from the mountains, for fully a hundred miles west of Yakutat bay, unite on the plain between the base of the mountains and the sea, and form one immense *Piedmont glacier*. This has been named the

#### *Malaspina Glacier.*

*Area.*—This glacier extends with unbroken continuity from Yakutat bay seventy miles westward, and has an average breadth of between twenty and twenty-five miles; its area is approximately 1500 square miles, or intermediate in extent, between the State of Rhode Island and the State of Delaware.

The Malaspina glacier is a vast, nearly horizontal, plateau of ice, with a general elevation of about 1500 feet. The central portion is free from moraines and dirt but is rough and broken

by thousands and tens of thousands of small crevasses. Its surface is broadly undulating, and recalls the appearance of portions of the rolling prairie lands west of the Mississippi. It is in fact a dreary and lifeless prairie of ice. From the higher swells of its surface one may see for miles in all directions without observing a single object to break the even monotony of the broken ice plain.

On looking down on the glacier from an elevation of two or three thousand feet on the hills bordering it on the north, even on the wonderfully clear days that follow storms, its limits are beyond the reach of vision.

*Moraines.*—From any commanding station overlooking the Malaspina glacier, as from the summit of the Chaix hills for example, one sees that the great central area of clear, white ice, is bordered on the south by a broad, dark band formed of boulders and stones. Outside of this and forming a belt concentric with it, is a forest covered area, in many places four or five miles wide.

In a general view, by far the greater part of the surface of the glacier is seen to be formed of clear ice; but in crossing it, one comes first to the moraine and forest covered border, which owing to the great obstacles it presents to travel, impresses one as being far more extensive than it is in reality.

The moraines not only cover all of the outer border of the glacier, but stream off from the mountain spurs that project into its northern border. One of these trains starting from a spur of the Samovar hills crosses the entire breadth of the glacier and joins the marginal moraine on its southern border. This long train of stones and boulders is really a highly compound medial moraine, formed at the junction of the expanded extremities of the Seward and Agassiz glaciers. These two great ice-rivers are entirely above the snow line, and the debris which they carry only appears at the surface after the ice descends to the Piedmont region where the annual waste is in excess of the annual supply. The stones and dirt previously contained in the glacier are then concentrated at the surface, owing to the melting of the ice that contains them. This is the history of all of the moraines of the Malaspina glacier. They are formed of the debris brought out of the mountains by the tributary Alpine glaciers, and concentrated at the surface by reason of the ablation of the ice.

*Lobes.*—The Malaspina glacier consists of three principal lobes, each of which is the expansion of a large tributary ice stream. The largest lobe has an eastward flow, toward Yakutat bay, and is supplied mainly by the Seward glacier. The next lobe to the west, is the expanded terminus of the Agassiz glacier; its current is toward the southwest. The third great

lobe lies between the Chaix and Robinson hills, and its main supply of ice is from the Tyndall and Guyot glaciers; its central current is southward. The direction of flow in the several lobes explains the distribution of the moraines about their borders.

The Seward lobe melts away before reaching Yakutat bay, but its southern margin has been eaten into by the ocean, forming the Sitkagi bluffs. The Agassiz lobe is complete, and is fringed all about its distal extremity by broad moraines. The Guyot lobe pushes boldly out into the ocean and breaking off, forms magnificent ice cliffs which are the finest of any of the tide-water glaciers of the Pacific coast. The waves undermining these cliffs, cause large masses of ice to break away and topple over into the sea, thus forming great numbers of bergs. This is the only instance known in Alaska, where a glacier advances into the open ocean.

*Surface of fringing Moraine.*—A peculiar and interesting feature of the moraines on the stagnant borders of the Malaspina glacier, is furnished by the lakelets which occur everywhere upon them. These are found in great numbers both in the forest-covered moraine and in the outer border of the barren moraine. They are usually rudely circular and have steep walls of dirty ice, which slope towards the water at high angles, but are undercut at the bottom, so that in a vertical section they have something of an hour-glass form. The crater-like walls are all the time melting, and the morainal material which forms the upper two or three feet of their rims, is undermined and slides and rolls down the steep slopes, and accumulates in the basins below. These lakes last from year to year, but are finally drained, usually through a crevasse or opening of some sort at the bottom, and the basins are left with a deep filling of bowlders and stones. As the general surface of the glacier melts away, the ice beneath these thick accumulations of debris is protected and left in relief as the less deeply covered surface melts. The debris is thus raised on a pedestal, but does not behave like a single great bowlder. It slides away in all directions and a pyramid of ice sheathed with debris is the result. What was a crater-like depression, possibly seventy-five or a hundred yards across and a hundred feet deep, becomes in this way a pyramid fifty or sixty feet high. These pyramids are of the nature of the sand cones so common on many glaciers which are covered with light moraines, but instead of being annual as are most sand cones, they are perennial and only pass through their cycle of change once in several years. The alternate formation of lake basins and of debris pyramids, has an important effect in breaking up the stones and bowlders of which the moraines

resting on the stagnant glaciers, are composed. The rolling and sliding of the debris down the sides of the lake basins as they enlarge, and from the steep sides of the debris pyramids as they waste away, cause it to become more and more broken.

While traveling over the moraine-covered surfaces of the stagnant portions of the glaciers, especially on bright sunny days or when rain is falling, one is constantly startled by the rattle of stones and boulders as they roll down the steep walls of the lakelets and plunge with a great splash into the muddy waters below.

This constant movement in the moraines whereby the blocks of which they are composed are broken finer and finer, is confined principally to the stagnant portions of the glaciers. When the glaciers are moving, lakelets cannot form for the reason that their basins become broken, and the water escapes.

*Forests on the Moraines.*—The outer and consequently older portions of the fringing moraines, are covered with vegetation, which in places, particularly near the outer margin of the belt, has all the characteristics of old forests. It consists principally of spruce trees some of which are three feet in diameter, and cottonwood, alder, and a great variety of shrubs and bushes, together with rank ferns which grow so densely that one can scarcely force a passage through them. The vegetation grows on the moraines resting on the ice, which in many places is not less than a thousand feet thick.

The vegetation is confined principally to the border of the Seward lobe. Near Icy bay it forms a belt five miles broad, but decreases in width toward the east, and is wanting at the Sitkagi bluffs, where the glacier is being eaten away by the sea. This is an interesting fact, for the reason that on the maps of this coast published by Vancouver, a cape is indicated at the locality where the glacier now comes down to the ocean. Evidently the cape has been cut away during the past one hundred years, and the recession has progressed until the forest covered border of the glacier has been removed. The forests appear again on the margin of the glacier to the east of Sitkagi bluffs, and also on the north border of the glacier. But on the portion adjacent to Yakutat bay it is wanting; the flow of the ice is toward Yakutat bay, which probably accounts for the absence of vegetation on that portion of the glacier. It is only on the stagnant border of the ice sheet that forests occur. The forest-covered area is by estimate, between twenty and twenty-five square miles in extent.

*Drainage.*—The drainage of the Malaspina glacier is almost entirely inter glacial or sub-glacial. There is no surface drainage, excepting in a few localities where there is a surface slope,

but even in such places the streams are short and soon plunge into a crevasse or a moulin and join the drainage beneath.

On the lower portions of the Alpine glaciers, tributary to the Malaspina, there are sometimes small streams coursing along in ice channels, but they are short-lived. On the borders of these tributaries there are frequently important streams, flowing between the ice and a mountain slope, but where these come down to the Malaspina, they flow into tunnels and are lost to view.

Along the southern margin of the Malaspina glacier, between the Yahtse and Point Manby, there are hundreds of streams which pour out of the escarpment formed by the border of the glacier, or rise like great fountains from the gravel and boulders at its base. All of these streams are brown and heavy with sediment and overloaded with boulders and stones.

One of the largest streams draining the glacier is the Yahtse. This rises in two principal branches at the base of the Chaix hills, and flowing through a tunnel some six or eight miles long, emerges at the southern border of the glacier as a swift, brown flood, fully one hundred feet across and fifteen or twenty feet deep. The stream after its sub-glacial course, spreads out into many branches, and has built up an alluvial fan which has invaded and buried thousands of acres of forest. In traversing the coast from the Yahtse to Yakutat bay, we crossed scores of ice water streams which drain the ice field to the north. The greater part of these could be waded, but some of them are rivers which it was impossible to ford.

The most interesting of these is Fountain stream. This comes to the surface in one great spring fully one hundred feet across. The water rises under such pressure that it is thrown twelve or fifteen feet into the air, and sends up jets of spray six or eight feet higher. It then rolls seaward, forming a broad, swift river which divides and spreads out in many channels both to the right and left and has inundated several hundred acres of forest land with gravel and sand. Where the streams flowing away from the glacier are large, they divide as do the Yahtse and Fountain, and enter the sea by several mouths. When they are small, they usually unite to form large rivers before entering the ocean. The Yahtse and Fountain, as we have seen, are examples of the first, while Manby stream is an example of the second class. This rises in hundreds of small springs along the base of the escarpment formed by the great glacier, and flowing across a desolate torrent-swept area, unite just before reaching the ocean into one broad swift flood of muddy water, much too deep for one to wade.

All of the streams where they leave the glacier are overloaded and at once deposit the coarser portions of their burdens. Those which bifurcate, continue to build up their channels all the way to the sea; while the rivers, formed by the union of many small branches, excavates channels, the depth of which is regulated by the elevation of the land above sea level. All of the streams bear quantities of debris to the ocean, but there their work ends. The waves and currents in the ocean seize the debris delivered to them and build it into beaches and bars. Nearly all of the streams near their mouths are turned westward on account of sand bars thrown across them by the prevailing ocean currents. Nothing of the nature of stream channels beneath sea level is suggested, or could reasonably be expected.

On the border of the glacier facing Yakutat bay the drainage is different from that on the southern border. The flow of the ice is there eastward and instead of forming a bold, continuous escarpment, ends irregularly with a low frontal slope.

The principal streams on the eastern margin in 1891, were the Osar, Kame and Kwik. Each of these issues from a tunnel and then flows for some distance between walls of ice. Of the three streams, mentioned, the most interesting is the Kame. This issues from the mouth of a tunnel in the ice about three miles back from the actual border of the glacier, and flows for half a mile in a narrow cañon with walls of dirty ice fifty feet or more high. The cañon then expands and forms a valley bordered by moraine-covered hills of ice, which gradually widens toward the east, until it merges with a low marshy tract bordering the shore of the bay. Well rounded sand and gravel is being deposited by this stream in large quantities. This covers the ice over which the stream flows, and during former stages, was deposited in terraces along the lower portion of the channel. These terraces, in part at least, rest on ice. The rounded and worn condition of the gravel and sand brought out of the tunnel, is proof that it has had a long inter- or sub-glacial journey.

On the north side of the open channel of Kame stream there is a sharp ridge of well rounded gravel which runs parallel with the present river, and in places can be seen to rest on an icy bed. This was evidently deposited by a stream similar to the present one, but which flowed fully one hundred feet higher. This ridge of gravel seems to be of the same general character as the Kames of New England and other glaciated regions.

Near the shore of Yakutat bay, Kame, Osar and other streams of the same character, spread out in lagoons and sand flats, where the finer material which they carry is deposited.

Sometimes this debris is spread out on the ice, and forms level terraces of sand and mud, which become prominent as the glacier wastes away.

The formation of osars seems fully explained by the subglacial drainage of the Malaspina ice sheet. On the north side of the glacier there are many streams which flow into tunnels and carry with them large quantities of gravel, sand and mud; while on its southern and eastern margin many streams emerge from tunnels and bring out large quantities of water-worn debris. The openings of the tunnels on the outer margin of the glacier, are choked with debris, the coarser part of which, as already stated, is deposited as soon as the streams have an opportunity to expand and bifurcate. With the material swept out of the tunnels there is also deposited many large boulders as well as much small angular debris, contributed by the moraines resting on the margin of the ice. The deposits formed by the streams below the mouth of the tunnels from which they emerge, have the form of low cones, which are being built up rapidly at the apex, and consequently expand at the same time in all directions. In expanding they frequently invade and bury large areas of forested country, as already noticed in the case of the Yahtse. It is evident that so long as the margin of the Malaspina glacier remains stationary or retreats, the alluvial cones about its outer margin will continue to grow. This much of the genesis of these accumulations is a matter of observation, and affords data for judging of the character of the deposits that are being formed in the tunnels through which the glacier is drained.

The growth of the alluvial cones described above, tends to obstruct the flow of water through the tunnels connecting with them, and must cause the streams to deposit a portion of their load on the bottoms of the channels which they occupy. The water is thus brought in contact with the ice forming the roofs of the tunnels, which is melted away and gives room for a farther increase in the thickness of the subglacial stream-deposits. In the case of a stagnant ice-sheet the accumulation of gravel in the tunnels by which it is drained, would continue to increase until the water finds new channels. In this way deep narrow deposits of cross stratified gravel might be formed within a glacier, which when the ice melted would assume an anticlinal structure, owing to the displacement of the material along its sides.

In this brief digression, I have not attempted to give a complete analysis of the subglacial drainage of the Malaspina glacier; but simply endeavored to show that the tunnels through which it is drained, must be occupied in part by

gravel deposits, similar in many ways to the long, winding ridges to which the name *osar* has been applied.

*Marginal lakes.*—Along the northern margin of the Malaspina glacier wherever a mountain spur projects into the ice, the rocks become warmed, and radiating heat, causes the adjacent border of the glacier to melt away. This forms a valley which becomes a line of drainage. When the streams, following the sides of a mountain spur projecting into the glacier, come together, a lake is formed which discharges through a tunnel in the ice. When the glacier passes the mouth of a lateral valley the drainage is checked and a lake formed. There are several lakes of this character about the Chaix hills. There are other methods by which the great glacier acts as a dam and cause lakes to form, but we have not time to trace out all of their histories.

These marginal lakes on the north side of the Malaspina glacier are situated at an elevation of from a thousand to fifteen hundred feet on the sides of the mountains, and receive the debris brought down by tributary streams, which is built into deltas and terraces. When the glacier melts away these deposits will be left as irregular terraces on the mountain side. Lakes will be formed about the same mountain spurs, again and again, as the surface of the ice is lowered, thus making an irregular record with considerable vertical range. It seems to me that similar records should be found on the southern slopes of the mountains of New England, and other regions, which were formerly covered by ice-sheets, analogous to the Malaspina glacier.

Photographs of the magnificent scenery of the St. Elias region were exhibited at the close of the lecture.

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ART. XXI.—*Hudson River "Fiord"*; by ARTHUR M. EDWARDS, M.D.

I HAVE been for sometime investigating the deposit thrown down during the Champlain period in the Hudson River, New York, more especially to find out if it is the same as that of the bay of Newark, N. J., and I have decided that they are different; that of Newark being newer than that of the Hudson River. But I have been called upon to examine the soundings from the Hudson River "Fiord" made by Mr. A. Lindenkohl of the U. S. Coast Survey which he has kindly furnished to me and they are with the following results. In

lat.  $39^{\circ} 34'$ , long.  $72^{\circ} 26'$ , depth 168 fathoms there were found *Achnanthes brevipes* C. A. A., *Actinocyclus Ehrenbergii* J. R. with three rays (*A. ternarius* C. G. E.) and with five rays (*A. quinarius* C. G. E.), *Actinoptychus undulatus* J. W. B., *Chatoceros Wighamii* T. B., *Cocconeis scutellum* C. G. E., *Coscinodiscus lineatus* C. G. E., *C. minor* C. G. E., *C. oculus-iridis* C. G. E., *C. radiatus* C. G. E., *C. subtilis* C. G. E., *Cyclotella operculata* F. T. K., *Dictyocha fibula* C. G. E., *D. spicula* C. G. E., *Denticula palea* D. C. L. N., *Epithemia Jurgensii* C. A. A., *Goniothecium ananulus* C. G. E., *Gaillionella granulata* C. G. E., *Hyalodiscus stelliger* J. W. B., *Navicula elliptica* F. T. K., *Synedra ulna* D. C. L. N., *Triceratium alternans* J. W. B., *T. favus* C. G. E., *T. reticulum* C. G. E.,—*Foramenifera, Polycistina*. In lat.  $39^{\circ} 32'$ , long.  $22^{\circ} 8'$ , depth 261 fathoms, there were found *Actinocyclus undulatus* J. W. B., *Actinoptychus Ehrenbergii* J. R., *Coscinodiscus eccentricus* C. G. E., *C. oculus-iridis* C. G. E., *C. radiatus* C. G. E., *C. subtilis* C. G. E., *Cyclotella Kutzingiana* G. H. K. T., *C. operculata* F. T. K., *Chatoceros Wighamii* T. B., *Denticula palea* D. C. L. N., *Dictyocha fibula* C. G. E., *Doryphora amphicerus* C. G. E., *Gaillionella granulata* C. G. E., *G. sulcata* C. G. E., *Navicula elliptica* F. T. K., *Synedra* —?, *Triceratium alternans* J. W. B.,—*Sponge spicules, Polens pirni*. In lat.  $39^{\circ} 56'$ , long.  $72^{\circ} 11'$ , depth  $47\frac{1}{2}$  fathoms there were found *Actinocyclus undulatus* S. W. B., *Gaillionella sulcata* C. G. E.,—*Sponge spicules*. In 43 fathoms between the fiord and Montauk Point *Actinocyclus undulatus* S. W. B., *Coscinodiscus oculus-iridis* C. G. E., *C. radiatus* C. G. E., *Gaillionella granulata* C. G. E., *G. sulcata* C. G. E., *Pinnularia peregrina* C. G. E., *P. viridis* D. C. L. N., *Triceratium alternans* J. W. B., *T. reticulum* C. G. E.,—*Sponge spicules*. As these species are the same, or rather the grouping of them, as are living on the coast we may consider this as made up the recent forms. There is also present besides quartz sand, which makes up the mass of the soundings, broken crystals of magnetic oxide of iron and transparent green crystals of hornblende showing that they come from the Palisades of New Jersey or the Trap rocks of Connecticut, most likely of Connecticut, for this is the way north or somewhat to the east, the ice came which formed the moraine on the coast. The microscopic organisms are not those of the Newark bay as they are not of brackish or fresh-water origin as those are, showing the “fiord” is not a continuation of Newark bay but rather of the Hudson River. This may serve as a contribution to the knowledge of the Hudson River “fiord.”

ART. XXII.—*Contributions to Mineralogy, No. 52*; by F. A. GENTH. *With Crystallographic Notes*; by SAMUEL L. PENFIELD.

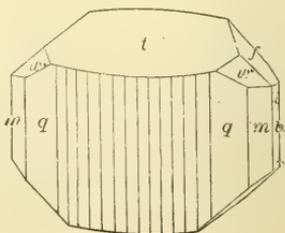
1. *On Hübnerite.*

*a.* FROM the North Star Mine, Sultan Mountain, Silverton, San Juan Co., Col.

The specimens which were used for crystallographic examination were from the private collection of Mr. Geo. L. English, of New York. The occurrence of well terminated hübnerite crystals is not without interest, as our knowledge of the crystallization of this species is at present confined to a description, by Professors P. Groth and A. Arzruni,\* of artificial crystals. These were not sufficiently developed to admit of an accurate determination of the crystallographic constants, although the authors were able to show a close similarity in form and angles between artificial  $MnWO_4$  and  $FeWO_4$  and the mineral wolframite ( $Mn, Fe$ ) $WO_4$ .

The ore, in which the hübnerite occurs, consists mostly of quartz with galena, pyrite and tetrahedrite disseminated through it. Cavities are lined with drusy quartz and contain crystals of hübnerite, tetrahedrite and occasionally very pretty rhombohedrons of rhodochrosite. The hübnerite usually occurs in groups of radiating and divergent, long-prismatic crystals; these are often coated with a thin layer of drusy quartz, which sometimes can be removed, by gentle pressure, leaving the prismatic faces smooth and glistening but as the faces at the termination of the crystal are usually rough, the quartz coating adheres there more tenaciously. On one specimen, groups of these long-prismatic crystals, covered with quartz, were found in one cavity, while in another, less than two inches removed, short-prismatic, doubly terminated and isolated crystals were found, which were not coated and which served for accurate crystallographic measurement. These crystals, which measure about 4 mm. in the direction of the ortho-axis, have the habit shown in the accompanying figure. The forms which were observed are:

$b$ , 010, $i-\bar{1}$	$t$ , 102, $-\frac{1}{2}\bar{2}$
$m$ , 110, I	$f$ , 011, $1-\bar{1}$
$q$ , 830, $i-\frac{8}{3}$	$\omega$ , 111, $-1$



\* Pogg. Ann., cxlix, p. 236, 1873.

Of these, the only faces which were suited for exact measurement were  $m$  and  $f$ ;  $b$  was bright but, owing to a fine vertical striation, it gave a multiple reflection of the signal on the goniometer. By taking advantage, however, of the perfect clino-pinacoid cleavage, a face parallel to  $b$  was developed, which gave a single reflection and, when tested on the goniometer, exactly truncated the prism  $m$ . The measurements from these faces, which were taken as fundamental are:

$$\begin{array}{rcl} m \wedge m, & 110 \wedge \bar{1}10 = & 100^\circ 12' \\ f \wedge m, & 011 \wedge \bar{1}10 = & 65^\circ 43' \\ f \wedge b, & 011 \wedge 010 = & 49^\circ 5' \end{array}$$

from which the following axial ratio was calculated:

$$a : \bar{b} : c = .83623 : 1 : .86684, \beta = 100 \wedge 001 = 89^\circ 7\frac{1}{2}'$$

The axial ratio established by Des Cloizeaux\* for wolframite is;

$$a : \bar{b} : c = .83000 : 1 : .86781, \beta = 89^\circ 22'$$

Besides the measurements given above as fundamental, the only accurate measurement which could be made was

$$f \wedge m, 011 \wedge 110 = 64^\circ 32' \text{ calculated } 64^\circ 36'$$

The faces in the prismatic zone are usually vertically striated. This is especially true of  $q$ , the obtuse edge of which is rounded as indicated in the figure. Owing to these striations, no exact measurements could be obtained from  $q$ ; however, the symbol given above agreed best with the measurements and, as will be shown later, this prism is prominent on crystals from another locality. Possibly a pinacoid  $a$ , 100,  $i\bar{2}$ , oscillates with  $q$  but no distinct reflection was obtained from the striated part to indicate its existence. With the exception of  $f$ , the faces which terminate the crystals are usually poorly developed;  $\omega$  was determined by approximate measurements only;  $t$  usually gave no reflection whatever.

Cleavage sections, parallel to  $b$ , show with the polarizing microscope an extinction, inclined about  $17^\circ$  from the vertical axis, in the obtuse angle  $\beta$ . This direction corresponds to the axis of least elasticity  $c$ . In convergent polarized light an obtuse bisectrix could be seen, but the section was too small to admit of a measurement of the angle of the optical axes. The sections transmit a brown light. The pleochroism is marked; for rays vibrating parallel to  $c$  green; parallel to  $b$  yellowish brown, but varying somewhat, even in the same section. An increase of color is probably due to a slight percentage of  $\text{FeO}$ , the lighter colored material is probably nearly pure  $\text{MnWO}_4$ .

\* Ann. Chimie et Phys., IV, xix, p. 168, 1870.

Some groups of radiating crystals of a brownish yellow color, not over 2<sup>mm</sup> in diameter have been noticed, which probably are also hübnerite.

An analysis of the radiated variety of a brownish black color, yielding a pale grayish brown powder, and having the specific gravity 6.713 gave, after deducting 8.608 per cent quartz:

WO <sub>3</sub> .....	74.75
FeO .....	2.91
MnO .....	21.93
CaO .....	0.11
MgO .....	trace.
	<hr/>
	99.70

*b.* From Cement Creek on Bonita Mountain near Silverton, San Juan Co., Colorado.

This variety we have not been able to obtain in isolated crystals. It is associated with quartz and pyrite and occurs in a radiating and divergent mass, up to 40 to 50<sup>mm</sup> in length, with distinct clino-pinacoid cleavage. Color hair-brown to reddish and yellowish brown, in thin splinters transparent, luster sub-metallic, inclined to silky. The fine powder is of isabella color. Sp. gr.=6.891.

The analysis gave, after deducting 2.4 per cent of quartz:

		Harry F. Keller.*
WO <sub>3</sub> .....	76.63	76.14
FeO .....	1.61	—1.63 2.11
MnO .....	21.78	21.63
CaO .....	0.09	0.12
MgO .....	trace	trace
	<hr/>	<hr/>
	100.11	100.00
		Sp. gr.= 6.780

*a.* From Bonito Mountain near White Oakes, Lincoln Co., N. M.

This variety occurs in fissures in granite. The crystals are long prismatic and for the most part coated with drusy quartz. The prismatic faces are usually vertically striated, but a few crystals were found which gave very good reflections. In the prismatic zone *b*, *m* and *q*, were observed, but *q*, which is new, was the most prominent. The symbol  $830, i-\frac{8}{3}$ , approximates to  $310, i-\bar{3}$ , which has been observed on wolframite, but four independent measurements, where the reflection from *q* were sharp and distinct, gave  $q \wedge b = 72^\circ 55'$ ;  $72^\circ 46'$ ;  $72^\circ 41'$  and

\* After deducting 2.13 per cent of quartz, the analysis of Harry F. Keller of the same variety (megabasite from Bonita Mountain near Silverton, Col., in Franklin Institute Journal, August, 1889), gave the above composition.

72° 21', average 72° 41', calculated for 830  $\wedge$  010 = 72° 35½', while for 310  $\wedge$  010 the calculated angle is 74° 26'. The crystals are usually terminated by *t*, or by *t* and a pyramid  $\Delta$ , 112, in the zone *t*, *b*. The dome *t* was either dull or had a sort of undulatory surface, so that it gave no distinct reflection. The pyramid  $\Delta$  gave only faint reflections and yielded the following measurements.

	Measured.	Calculated.
$\Delta \wedge b, 112 \wedge 010 =$	68° 51' and 69° 20'	69° 4½'
$\Delta \wedge g, 112 \wedge \bar{8}30 =$	108° 28'	108° 14'

Only the thinnest cleavage splinters of this material were at all transparent, so that no attempt was made to study the optical properties.

Color iron black to brownish black, luster submetallic, inclining to adamantine. Powder greenish gray. Sp. Gr. = 7.163 – 7.091.

The analysis gave, after deducting 0.34 per cent of quartz :

	I. Lincoln Co., N. M. (Genth.)	II. Mammoth Dist., Nevada.
WO <sub>3</sub> .....	76.33	74.88
FeO .....	3.82 — 3.98	0.56
MnO .....	19.72 — 20.08	23.87
CaO .....	0.13	0.14
MgO .....	trace	} CuO 0.08
	-----	} 0.08
	100.00	-----
		99.61

*d.* From Monmouth District, Nye Co., Nevada.

For comparison we have examined the hübnerite from Riotte's original locality. The specimens at our disposal showed no distinct crystals but only cleavage masses, implanted on quartz. Color brownish black to iron-black, powder greenish-gray. A little of the manganese is higher oxydized, as the mineral evolved some chlorine, when treated with hydrochloric acid. The analysis is given under II above

2. *Hessite from Mexico.*

Prof. Carlos F. de Landero of Guadalajara kindly presented a specimen of hessite from a recent occurrence at the Refugio Mine, San Sebastian District, State of Jalisco, Mexico, which was analyzed by Mr. Jas. S. de Benneville. It is granular, of a dark lead gray color, and so very largely and intimately intermixed with quartz, that no pure material could be picked out for analysis. The composition of the mixture was found to be

SiO <sub>2</sub> -----	33.33		
Al <sub>2</sub> O <sub>3</sub> -----	0.70		
CaO -----	0.49		
Fe -----	0.16		
Cu -----	trace		
Pb -----	1.21	equivalent of Te....	0.75
Ag-----	39.42	“ “ -----	23.38
Te -----	25.53		
Se -----	trace		
			24.13
	100.84		

This would represent: 62.80 per cent Ag<sub>2</sub>Te, 1.96 per cent PbTe with 1.40 per cent of tellurium, which may be present as native tellurium or perhaps as tellurous oxide. The presence of some incrustations, resembling tellurite, would indicate that the latter supposition is probably the correct one.

### 3. *Bismutite.*

Associated with the phenacite of Mount Antero in Chaffee County, Colorado, are quartz, orthoclase, scales of muscovite, hematite, and a grayish or yellowish green bismuth mineral in prismatic form. The hematite occurs in small brilliant crystals, the largest not over 4<sup>mm</sup> broad and about 1.5<sup>mm</sup> thick, the combination being short prisms terminated by a flat rhombohedron. Of the bismuth mineral only one fragment of a crystal was observed of a darker greenish color and having angles agreeing with the sulphide Bi<sub>2</sub>S<sub>3</sub>, from the alteration of which it probably had been derived. Other small crystalline masses were observed, resembling bundles of deeply striated crystals, the largest about 30<sup>mm</sup> in size, but, unfortunately, throughout the whole mass, contaminated with salts of lead, copper, zinc, ferruginous clay, etc. Examining the association it appears that quartz, muscovite in hexagonal plates and hematite are the oldest, after which the bismuth mineral was deposited, and upon this, the most recent phenacite, which frequently is found upon the bismuth mineral and between its fissures,—or the phenacite has crystallized around fragments of the same.

It was impossible to obtain the bismuth mineral in a state of purity. The best gave the composition given below, after deducting in analysis I, 5.11 per cent of impurities, such as hematite, muscovite and ferruginous clay—in analysis II, 4.22 of the same.

The sp. gr. of the material for analysis was found to be: 6.293, while the darker greenish crystal yielded: 7.330. The analyses gave:

	I		II	
	a	b	a	b
		Less		Less
Impurities ..	5·11	impurities	4·22	impurities
[Ignition, 9·18]				
H <sub>2</sub> O .....	2·02	2·11	2·33	2·43
CO <sub>2</sub> .....	7·16	7·47	6·85	7·14
CuO .....	0·31	0·32	0·32	0·33
PbO .....	4·83	5·04	4·63	4·82
Bi <sub>2</sub> O <sub>3</sub> .....	80·13	83·64	80·41	83·81
ZnO .....	0·86	0·90	0·86	0·89
SO <sub>3</sub> .....	0·50	0·52	0·56	0·58
	<hr/>	<hr/>	<hr/>	<hr/>
	100·92	100·00	100·18	100·00

The lead is probably present as PbCO<sub>3</sub> and PbSO<sub>4</sub>, the copper as malachite, the zinc as ZnCO<sub>3</sub> and the bismuth as hydrated-carbonate, but the material is too impure to attempt the construction of a formula.

#### 4. Natrolite.

Associated with aegirite, eudialyte, titanite, etc., natrolite occurs at Magnet Cove, Ark., in large colorless, cleavable masses, the individuals being about 50<sup>mm</sup> in length and 5·8<sup>mm</sup> broad. The cleavage, although apparently perfect, does not yield good surfaces for reflecting light. The angle between the cleavages is very near 90°, but most of the measurements which were made are near 91° and 89°. The crystals are colorless, some portions, however, are more or less opaque. It was found that the latter contain a minute quantity of lime, while the colorless portion is free from it. The spec. gravity was found to be 2·243. The analysis gave :

H <sub>2</sub> O .....	9·81
SiO <sub>2</sub> .....	47·97
Al <sub>2</sub> O <sub>3</sub> .....	26·51
Na <sub>2</sub> O .....	15·98
	<hr/>
	100·27

Chemical Laboratory, 111 S. 10th St.,  
Philadelphia, October 25th, 1891.

ART. XXIII.—*Tschermak's Theory of the Chlorite Group and its Alternative*; by F. W. CLARKE.

IN the micas, vermiculites, the clintonite group, and the chlorites, we meet a large number of minerals having similar properties. All are probably monoclinic, all are commonly foliated in structure, and within certain limits they shade into each other in composition. The resemblances between them are very close externally; and it is therefore a fair presumption that they are also alike in constitution. A satisfactory explanation of their chemical structure ought to emphasize their obvious relationships, and be sufficiently general to include all the individual species in a single definite theory. The problem is easily stated, but its solution can be effected only by slow degrees. Like other similar problems, it must be solved by a series of approximations; and every step towards order is a gain, even though it be not absolutely final.

Among the men who have advanced our knowledge of these minerals, no one is entitled to higher credit than Professor Tschermak. His successive papers upon the mica, clintonite, and chlorite groups have all been long strides forward; and whether his interpretations are ultimately confirmed or abandoned, they have none the less been of real service in the development of knowledge.

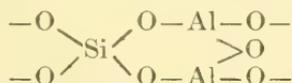
In his latest paper,\* Professor Tschermak seeks to explain the chemical structure of the chlorites, and masses the available evidence most admirably. This group of minerals he divides into two sub-groups, called orthochlorites and leptochlorites respectively, and for each division a special explanation is offered. The orthochlorites, which include pennine, clinochlore, leuchtenbergite, prochlorite and corundophilite, are simply represented as mixtures of two end products, serpentine and amesite; and so far as the mere ultimate composition of the minerals is concerned, the interpretation is quite satisfactory. On theoretical grounds it leaves something to be desired, as will appear later. The leptochlorites, however, or chlorites outside of the main series, are less easily handled; and for these, in addition to the serpentine and amesite molecules, four other fundamental compounds are assumed; namely, two derivatives of amesite, strigovite and chloritoid. Six types of molecule are in all adopted; which, by mixtures in various proportions account for all the species. Written semi-empirically, these molecules are as follows:

\* Die Chloritgruppe, II, Theil, Sitzungsab. Akad. d. Wiss. in Wien, 19 Feb., 1891.

Serpentine,	Sp.	$MgSi_2O_7 \cdot H_2 \cdot (MgOH)_2$
Amesite,	At.	$Al_2SiO_7 \cdot H_2 \cdot (MgOH)_2$
"    1st deriv.,	At'.	$Al_2SiO_7 \cdot H_3 \cdot MgOH$
"    2d    "	At''.	$Al_2SiO_7 \cdot H_4$
Strigovite,	St.	$SiO_2 \cdot Al_2SiO_7 \cdot H_2 \cdot (MgOH)_2$
Chloritoid,	Ct.	$Al_2SiO_7 \cdot H_2 \cdot Mg$

Of these compounds, four are represented by known minerals; although the amesite and strigovite formulæ rest each upon a single analysis. Two, the molecules At' and At'', are hypothetical. Empirically, all the chlorites of well established character correspond in composition to mixtures of these six molecules; but a few of the allied minerals, such as epichlorite and stilpnomelane, are unaccounted for. The latter are yet to be brought into line.

At a first glance the six molecules, as just written, appear to be remarkably alike in form. But when they are written structurally, as Tschermak himself writes them, they become somewhat dissimilar. Serpentine is then represented as a salt of the acid  $H_6Si_2O_7$ . Amesite, with its two derivatives and chloritoid, appear as basic orthosilicates. Strigovite is given as a salt of the acid  $H_4Si_2O_6$ . That is, three different silicic acids are involved in Tschermak's theory, and the first apparent simplicity of the scheme disappears. All of the six molecules, however, with the single exception of the non aluminous serpentine, are supposed to contain the structural nucleus



to which the remarkable similarities of the chlorites may be due. Through chloritoid the chlorites become affiliated with the clintonite group; but with the micas, at least as the latter have been interpreted by Tschermak hitherto, no special analogies of structure appear.

Now, admitting that Tschermak's theory accounts for the known facts as fully as he believes, the question arises whether his mode of interpretation is the only one possible. If it is, then the problem of the chlorite group is solved, and controversy is out of court. But if other schemes can be devised, representing the facts equally well, further investigation becomes necessary. Pending the acquirement of new experimental evidence, we may discuss rival systems upon philosophic grounds; and that which is simplest, most general, and best supported by analogies, should have preference. Ultimately, of course, the problem must be attacked by means of experiment; through which alone the questions at issue can be finally settled.

In several previous papers, some of them written in joint authorship with others,\* I have sought to establish the hypothesis that the more complex silicates are merely substitution derivatives of normal salts. For instance, many minerals are easily and naturally represented as so derived from the normal aluminum compound  $Al_4(SiO_4)_3$ ; successive aluminum atoms being equivalently replaced by other atoms or groups. Among these minerals, the micas seem to form a conspicuous family, and with them are found the clintonite group and some vermiculites. To this family I shall recur later.

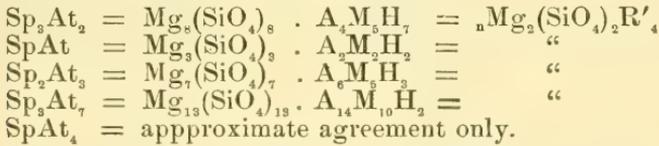
In two quite recent papers, Schneider and I have tried, by experimental methods, to obtain some positive evidence as to the nature of the chlorites. That our results are not final, and that Tschermak's criticism of them is perfectly legitimate, I cheerfully concede, and yet we have found clues which are not without meaning. The reaction between dry hydrochloric acid and the hydromagnesian silicates we are still investigating, and its actual character and significance we hope to determine in due time. So far, however, in every case of a true chlorite examined by us, and in the case of serpentine also, we have found that the chemical constitution *may* be represented by a mixture of molecules of the general form  $Mg_2(SiO_4)_2 R'_4$ , in which  $R'$  may be either  $AlH_2O_2$ ,  $MgOH$ , or  $H$ , with of course the usual equivalent replacements of aluminum and magnesium by ferric and ferrous iron. These molecules are evidently substitution derivatives of the normal compound olivine, when the ordinary formula of the latter is doubled and made  $Mg_4(SiO_4)_2$ . Since we do not know the true molecular weight of any metallic silicate, this doubling of the simplest possible formula is perfectly allowable, and a reason for it will appear later. Here then, for a few chlorites at least, is a scheme of interpretation quite unlike Tschermak's; and we have to determine whether it is equally exact and equally general.

Taking Tschermak's paper as a basis for comparison, and discussing at first only the analyses discussed by him, I find that all of his orthochlorite series, except corundophilite and amesite, reduce sharply to the above given type of formula. Omitting amesite, which will be separately considered further on, every orthochlorite may be written  $R''_2(SiO_4)_2 R'_4$ , with various relations between the several components collectively represented by  $R'_4$ . In fact, Tschermak's formulæ and mine, although quite dissimilar, are curiously parallel; as the following scheme, based upon his classification of the orthochlorites, plainly shows. His arrangement of the sub-group is this:

\* See U. S. Geological Survey Bulletins, numbers 27, 42, 60, 64 and 78. Also this Journal for Sept., 1891.

Pennine,	$\text{Sp}_3\text{At}_2$ to $\text{SpAt}$
Clinochlore,	$\text{SpAt}$ to $\text{Sp}_2\text{At}_3$
Prochlorite,	$\text{Sp}_2\text{At}_3$ to $\text{Sp}_5\text{At}_7$
Corundophilite,	$\text{Sp}_3\text{At}_7$ to $\text{SpAt}_4$

Transforming these expressions, and, for brevity, writing  $\text{AlH}_2\text{O}_2 = \text{A}$ , and  $\text{MgOH} = \text{M}$ , we have :



In the last case, corundophilite, Tschermak's formula agrees better with the actual analyses than any formula derived from my system. The cause of divergence will be considered in connection with the structure of amesite, later. Although the difference is small it ought not to be ignored.

In general, then, the orthochlorites may be provisionally regarded as mixtures of the three typical or generic salts  $\text{Mg}_2(\text{SiO}_4)_2\text{A}_4$ ,  $\text{Mg}_2(\text{SiO}_4)_2\text{M}_4$ , and  $\text{Mg}_2(\text{SiO}_4)_2\text{H}_4$ . Whether these compounds exist separately in the mineral kingdom is an open question, and one not easy to answer. To each of them there are approximations; ekmannite for example is near  $\text{Fe}_2(\text{SiO}_4)_2\text{H}_4$  in composition; but it is more probable that the chlorites proper are mixtures of intermediate salts. Some pennines, for instance, fall near the compound  $\text{Mg}_2(\text{SiO}_4)_2\text{AMH}_2$ ; and other like substances appear among the minerals which Tschermak places in the subgroup of leptochlorites. A consideration of the latter must precede further discussion of theory.

According to Tschermak, the leptochlorites form three subgroups, as follows :

I. Daphnite,	$\text{At}_5\text{At}'_6\text{Sp}$
Chamosite,	$\text{At}_3\text{At}'_3\text{Sp}$
II. Metachlorite,	$\text{At}_6\text{St}_2\text{Sp}_3$
Klementite,	$\text{At}_4\text{St}_2\text{Sp}$
Cronstedtite,	$\text{AtSt}_3$
Thuringite,	$\text{AtSt}$
Euralite,	$\text{At}_3\text{St}_4$
Strigovite,	$\text{St}$
III. Diabantite,	$\text{Ct}_4\text{Sp}_7$
Aphrosiderite,	$\text{Ct}_6\text{At}_6\text{Sp}_4$ to $\text{Ct}_3\text{At}_4\text{Sp}_4$
Delessite,	$\text{Ct}_2\text{At}_2\text{Sp}_5$ to $\text{CtSp}$
Rumpfite,	$\text{Ct}_4\text{At}'_4\text{Sp}$

Epichlorite, grengesite, melanolite, etc., he regards as chlorites, but as not yet definable. The delessite from Friedrichsroda he places provisionally in the first division of the leptochlorites, along with daphnite and chamosite. The formulæ given are deduced from specific analyses, but when several

analyses exist for a species, a considerable variability becomes manifest, which must influence all attempts to fix the molecular structure.

Taking now the analyses as cited by Tschermak, a number of them reduce at once to the same type of substitution formula as that which I have assigned to the orthochlorites. Uniting like oxides,  $Fe_2O_3$  with  $Al_2O_3$ ,  $MgO$  with  $FeO$ , etc., we get at once the following expressions from the analytical data. The name of the analyst follows the name of the species :

Daphnite, Zeynek,	$Fe^{99}_{40}(SiO_4)_{40} \cdot H_{16}A_{44}M_{22}$
Chamosite, Boricky,	$Fe^{92}_{42}(SiO_4)_{43} \cdot H_{29}A_{37}M_{23}$
Delessite, Pufehl,	$Mg^{49}_{40}(SiO_4)_{50} \cdot H_{98}A_{40}M_{22}$
Thuringite, Gintl,	$Fe^{99}_{41}(SiO_4)_{39} \cdot H_{11}A_{49}M_{15}$
“ Keyser,	$Fe^{99}_{44}(SiO_4)_{40} \cdot H_{12}A_{50}M_{11}$

An approximation to close agreement with theory is evident at a glance ; but a better conception of the agreement may be obtained by calculation, using the following formulæ :

Daphnite,	$Fe_2(SiO_4)_2A_2(FeOH)_1H_1$
Chamosite,	
Delessite,	$\left\{ \begin{array}{l} 1 Fe_2(SiO_4)_2A_2(FeOH)_1H_1 \\ 3 Mg_2(SiO_4)_2A_2M_1H_1 \\ 1 Fe_2(SiO_4)_2H_4 \end{array} \right.$
(Friedrichsroda)	
Thuringite,	

To this list we may add the thuringite from Lake Superior, analyzed by Penfield and Sperry, which becomes  $5Fe_2(SiO_4)_2(FeOH)_4 + 9Fe_2(SiO_4)_2A_4$ . The analyses, reduced to typical form and to 100 per cent, as is usual, are as follows :

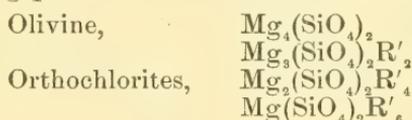
	Daphnite. Zeynek.	Chamosite. Boricky.	Delessite. Pufahl.	Thuringite. Gintl.	Thuringite. Keyser.	Thuringite. P. & S.
$SiO_2$	23.44	25.17	29.75	23.58	24.15	21.35
$Al_2O_3$	22.08	18.41	20.58	25.11	25.44	24.02
$FeO$	43.41	45.37	19.42	40.08	39.39	43.88
$MgO$	----	----	17.53	----	----	----
$H_2O$	11.07	11.05	12.72	11.23	11.02	10.75
	<hr/> 100.00	<hr/> 100.00	<hr/> 100.00	<hr/> 100.00	<hr/> 100.00	<hr/> 100.00

Calculated from the formulæ just given they become :

	Daph. & Cham.	Deless.	Thuring. G. & K.	Thuringite, P. & S.
$SiO_2$	24.39	30.30	23.81	21.54
$Al_2O_3$	20.73	20.60	25.30	23.54
$FeO$	43.90	18.18	39.29	44.31
$MgO$	----	18.18	----	----
$H_2O$	10.98	12.74	11.60	10.61
	<hr/> 100.00	<hr/> 100.00	<hr/> 100.00	<hr/> 100.00

In short, these chlorites are apparently compounds of precisely the same type as the orthochlorites. Daphnite and chamosite vary from theory by small amounts in opposite directions, the one having a trifling excess of an FeOH salt, the other an excess of an  $\text{AlH}_2\text{O}_2$  compound. Closer agreements could not be reasonably expected.

In order to properly interpret the remaining leptochlorites, we must return to the fundamental idea of the substitution hypothesis. Starting with the normal ortho-salt, we get at once the following probable series of derivatives.



In the first of these derivatives, the compound intermediate between the orthochlorite type and olivine, we find the key to most of the leptochlorites. Again discussing the analyses mainly considered by Tschermak, omitting strigovite and rumpfite for separate inspection, we get the subjoined semi-empirical expressions :

Metachlorite,	Zeynek,	$\text{Fe}_{45}''(\text{SiO}_4)_{40} \cdot \text{H}_{12}\text{A}_{41}\text{M}_{30}$
Euralite,	Wiik,	$\text{Mg}_{65}(\text{SiO}_4)_{56} \cdot \text{H}_{59}\text{A}_{32}\text{M}_4$
Diabantite,	Hawes,	$\text{Mg}_{69}(\text{SiO}_4)_{56} \cdot \text{H}_{53}\text{A}_{35}\text{M}_9$
Klementite,	Klement,	$\text{Mg}_{61}(\text{SiO}_4)_{48} \cdot \text{H}_7\text{A}_{56}\text{M}_7$
Delessite,	Hedde,*	$\text{Mg}_{75}(\text{SiO}_4)_{57} \cdot \text{H}_{39}\text{A}_{38}\text{M}_1 + 34 \text{ aq.}$
Cronstedtite,	Ludwig,	$\text{Fe}_{49}(\text{SiO}_4)_{35} \cdot \text{A}_{44}$ , nearly.
Aphrosiderite,	Rammelsberg,	$\text{Fe}_{54}(\text{SiO}_4)_{41} \cdot \text{H}_3\text{M}_8\text{A}_{44}$

Metachlorite, at one end of this series, corresponds nearly to the orthochlorites; while aphrosiderite, at the other end, approaches the composition  $\text{Fe}_3(\text{SiO}_4)_2\text{A}_4$ . All the other minerals in the series fall between these extremes. Reduced to general form, the expressions become :

Metachlorite,	$4\text{R}'_2(\text{SiO}_4)_2\text{R}'_4 + 1\text{R}''_3(\text{SiO}_4)_2\text{A}_2$
Euralite,	7 " + 3 "
Diabantite,	4 " + 3 "
Klementite,	1 " + 1 "
Delessite,	1 " + 2 "
Cronstedtite,	1 " + 4 "
Aphrosiderite,	0 " + 1 "

These ratios, of course, are not rigidly exact, but they vary no more from the analyses considered than the analyses of the different occurrences in any one species vary among themselves. In the last case, the actual analyses show small admixtures of the orthochlorite type; but the approximation is

\* The delessite from Bowling Quarry. The samples from Dumbuck and Long Craig agree well with this.



	Delessite.	
	Found.	Calc.
SiO <sub>2</sub>	34·00	33·83
Al <sub>2</sub> O <sub>3</sub>	19·34	19·17
MgO	30·24	30·08
H <sub>2</sub> O	10·36	10·15
Aq	6·06	6·77
	<hr/>	<hr/>
	100·00	100·00

In reducing the data, and in calculating the formulæ, I have commonly assumed R'' to be all magnesium or all iron according as one or the other predominated. Only in diabantite the relation between the Fe and Mg was so simple that it seemed desirable to keep both in view. I have also used relatively simple ratios between component molecules, rather than the more complex terms which might give a closer agreement between analyses and theory. That is, when Mg<sub>2</sub>(SiO<sub>4</sub>)<sub>2</sub>R'<sub>4</sub> and Mg<sub>3</sub>(SiO<sub>4</sub>)<sub>2</sub>A<sub>2</sub> stood actually in the relation of 11 to 10, I have computed on the basis of 1:1. Most of the divergences between "found" and "calculated" are due to this cause; but in the case of cronstedtite, which is least concordant of all, there is probably a small admixture of some more basic compound, of the character, possibly, of amesite.

There now remains to be considered, of all of Tschermak's typical chlorites, only strigovite, rumpfite, amesite, and in part corundophilite. Of these, the first three depend each upon a single analysis, and the available evidence is therefore not conclusive. To strigovite, the general formula H<sub>4</sub>Fe''<sub>2</sub>Al<sub>2</sub>Si<sub>2</sub>O<sub>11</sub> seems to apply; which, in the constitutional expression given to it by Tschermak has already been cited. This may also be written Fe<sub>2</sub>(SiO<sub>4</sub>)<sub>2</sub>·H(AlH<sub>2</sub>O<sub>2</sub>)(AlOH), which is of the orthochlorite type with the bivalent group AlOH in place of R'<sub>2</sub>. In rumpfite, which has the empirical formula H<sub>28</sub>Mg<sub>7</sub>Al<sub>16</sub>Si<sub>10</sub>O<sub>65</sub>, the same group AlOH appears, and also a molecule of the form of the last derivative of olivine, Mg(SiO<sub>4</sub>)<sub>2</sub>R'<sub>6</sub>. In detail, rumpfite agrees very nearly with the composition

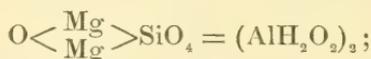


which gives with the analysis by Firtsch reduced as usual, the following comparison:

	Rumpfite.	
	Found.	Calc.
SiO <sub>2</sub>	31·01	30·20
Al <sub>2</sub> O <sub>3</sub>	42·02	42·79
MgO	13·73	13·42
H <sub>2</sub> O	13·24	13·59
	<hr/>	<hr/>
	100·00	100·00

It must be remembered that in order to account for rumpfite, Tschermak assumed the existence of the constituent molecule  $At''$ , which appears in none of his other chlorites. Both in his scheme and in mine the mineral is exceptional, and undoubtedly it needs further study.

In amesite, which occurs with corundophilite, we find another chlorite of peculiar composition. It is the most basic member of the group, and contains more oxygen relatively to its silicon, than any other chlorite known. Its formula, as written by Tschermak, is  $Al_2SiO_7, H_2(MgOH)_2$ , which is the equivalent of his serpentine molecule, with  $Al_2$  in place of  $MgSi$ . As we have no experimental evidence from which to reason, we may with equal propriety regard amesite as having the structure



when it becomes analogous in structure to the other chlorites, standing in a similar relation to them as that which the clintonite group bears toward the micas. On this supposition the micas and chlorites, as has already been shown elsewhere,\* form two parallel series of compounds, as follows:

Normal orthosilicate,	$Al_4(SiO_4)_3$		$Mg_4(SiO_4)_2$
Whence derive—	<i>Micas</i>		<i>Chlorites</i>
Muscovite,	$Al_3(SiO_4)_3R_3$	Aphrosiderite,	$Mg_3(SiO_4)_2R_2$
Normal biotite,	$Al_2(SiO_4)_3R_6$	Orthochlorites,	$Mg_2(SiO_4)_2R_4$
“ phlogopite,	$Al_2(SiO_4)_3R_6$		$Mg(SiO_4)_2R_6$
Clintonite,	$Al \left\langle \begin{matrix} O \\ O \end{matrix} \right\rangle R''$	Amesite,	$O \left\langle \begin{matrix} Mg \\ Mg \end{matrix} \right\rangle SiO_4 = R_2$
	$\backslash SiO_4 \equiv R_3$		

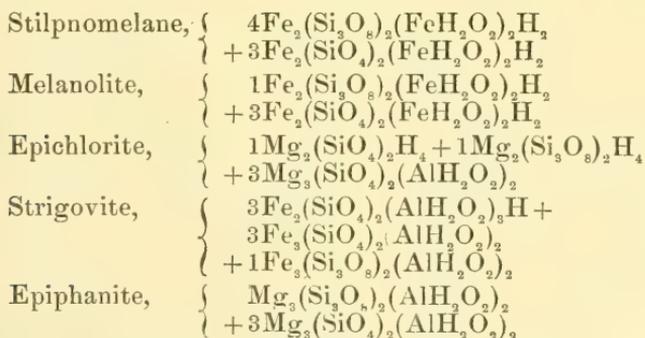
In certain respects, this general scheme is not incompatible with Tschermak's views. The orthochlorites, for example, he regards as mixtures of serpentine and amesite, representing the structure of those compounds in a special way. But if serpentine be written  $Mg_2(SiO_4)_2H_2(MgOH)$ , and amesite as I have just suggested, the theory of substitution is satisfied, and the orthochlorites may be classified as intermediate between the two end terms. Then, however, the leptochlorites fall less easily into line, and the slight gain in apparent simplicity in the ortho series is offset by loss elsewhere. It is quite probable, however, that corundophilite is a mixture containing amesite molecules; and the formula which I give the latter mineral is sustained to some extent by the fact that both minerals occur intimately associated with diaspore. At Chester, the only locality for either corundophilite or amesite represented by analyses, the chlorites are commonly found in seams

\* Clarke and Schneider, this Journal, Sept., 1891.

with diaspore on one side and emery on the other. Hence the group  $\text{AlH}_2\text{O}_2$  is at least as likely to be found in amesite as the magnesian compound  $\text{MgOH}$ .

Still another analogy between the micas and the chlorites remains to be noted. In the phengitic muscovites, in some phlogopites and in the lithia micas, the ratio of silicon to oxygen is less than 1:4, and often approaches 1:3. This variability, as I have shown in my paper upon "A theory of the mica group,"\* is easily explained by supposing an admixture of molecules containing the group  $\text{Si}_3\text{O}_8$  in place of  $\text{SiO}_4$ . This equivalency is well recognized in the feldspar series; and among the micas it is forcibly emphasized by the existence of Lorenzen's polyolithionite, in which the group  $\text{Si}_3\text{O}_8$  replaces  $\text{SiO}_4$  entirely. Does this group occur in chlorites also?

At the end of his discussion of the leptochlorites, Tschermak dismisses a number of minerals as doubtful in character, either because of unsatisfactory analyses, or uncertainty in the material described. In particular he names the species grengesite, hullite, melanolite and stilpnomelane, to which he adds epichlorite. All of these minerals, together with epiphanite and possibly strigovite, may be reduced to typical form by assuming the presence of  $\text{Si}_3\text{O}_8$ . For grengesite and hullite the analyses are not satisfactory, and the formulæ deducible have therefore no weight. Strigovite has been already explained by assuming in it the group  $\text{AlOH}$ , but a reconsideration here is worth noting as offering an alternative formula to that previously given. The formulæ which I have obtained are as follows:



Here we find stilpnomelane and melanolite are orthochloritic in type; epiphanite is equivalent to aphrosiderite, and the other species are intermediate like most of the leptochlorites. The analyses discussed are these:

Stilpnomelane from Antwerp, N. Y., by Brush.

Melanolite, Somerville, Mass., by H. Wurtz.

\* Bulletin, U. S. Geological Survey, No. 64.

Epichlorite, from the Hartz, by Rammelsberg.

Strigovite, Striegau, by Websky.

Epiphanite, Wernland, by Igelström.

The reduced analyses are as follows :

	Stilpnomelane.		Melanolite.	
	Found.	Calc.	Found.	Calc.
SiO <sub>2</sub>	42·85	41·80	34·25	33·46
Fe <sub>2</sub> O <sub>3</sub>	24·74	26·01	29·32	29·74
FeO	23·69	23·41	26·48	26·76
H <sub>2</sub> O	8·72	8·78	9·95	10·04
	<hr/>	<hr/>	<hr/>	<hr/>
	100·00	100·00	100·00	100·00
	Epichlorite.		Strigovite.	
	Found.	Calc.	Found.	Calc.
SiO <sub>2</sub>	43·94	45·50	29·51	30·20
Al <sub>2</sub> O <sub>3</sub>	17·75	16·58	24·78	24·25
FeO	----	----	36·05	36·24
MgO	27·38	28·17	----	----
H <sub>2</sub> O	10·93	9·75	9·66	9·31
	<hr/>	<hr/>	<hr/>	<hr/>
	100·00	100·00	100·00	100·00

For epiphanite Igelström's analysis needs no reduction, if we calculate with a ratio of Mg:Fe::7:5.

	Found.	Calc.
SiO <sub>2</sub>	37·10	37·66
Al <sub>2</sub> O <sub>3</sub>	21·13	21·34
FeO	20·00	18·83
MgO	14·03	14·64
H <sub>2</sub> O	7·83	7·53
	<hr/>	<hr/>
	100·09	100·00

The agreements are sufficiently close to establish the validity of the hypothesis upon which the calculations rest, although they are not as good in all cases as might be desired. Still, the formulæ offered bring some order out of chaos, and are therefore entitled to consideration until something better is proposed.

As between Tschermak's theory and mine, both representing the known facts fairly well, experimental research must be the final arbiter. Until experiment has given grounds for decision either theory may properly be used as a guide. Mine is offered as a possible simplification of the problem; but both may be supplanted by something more general still. Neither theory exhausts all the possibilities of the question, and neither can claim to be much more than a step forward in the series of approximations by which the truth may be at last attained.

Washington, Dec. 12, 1891.

ART. XXIV.—*Recent Fossils near Boston*; by WARREN UPHAM.

[Read before the Boston Society of Natural History, Nov. 4, 1891.]

FOSSIL marine shells of the Postglacial or Recent epoch have been lately discovered at several places in the vicinity of Boston, indicating slight postglacial changes in the relative levels of land and sea, and proving considerable changes in the temperature of the sea there. These fossils have been carefully collected and studied by Miss D. L. Bryant, of the class of 1891, Massachusetts Institute of Technology; and, with topographic and geologic notes of the localities of their occurrence, they were the theme of her graduating thesis, to which I am indebted for a large share of both the observed facts and the conclusions drawn from them, as here presented. Another interesting collection has been made by Mr. Collier Cobb, of the Institute of Technology, instructor in geology and palæontology. Miss Bryant gives lists of species obtained by excavations and dredging in three localities.

1. Grading and deep trenches along the valley and estuary of Muddy River, adjoining Brookline and forming the western continuation of a new park of the city of Boston, encountered a fossiliferous clayey stratum a few feet thick, lying near the present level of low tide, underlain by stratified clay, and directly overlain by a bed of peat about one foot thick, which is succeeded by the latest fine muddy alluvium of this stream, from 5 to 12 feet in thickness. In the upper part of the clay, the thirteen species noted by asterisks in the first column of the following table were found, occurring in abundance together, except that the oysters were restricted chiefly to one place.

2. In the dredging of the Charles River during the construction of the new bridge from the Back Bay district of Boston to Cambridgeport, at a distance about one and a half miles west of the State House, there was brought up first river mud, which had a thickness of several feet, and next sand containing shells of twelve species noted in the second column of the table. The river here is a broad tidal estuary, a great part of which has been filled and now constitutes the Back Bay district; and the ground where these fossils were dredged forms part of the deepest channel of this bay or enlargement of the Charles River back of the original peninsula of Boston. The fossiliferous sand was ten feet or more below mean low

tide level, above which the mean height of the tide, both in the Charles River and in Boston Harbor, is ten feet.

The most abundant species here, occurring in great numbers and of large size, are *Mya arenaria*, *Venus mercenaria*, *Pecten irradians*, and *Ostrea Virginiana*. Some of the shells of the long clam (*Mya*) measure five inches in length and three inches in width. A small oyster shell in this bed is exceptional, the usual length being eight inches, with a width of two to three inches; while many are ten inches long, and one valve has a thickness of one and a half inches.

Table of Recent Fossils, Boston, Mass.

Species.	Muddy River.	Charles River.	City Point.	Present geographic range.
<i>Balanus balanoides</i> Stimpson.	*			Shores of whole North Atlantic.
<i>Tritia trivittata</i> Adams.	*	*	*	Fla. to G. of St. Lawrence.
<i>Ityanassa obsoleta</i> Stimpson.	*	*	*	G. of Mex. to Cape Cod; local north to G. of St. Lawrence.
<i>Urosalpinx cinerea</i> Stimpson.	*	*	*	Same as preceding.
<i>Purpura lapillus</i> Lam.			*	E. end of Long Island to Arctic Ocean.
<i>Anachis avara</i> Perkins.		*		G. of Mex. to Mass. Bay.
<i>Lunatia heros</i> Adams.	*	*	*	Ga. to S. Labrador.
<i>Crepidula fornicata</i> Lam.			*	G. of Mex. to Mass. Bay; local north to G. of St. L.
<i>Crepidula plana</i> Say.			*	Same as preceding.
<i>Littorina rudis</i> Gould.	*			N. J. to Arctic Ocean.
<i>Utriculus canaliculatus</i> Stimpson.	*			S. C. to Mass. Bay.
<i>Mya arenaria</i> L.	*			S. C. to Arctic Ocean.
<i>Tagelus gibbus</i> Gray.			*	W. Indies and G. of Mex. to Cape Cod.
<i>Macoma fragilis</i> Adams.	*	*	*	Ga. to Greenland.
<i>Mactra solidissima</i> Chemnitz.			*	Texas to Labrador.
<i>Mulinia lateralis</i> Gray.	*	*	*	Texas to Mass. Bay.
<i>Venus mercenaria</i> L.	*	*	*	Fla. to Mass. Bay; local north to G. of St. L.
<i>Lævicardium Mortoni</i> Perkins.			*	G. of Mex. to Cape Cod; local north to N. S.
<i>Astarte undata</i> Gould.			*	L. I. Sound to G. of St. Lawrence.
<i>Lucina filosa</i> Stimpson.			*	Conn. to Maine.
<i>Modiola plicatula</i> Lam.	*	*	*	Ga. to Casco Bay, Maine; local north to G. of St. L.
<i>Pecten irradians</i> Lam.		*	*	G. of Mex. to Cape Cod; local north to N. S.
<i>Pecten tenuicostatus</i> Mighels.			*	N. J. to Labrador.
<i>Anomia glabra</i> Verrill.			*	Fla. to Cape Cod; local north to Cape Sable, N. S.
<i>Ostrea Virginiana</i> Lister.	*	*	*	G. of Mex. to Cape Cod; local N. to Bay of Chaleurs, G. of St. L.

3. At City Point, the east extremity of South Boston (known as Dorchester Heights in the history of the Revolution), dredging is in progress for deepening an adjacent part of the harbor, and the mud and sand thus removed are used in the extension of City Point for the site of the Marine Park. The depth of water where the dredging is being done, midway between the Point and Castle Island, is about ten feet below mean low tide, and the excavation goes several feet lower, bringing up abundant fossil shells. Twenty-one species, noted in the third column, have been identified here.

The four species mentioned for their abundance in the Charles River are also very plentiful at City Point, having similar large size, which shows that in both places they had favorable conditions for luxuriant growth. Chief among these conditions are mild temperature and clearness of the water, such as are found in estuaries and shallow bays, sheltered from the waves of storms.

Taken as a whole, the twenty-five species comprised in the identified fauna of the three localities belong in their present geographic range to a somewhat more southern and warmer portion of our coast. Fourteen are distinctly southern, and reach their northward limits at Cape Cod or in Massachusetts Bay, and in one instance near Portland, Maine; excepting that several of them occur in isolated colonies far north of their general and continuous range, as in Casco and Quahog Bays, Maine, and especially in the shallow southern part or Acadian Bay of the Gulf of St. Lawrence, from Cape Breton Island to the Bay of Chaleurs.\* The occurrence of these southern mollusks, which are mostly now absent, or local and rare, north of Cape Cod, shows that the sea here during some part of the Recent epoch has been warmer than at the present time. Six of the fourteen, namely, *Iyanassa obsoleta*, *Urosalpinx cinerea*, *Mulinia lateralis*, *Venus mercenaria*, *Modiola plicatula*, and *Ostrea Virginiana*, occur in each of the three localities noted, and indicate the contemporaneousness of these deposits. All of the eleven northern species, some of which

\* After the presentation of this paper before the Boston Society of Natural History, the author learned of Mr. W. F. Ganong's admirable memoir, "Southern Invertebrates on the Shores of Acadia," published a few months ago in the Transactions of the Royal Society of Canada, vol. viii, sec. iv, for 1890, pp. 167-185. Mr. Ganong gives a history of the discovery of the character of the colonies; a list of marine invertebrates belonging to the Virginian fauna, which occur upon the coasts of Acadia and Maine, with tabular reference to their known localities; and a discussion of their recent extinction on intervening portions of the coast thence south to Massachusetts Bay and Cape Cod. He accepts the explanation of Verrill and Dawson, noticed on a following page, for the present refrigeration of the sea here; but also points to the recent increasing severity of cold in Greenland and Iceland, and suggests that the marine currents there likewise have been lately warmer than now.

extend to the Arctic Ocean, but including one found only on the coast of New England, range to southward limits beyond Cape Cod. In short, the temperature of the sea in Massachusetts Bay and in the estuaries of its rivers, at the time represented by these deposits, was evidently like that of the sea now on the southern coast of New England, which, besides the increase of the sun's heat due to the lower latitude, receives some contribution from the warmth of the Gulf Stream, whereas the waters of the Gulf of Maine and Massachusetts Bay are chilled by a coastal current from the north.

The relative heights of land and sea were apparently almost the same as now. Every one of the twenty-five recorded species flourishes on the shore between the levels of high and low tide, or at the plane of extreme low tide, or in shallow water of a few fathoms. In the list of each locality are species that prefer a depth slightly below the lowest tide, and each also has other species that are chiefly restricted to the shore above low water mark. Probably the best interpretation is that suggested by the layer of peat at the first locality, immediately overlying the fossils, near the low tide level. The water there was gradually becoming shallower, and the land was finally lifted above the reach of the tide at the time of formation of the peat. Subsequently it has been depressed at least several feet, which latest movement has now apparently ceased on this part of the coast.

Postglacial oscillations of considerable amount, thus lifting the land and afterward depressing it, are known to have affected a large part of our Atlantic seaboard; and Prof. A. E. Verrill\* and Sir William Dawson† believe that these recent changes of level have been sufficient to explain the important changes of temperature of the sea here, whereby southern mollusks were permitted to extend northward to the Gulf of St. Lawrence but have since been exterminated, excepting isolated colonies, north of Cape Cod and Massachusetts Bay. Both these authors are inclined to attribute the northward extension of the southern fauna to a recent time of greater elevation of our coast, which is abundantly attested to a certain amount, ranging from 10 to at least 40 feet,‡ by stumps of forests, rooted where they grew, and by peat bogs, now found submerged by the sea at many places along all the distance from New Jersey to Newfoundland. Professor Verrill

\*This Journal, III, vol. vii, pp. 134-8, Feb., 1874.

†Acadian Geology, Third edition, with Supplement, 1878.

‡According to Sir William Dawson, l. c., p. 31. Since this paper was prepared, the author finds that Mr. Robert Chalmers reports a peat bed under the Tantramars salt marsh at the head of the Bay of Fundy, about 80 feet below the present high tide level (Annual Report of the Geological and Natural History Survey of Canada, new series, vol. iv, for 1888-89, pp. 42 A and 10 N).

suggests that the Strait of Belle Isle, which is about ten miles wide and 180 feet deep in its narrowest and shallowest part, may have been closed by the elevation, shutting out the cold waters that pour through it, carrying small icebergs and floes into the Gulf of St. Lawrence; while as great an uplift of the extensive shallow Fishing Banks would ward off the arctic current far into the ocean. If we had to consider this coast alone, the explanation would seem very acceptable; but evidences of such warmer postglacial temperature, both of sea and land, succeeded now by a moderate degree of refrigeration, are found to extend over all the North Atlantic region, including also Greenland, Iceland, northwestern Europe, and even Spitzbergen.\* We therefore must conclude that these climatic changes probably have depended in common on farther reaching causes and conditions, which may yet have consisted chiefly in geographic movements of elevation and subsidence, with their effect on the general oceanic circulation.

Between the time of departure of the ice-sheet, at the close of the Glacial period, and the time of northward migration of the southern marine fauna, a very important upward movement had taken place, affecting the eastern provinces of Canada and the northern two-thirds of New England, extending south to the latitude of Boston. To speak more strictly, however, this uplifting of our part of the continent was limited southeastward by a line drawn approximately from the mouth of the Hudson northeast to Boston and onward through Nova Scotia. When the ice-sheet was being withdrawn from this region, the country south of this line stood somewhat higher than now, as is shown by the channels of streams that flowed away from the melting ice and ran across the modified drift plains which form the southern shores of Long Island, Martha's Vineyard, Nantucket, and Cape Cod. A subsequent depression of the land there, continuing perhaps to the present time, has brought the sea into these old river courses. But north and northwest from this line the land at the time of recession of the ice-sheet was lower than now, and the coast and estuaries were more submerged by the sea. At Boston and northward to Cape Ann the depression appears to have been no more than 10 to 25 feet. Fossiliferous beds overlying the till show that the vertical amount of the marine submergence in the vicinity of Portsmouth was about 150 feet; along the coast of Maine, from 150 to about 300 feet; on the northwestern shore of Nova Scotia, about 40 feet; thence increasing westward to about 200 feet in the basin of the Bay of Chaleurs, 375 feet in

\* James Geikie, *Prehistoric Europe*, chapters xx and xxi, 1881. Warren Upham, "On the Cause of the Glacial Period," *Am. Geologist*, vol. vi, pp. 327-339, Dec., 1890.

the St. Lawrence valley opposite the Saguenay, and 520 feet at Montreal; 300 to 400 feet, increasing from south to north, in the basin of Lake Champlain; about 275 feet at Ogdensburg, and 450 feet near the city of Ottawa; 300 to 500 feet on the country southwest of James Bay; in Labrador increasing northward to 1,500 feet at Nachvak, according to Dr. Robert Bell; and in northern Greenland and Grinnell Land, from 1,000 to 2,000 feet. That the land northward from Boston was so much lower while the ice-sheet was being melted away, is proved by the occurrence of fossil shells of *Leda arctica* Gray, which is now found living only in Arctic seas where they receive muddy streams from existing glaciers and from the Greenland ice-sheet. This species is plentiful in the stratified clays resting on the till in the St. Lawrence valley, in New Brunswick, and Maine, extending south to Portsmouth, N. H. But it is known that the land was elevated from this depression to about its present height before the sea here became warm and the southern mollusks migrated along this coast to the Gulf of St. Lawrence; for in the extensive lists of the fossil fauna of these beds none of the southern species is included, excepting perhaps the oyster in southwestern Maine.\*

From the Champlain submergence attending the departure of the ice, the land was raised somewhat higher than now, and its latest movement from New Jersey to southern Greenland has been a moderate depression. The vertical amount of this recent subsidence is undetermined, beyond that known by stumps and peat now covered by the sea; and it is difficult to estimate how far this recent and probably slight oscillation may have tended to produce formerly warmer and now cold sea currents, with the faunal migration that is represented by the marine colonies of southern species. It seems unlikely, however, as before remarked, that the warmer marine temperature was due to local conditions of our coast, since it prevailed throughout all the North Atlantic Ocean. The fossils of the Champlain beds of our northeastern shores and also of northwestern Europe show a gradual change from an Arctic and glacial climate at the maximum of the depression to a cool temperate climate, nearly the same as now, before the re-elevation brought the land up to its present height. After this level was generally attained or somewhat surpassed, the southern warmer temperate species spread northward along both sides of the Atlantic to boreal and even Arctic regions, where

\*C. H. Hitchcock, "The Geology of Portland," Proc. A. A. A. S., vol. xxii, for 1873, pp. 163-175. A. S. Packard, "Observations on the Glacial Phenomena of Labrador and Maine," Memoirs of the Boston Society of Natural History, vol. i, 1865, pp. 210-262. J. W. Dawson, Notes on the Post-pliocene Geology of Canada, 1872, pp. 112 (from the Canadian Naturalist, new series, vol. vi).

they are no longer able to live excepting in isolated colonies that are preserved here and there in sheltered shallow bays.

Looking for causes of these changes of temperature in the North Atlantic and the adjoining countries, it seems to me very probable that they were due mainly to a formerly larger volume of the warm oceanic current which is named the Gulf Stream because a considerable part of it issues from the Gulf of Mexico, flowing through the Strait of Florida, while perhaps a larger part leaves the tropics east of Cuba and the Bahamas. This very broad current pours northward to the Arctic regions and there enters an otherwise almost completely enclosed ocean, from which counter currents nearly at the temperature of melting ice flow back along the Labrador coast and in the depths of the Atlantic under its warmer surface. But within the Recent epoch, during which these climatal changes have taken place, an elevation of a large region of Alaska and eastern Siberia has been in progress, slowly diminishing the depth and width of Bering Strait.\* The recency of this uplifting, probably still going on, is shown, like that of the basin of Hudson Bay, by drift-wood on the sea shores, lying far above the level now reached by storm waves at the highest tides. Mr. Dall reports that the current of the shallow Bering Strait, which has a maximum depth of only 180 feet and is about 36 miles wide, passes north into the Arctic Ocean; † but it may have been reversed when the strait was formerly much larger, being thus an outlet for a part of the waters carried north by the Gulf Stream. The North Atlantic and the Arctic Ocean could then have received more of its northward warm current, giving a milder climate to northeastern North America and northwestern Europe and adjacent Arctic lands. On the other hand, an outflow from the polar sea through Bering Strait would be a frigid current, carrying greater cold to Alaska, British Columbia, and the Pacific coast of the United States.

So nicely balanced are the conditions on which variations of climate depend, that the former depression of Bering Strait, through resulting changes in the oceanic circulation, may have been a very important element, re-enforced probably by contemporaneous greater elevation of the Cordilleran mountain belt from the St. Elias range to the Sierra Nevada, in causing these mountains and the adjoining lower ground to bear very lately, as Russell and Becker have shown, extensive glaciers or even ice-sheets, which have now disappeared from the south-

\* William H. Dall, *Alaska and its Resources*, 1870, pp. 462-466.

† *Ibid.*, p. 285.

ern part of this belt and are fast retreating in Alaska.\* The last 500 or 1,000 years, according to Russell, have been marked by rapid glacial recession in the St. Elias region. But during the same or a longer time the North Atlantic area has been growing colder, gradually excluding the southern mollusks, causing the ice-sheet of Greenland to increase again, and giving to that country a much less hospitable climate than during the prosperous period of the Norse colonies, from 900 to 500 years ago. Both the decrease of the Alaskan glaciers and the increase of cold and of ice accumulation in Greenland are attributable, as I believe, to the present partial closure of the passage between the Arctic and Pacific Oceans.

In another way, however, which is perhaps more probable, that is, by assuming that the principal current through the formerly enlarged Bering Strait flowed as now northward, we may almost equally well explain the climatic changes of both the western Cordilleran belt and the North Atlantic area. Such increased northward outflow from the Pacific would be subtracted from the warm Kuro Siwo or Japan current, the greater part of which passes to the east and south along the shores of Alaska, British Columbia, and the Pacific States, and would thus tend to produce the cold of the recent Cordilleran glaciation. The formerly large branch of the Japan current entering the Arctic Ocean by Bering Strait would be partly, and probably almost wholly, carried thence eastward along the northern coast of North America and through its archipelago to Baffin Bay, Davis Strait, and the North Atlantic, bringing somewhat milder climatic conditions to Greenland and to all those shores where the colonies of southern marine mollusks are known. With the subsequent decrease of the size of Bering Strait, during the past 1,000 years, sending more of the Japan current to our Pacific coast, the Cordilleran and Alaskan glaciers would be melted away or greatly reduced, as to-day, but Greenland and the North Atlantic area would become colder, as seems to be well proved within the present historic period.

To the same very late date we must assign the extinction of the southern molluscan species on the eastern coast of New England and the southern coast of New Brunswick and Nova Scotia. During the time of accumulation of the aboriginal shell-heaps or *kjökken-möddings* of Maine, and even within the

\*I. C. Russell. Geological History of Lake Lahontan, U. S. Geol. Survey, Monograph xi, 1885, p. 273; Bulletin, G. S. A., vol. i, 1890, p. 142; Expedition to Mount St. Elias, Alaska, National Geographic Magazine, vol. iii, 1891, pp. 64, 93, 98, 100, 104, 112, 173. G. F. Becker, Bulletin, G. S. A., vol. ii, 1891, p. 196. Warren Upham, this Journal, III, vol. xli, pp. 41, 51, Jan., 1891; Am. Geologist, vol. viii, p. 150, Sept., 1891.

270 years since the first settlement in Massachusetts, very significant restriction and extinction can be shown. For example, Professor Verrill states that dredging reveals the occurrence of great beds of oyster shells a few feet beneath the harbor mud at Portland, where they are associated with the quahog (*Venus mercenaria*), scallop (*Pecten irradians*), and other southern species; and that the oysters and scallops "had apparently become extinct in the vicinity of Portland Harbor before the period of the Indian shell-heaps, for neither of these species occurs in the heaps on the adjacent islands, while the quahogs lingered on until that time, but have subsequently died out everywhere in this region, except at Quahog Bay."\* Still later and more surprising is the extinction of the oyster from many localities on the coast of Maine and eastern Massachusetts.† Native oyster banks in the Charles and Mystic Rivers two hundred years ago were so productive that an enumeration of the exports from Boston to the West Indies and Spain in 1687 included "oysters salted in barrels, great quantities of which are taken here." Now there probably remain, according to Ingersoll, only two localities on the New England coast north of Cape Cod, where native oysters survive, these being Great Bay in New Hampshire, back of Portsmouth, and the Sheepscot River in Maine. They are likewise almost wholly wanting on the Canadian continuation of the coast until Cape Breton Island is reached; but thence westward in the Gulf of St. Lawrence they are plentiful, with numerous other southern species, to the Bay of Chaleurs. The extinction of oysters, and of their southern associates, has been rapidly going on from Nova Scotia to Cape Cod since the earliest settlement of the country, due probably not so much to their exhaustion by being gathered for food, or to any and all other causes, as to a progressive refrigeration of the sea; and this seems referable, as before indicated, to changes in the volume and warmth of marine currents, which changes ultimately may have been caused by the former depression and present uplifting of the region of Bering Strait.

\* This Journal, III, vol. vii, p. 137.

† Ernest Ingersoll, Report on the Oyster-Industry of the United States, Tenth Census, 1881.

ART. XXV.—*The Highest Old Shore Line on Mackinac Island*,\* by F. B. TAYLOR.

EVIDENCE of post-glacial submergence has long been known to exist on Mackinac Island, which lies in the strait between Lake Huron and Lake Michigan. Its amount has been variously stated by different writers, some putting it at 250 feet, while others claim that evidences on the higher parts of the adjacent mainland indicate an amount of submergence that would rise far above the summit of the island which attains an altitude of about 300 feet above the present level of Lake Huron. The observations of which I give an account here were made during the autumns of 1890 and 1891.

With the exception of the rocky faces of the great limestone cliffs which rise on its eastern and western sides, all the lower levels of Mackinac Island show plain evidence of post-glacial submergence. The modern beach is composed almost entirely of limestone pebbles which are generally well rounded. The proportion of crystalline drift material from the north is not great and is confined mainly to boulders of considerable size. The narrow strip of land upon which the village is built, and which rises to an altitude of 40 to 50 feet at the base of the cliff, is composed entirely of the same characteristic beach material; as may be seen in any of the little gardens of the villagers and in the deep cut back of the Astor House and the old court house. But on ascending to the higher levels of the island the evidences of post-glacial submergence are even more marked. At an altitude of about 170 feet there is a heavy, well developed beach ridge. This ridge is the lowest of a series of four or five like ridges which rise by successive steps to an altitude of about 205 feet above the strait or about 787 feet above sea level. These old beaches may be seen to best advantage on the short target range back of Fort Mackinac. The ground is there cleared of trees and is covered with a short, thick turf, so that the whole series of beach ridges, with their intervening troughs and minor ridges, is admirably exposed to view. At this place the ridges are parallel and comparatively narrow, though strongly developed, and they are also more compactly arranged and more convenient of access than in any other part of the island.

The short target range crosses the beaches nearly at right angles and the width of the series is here a little less than a quarter of a mile. But on the southwestern side of the island

\* An abstract of this paper was read before the Geological Section of the A. A. A. S., at Washington.

it is three times this width. In some places two or more ridges run together and form one, as is often observed elsewhere. On the short range four heavy ridges are clearly seen with possibly a fifth less distinctly formed. In two of the wider troughs, which are five to six feet deep between the main ridges, there are apparently several other little ridges, one to two feet in height. A road which runs parallel to the range and close to its west side cuts the top of each ridge and shows its composition to be a characteristic beach formation. The 205 foot beach is not only the highest one of the series here described, but also the highest on the island. If this ridge be followed through its full extent around the higher ground, it will be found to surround a small tract on three sides. On the remaining side, which is a long, straight line of limestone cliffs facing towards the northeast, all the beach ridges, except the lowest or 170 foot ridge, are wanting. This beach is situated at a considerable distance from the cliff, and the ground between is a broad, level plain with an altitude of 170 to 175 feet. On this plain a heavy talus of fragments and angular limestone boulders lies against the base of the cliff. While the waves were forming the 205 foot beach around the other sides of the circumscribed tract, they were beating against this northeast cliff and the water on the plain at its base was 30 to 35 feet deep.

The little island of ancient times, thus defined, was about three-fourths of a mile long and less than half as wide, with its longer axis running about northwest and southeast. Its north end was a sharp promontory formed by the long cliff facing northeast, as just described, and another shorter one facing almost directly west. At the base of the latter the 205 foot beach is well developed, but it is very narrow and the ground drops off rapidly westward to the 170 foot plain. The highest point of the ancient island is at its southern end which forms a rounded promontory and rises to a little less than 100 feet above the 205 foot beach. This point is now crowned by the earthworks of old Fort Holmes, built in 1812, and the descent to the 170 foot plain on the east, and to the 205 foot beach on the south is a steep slope of drift. On its west side, and about a quarter of a mile south of its north point, the surface of the island descends gradually to the 205 foot level. The upper beach is here wide and flat and encloses a considerable tract of low ground behind it.

All of my measurements of altitude were made with an aneroid barometer and are subject to the inaccuracy of that instrument. But the 170 and 205 foot beach levels represent in each case the mean of more than a dozen independent observations taken under favorable conditions and are therefore

probably not far from true. But after determining the fact that the highest old shore line on Mackinac Island has an altitude of about 205 feet above Lake Huron, another broader and more difficult question arose. Did post-glacial submergence exceed this amount? Suppose that it did, as has been implied and suggested by those who point to shore lines at higher levels on the adjacent mainland. What evidence can be brought to bear upon this question?

A careful examination of the ancient little island of Mackinac, as described above, and of the surrounding mainland reveals among others, the following facts: The whole surface of the ancient island, except where the rocks were laid bare along the edges by the formation of cliffs, is covered with glacial drift. This drift is typical in its composition and topographical features. Its surface has that irregular rolling appearance which is characteristic of a drift-covered, broken country. Along the edges near the cliffs the drift has been notched by the little rain rills which carry away the surface water. Otherwise, the surface shows no evidence of post-glacial modification.

The composition of the drift is well shown in the excavations of old Fort Holmes on the highest point of the island. The parapet of the fort was built of material dug partly out of the interior of the enclosure and partly out of an outer ditch. This ditch is five or six feet deep and seems to have been excavated entirely out of boulder clay, which is well exposed in several foot paths which cross the earthworks. The clay is very tough and of a reddish color, and when wet is quite slippery under foot. But when it is dried in the sun, it forms a very hard surface. It contains a fair sprinkling of boulders of moderate size, but appears at the fort to include comparatively little sand and gravel. The clay and coarser constituents form a heterogeneous mixture in characteristic drift fashion, and a fair proportion of the boulders show striæ. Although the composition of the drift varies somewhat in different places, it everywhere presents such characters as clearly preclude the supposition that it has been washed or worked over by the action of waves since its deposition by the ice sheet.

The whole surface of the ancient island is well sprinkled with boulders and a large number of them are erratics of northern origin. With hardly an exception their exposed surfaces are strongly weathered. I found only two small surface boulders with striæ still preserved, and both looked so fresh that they probably came from some of the excavations near by. I examined hundreds of boulders below the 205 foot level, but found none with glacial scratches. Exposures in

road-cuts and gravel-pits are common on all parts of the island, but I found not a single striated pebble in any of those below the 205 foot level. Below this level the loose material of the island generally appears to be rounded and water-worn. The sharp angular fragments which are intermingled in small quantities are of the country rock and were probably freshly derived from the cliffs. I found nothing resembling boulder clay below the 205 foot level, though it probably occurs in protected places.

During the last season a pit was dug at the target on the short range which is against the foot of Fort Holmes hill, and an excavation was also made at a higher level to obtain material for filling in behind a log backstop. The pit is in the trough behind the 205 foot beach, and the backstop is about ten feet higher on the side of the hill. A number of beautifully striated pebbles were found which had been thrown out of the pit. Almost the whole mass of material excavated for the backstop consisted of Paleolithic flint chips originally derived, apparently, from the chert nodules of the limestone of the upper cliffs. This excavation was about four feet deep.

Altogether, the appearance of the surface of Mackinac Island seems to show that all parts of its surface, up to the level of 205 feet, has been modified by wave action since the deposition of the glacial drift; but that above that level no such modification has taken place.

An examination of the mainland north and south of the island shows that they, too, have been post-glacially submerged up to certain levels. Within a radius of 20 miles no land reaches an altitude of more than 160 to 170 feet. McGulpin's Point on the south side of the strait, with an altitude of about 110 feet, was completely submerged. So also was the high ground on the north side near Pointe La Barbe, altitude about 140 feet, and at Gros Cap farther west and a little higher. On the shores of Little Traverse Bay, about 40 miles southwest, a heavy shore line is found near Petoskey at an altitude of about 100 feet above the lake, and a little higher at Harbor Springs on the north side of the bay. At the latter place the shore line appears as a great terrace, and from the head of the bay it is developed westward and northward continuously for a distance of more than 20 miles to a point north-east of Cross Village. At a very early day this terrace was largely cleared by the red men and is said to have been almost one continuous village for its whole length.

At the time of the great post-glacial submergence the high tract north of Little Traverse Bay and west of the G. R. and I. Ry. was a large island, nearly round and about 15 miles in diameter. On the south side of the bay the shore line ex-

tends inland eastward from Petoskey at least 20 miles, and passes south of Crooked, Pickerel, Burt and Mullet Lakes. Beyond this its place is not yet determined. Southwest from Petoskey the old shore line is quite irregular but continuous, at least as far as Traverse City, a distance of about 50 miles, at which point the old delta of the Boardman River shows the water level to have been at an altitude of about 80 feet.

The identity of this great deserted shore line with that found on the shores of Lake Huron and Georgian Bay, called by Professor J. W. Spencer, the Algonquin beach, and described by him in recent numbers of this Journal, seems almost certain. The upper beaches of Mackinac Island are without doubt only an isolated part of the same great shore line.

It is well known that almost the whole of the northern peninsula of Michigan has been submerged since the glacial epoch. This area of submergence is continuous with that which I have described on the south side of Mackinac Strait, and includes a large part of the south shore of Lake Superior. Some years ago I saw deserted shore lines near Au Train, at Marquette and at the west end of Lake Superior which probably belong to some stage of the same epoch of submergence.

The old shore line between Traverse City and Mackinac Island shows the same northward rise as has been found in post-glacial shore lines elsewhere. From Petoskey to Mackinac Island the northward component of distance is about 33 miles and the Mackinac beach is about 100 feet higher than that at Petoskey. The northward component of differential elevation between these points is, therefore, three feet per mile. From Traverse City to Petoskey the northward component of distance is about 41 miles, and the difference of elevation of the beaches is approximately 20 feet, making the northward factor of differential elevation six inches per mile. Two isolated observations near Levering and Pellston 15 miles north of Petoskey on the G. R. and I. Ry. seem to show an elevation for the shore lines at those places of not less than 150 or 160 feet. This is somewhat higher than the plane directly connecting Petoskey and Mackinac Island. But the local variation of differential elevation which seems to be suggested by these two observations needs further verification.

Near Harbor Springs and Wequetonsing on the north side of Little Traverse Bay, and at Petoskey and Traverse City, the evidence that post-glacial submergence has not extended above the level of the observed old shore line is fully as plain as on the island of Mackinac. This statement applies to the surface forms and the composition of the drift, and also to the presence of striated boulders in the drift above the line and their absence below it. Back of Petoskey the hills rise 300

feet or more above the lake. They have been cleared for cultivation and they show those peculiarities of surface formation which characterize only an unmodified drift topography. They are heavily drifted and their surfaces have those long, graceful curves with upward convexities which are unerringly attributed to the constructive action of the ice sheet, and which are plainly not a product of any known destructive or eroding agent. In case of greater submergence they would be exposed, as the shore below is to-day, to the full force of the west and northwest winds, and they could hardly escape the eroding action of the waves. The modified course of Bear Creek proves that during the formation of the Algonquin beach at this point, and during the entire subsequent recession of the waters down to their present level, the waves of the west winds have played a strongly predominant part in the modification of the shore. Below the Standard Oil Co.'s station south of Petoskey, Bear Creek runs towards the northwest and once entered the lake in that direction through a narrow gorge. But its present course turns abruptly from northwest to northeast where its banks are about 90 to 100 feet above the lake. From this point it flows about half a mile to its mouth in a course nearly parallel with the present shore, and descends quite rapidly. There are good exposures in the banks at the bend and they show deep sections of characteristic beach material—rounded pebbles, gravel and sand—up to about 90 feet elevation. The position of this material shows that at the time of the Algonquin submergence the eastward littoral transportation was so great that it forced the stream to turn aside in the direction of the movement, and the continuation of the stream in the same modified course ever since shows that the same disturbing element has acted continuously at lower levels. The shortness of the rock gorge below the bend indicates a comparatively recent date for the change. Many lakes along this shore have been partly formed by littoral dams of Algonquin or later age.

But in respect to exposure to wave action, Mackinac Island seems to me to be a test case. For its geographical position is such that in the event of a general submergence of that region to or beyond the depth indicated by the Algonquin beach, it would stand alone in a wide expanse of water. The nearest mainland would then be about 30 miles to the south and the nearest islands about 20 miles to the north and southwest. In all other directions open water would stretch away 100 to 200 miles. From Traverse City to Mackinac Island and at least 25 miles farther north, the plane of wave erosion appears to have acted at every horizon up to the level of the Algonquin beach. But above that plane there is no evidence of such action; at

least up to a level of 100 feet above the Algonquin beach as seen on Mackinac Island, and 200 feet above it as seen at Petoskey.

It might be supposed that the small area of Mackinac Island was submerged and re-elevated by movements so sudden that the waves had no time for effective action at any horizon between 205 and 300 feet. But the difficulties in the way of such a supposition are many and great, and when it becomes necessary to extend the application of it to an area 100 miles long and even to the whole area of the three upper Great Lakes, the difficulties become insuperable.

The most impressive feature of the old shore line which I have described is the great strength of its development. The time during which the water level stood at or within 35 feet of its highest stage must have been of very long duration, for by far the strongest development is within this limit. The appearance is just such as would be produced if the water had risen slowly at a steadily decreasing rate, stood long at its highest level, and then had fallen away again as slowly and at a steadily increasing rate. The Iroquois beach of the Ontario basin, described by Dr. G. K. Gilbert and Professor J. W. Spencer, has the same strong development, except where lack of drift gave little loose material for the waves to work upon.

If the rise of the Algonquin beach on the east side of the Georgian Bay continues northward, it must extend far above the pass at Lake Nipissing. The Iroquois beach has the same northward rise, and if its approximate mean plane, not counting the exceptional high grade northeast of Watertown, N. Y., be produced northward, it too strikes much higher than the Nipissing pass. The two planes come as near together at Nipissing as could be expected in view of the considerable extent of irregular, local earth-warping. Considering this fact and the general similarity of the two beaches, it seems probable that the Iroquois and Algonquin beaches are in reality one continuous line. Terraces have been noted on the hills at Nipissing, at an altitude of several hundred feet above the pass and they are in all probability a part of the connecting link.

The generally accepted explanation of the origin of all the old shore lines of the basins of the Great Lakes is that they were made by bodies of water held as lakes in front of the ice sheet as it retreated northward. But this theory does not seem applicable to the Algonquin and Iroquois beaches. The long duration of wave action at one horizon, as attested by the strong development of these lines, is hardly reconcilable with the idea of an ice dam, which must have been formed by an

ice sheet which we know to have retreated with a halting, fluctuating movement.

But there is positive evidence of marine post-glacial submergence in the St. Lawrence valley. On the mountain at Montreal marine shell beds occur at an altitude of 520 feet above the sea, and in the Pleistocene deposits of Vermont near Lake Champlain the skeleton of a whale was found. In the depths of Lake Superior a marine or brackish water organism is found living to-day. These facts are all well known and their *prima facie* significance is unmistakable. Yet many geologists put them aside for the ice-dam theory which seems more complete. The idea of the ice dam accounts for the submergence which made the shore lines. But the facts proving marine submergence do not explain the cause of that submergence. There is no proof that the waves which washed the Iroquois beach were of fresh water. They may have been salt, but more probably were brackish. If there were no evidence of marine post-glacial submergence in the St. Lawrence valley, then, on purely negative evidence, we might remain in reasonable doubt. But the marine shells at Montreal and the Champlain whale are positive evidence of marine submergence of those localities, and they are not more than 150 miles from the Iroquois beach at Watertown, N. Y., and 100 miles from its position at Fine. No adequate reason can be given why we may not make the almost obvious inference that these marine beds are in the same area of post-glacial submergence as the Iroquois beach. We know that salt water stood more than 520 feet deep at Montreal, and we do *not* know that the Iroquois waves were of fresh water. It seems more pertinent, therefore, to ask what barrier could have held the salt water out of the Ontario basin, than what could have held a supposable body of fresh water in.

Higher shore lines exist in the Ontario and Erie basins, but they are generally comparatively weak in development and many of them are known to be of a distinctly fragmentary character, suggesting isolated areas of submergence and less duration of time in their formation. All those which have been thoroughly identified as shore lines are in hydrographic basins so situated with respect to the several lobes of the retreating ice sheet and certain old disused river beds as to strongly suggest the operation of ice dams. The longest beaches yet found at the higher levels are those of the Erie basin. The Maumee beach, which is the highest, extends eastward from Fort Wayne and ends at Cleveland, and Dr. Gilbert found the termini of others of the same series in western New York. All these termini are in comparatively open

country where the lines could easily be followed farther if they existed. No such end has ever been found for the Algonquin or Iroquois beaches. They have merely been lost in the bush, or rocky, scantily drifted regions, and await more careful and energetic exploration.

If shore lines are found in the highlands 50 to 70 miles south of Mackinac Island, as has been reported, they must have been formed by ice-dammed lakes which were drained off and had disappeared before the summit of the island itself emerged from the ice. The higher beaches of the Ontario basin and all those of the Erie basin were probably made by ice-dammed lakes. But the heavily developed and apparently continuous Algonquin and Iroquois beaches, including the 170–205 foot beaches of Mackinac Island,—probably all one line,—were made by waters which had open connection through a broad strait at Nipissing with the Gulf of St. Lawrence, and the Atlantic Ocean. The facts suggest a provisional classification of the deserted beaches of the Great Lakes into two divisions, produced by entirely different causes, and probably at widely separated times, namely: the higher level, fragmentary and comparatively weak beaches, probably produced by ice-dammed lakes, and the lower, strongly developed, continuous beaches of marine origin, formed, probably, long after the ice sheet had disappeared from eastern North America.

Fort Wayne, Ind., Nov. 18, 1891.

ART. XXVI.—*On the Nature of Colloid Solutions*; by  
C. E. LINEBARGER.

It seems to be the general opinion among scientists that the solutions of colloid substances, such as albumen, silicic acid, tungstic acid, etc., differ in their nature from solutions of crystalloid substances. The great difference in the velocity of diffusion of solutions of crystalloids on the one hand and of colloids on the other, together with the fact that certain animal membranes and parchment paper are impermeable for colloids, but allow crystalloids to pass freely through their pores, led Graham\* to invent the names *crystalloid* and *colloid*, thus dividing substances into two great classes. Graham in his paper states distinctly the differences existing between crystalloids and colloids and ventures the question whether the basis of the colloid state may not be in the complex

\* Liebig's Ann., cxxi, 1, 1862.

character of the molecule. However, the facts that the solutions of colloid substances do not have an appreciably higher boiling point than water nor a lower freezing point, and that, in dissolving a colloid, no change of temperature takes place, or, at least, but a very slight change, seems to indicate that a colloid solution is not a solution in the ordinary sense of the term, but rather a mechanical mixture, an emulsion, the colloid being held in a state of suspension in the water.

In the last few years, able investigators have occupied themselves with the subject, and their conclusion has pretty generally been that a colloid solution is really only an emulsion, i. e., a suspension of the finely-divided colloid in the solvent. Most of the experiments have been carried out with solutions of colloid silver. But silver has the property of assuming so many allotropic forms, as shown by the researches of Carey Lea, that it is hardly justifiable to apply the deductions drawn from the phenomena exhibited by it to other colloid substances. Muthmann\* describes two experiments which to his mind are convincing proof that colloid silver forms a "suspension" or emulsion with water and not a true solution.

If a solution of colloid silver be mixed with a solution of gum arabic, by adding alcohol, both silver and gum arabic are precipitated, although alcohol does not precipitate a solution of colloid silver alone. According to Muthmann, the explanation of the phenomenon is that the finely-divided silver held in suspension is dragged down by the gum arabic when alcohol is added. But Carey Lea states that a solution of litmus in water, which every one admits to be a true solution, mixed with a solution of gum arabic is also precipitated by alcohol. Muthmann's experiment can then hardly be said to prove the existence of colloid solutions differing from crystalloid solutions in that particular.

In the second experiment, Muthmann let a solution of colloid silver freeze. After melting, the originally red color of the solution had changed to a black, and it was possible by means of a good microscope to distinguish small particles of silver so finely divided, however, that after standing for a week but a portion settled down. Yet this experiment does not prove that the colloid silver is held in suspension in the water. It only shows that, by freezing, the silver is made to pass into a state of greater molecular aggregation, so that the "tagmas"† formed are visible under the microscope. I have frozen solid a solution of colloid tungstic acid, without that the properties of the solution were in the least changed. At any rate, colloid

\* Ber. der d. chem. Gesellschaft, xx, 983, 1887.

† By "tagma" is understood a combination of molecules, i. e., a molecule made up of several other molecules. See Pfeffer's "Osmotische Untersuchungen," p. 32.

silver is so anomalous in its behavior that the results of experiments carried out with it cannot be well applied to other colloid substances.

Exner\* has made an examination of finely-divided bodies suspended in a liquid with a view to explaining the phenomena of the Brownian movements. He prepared emulsions of gamboge by adding water to a solution of gamboge in alcohol. In this way so fine an emulsion was obtained that under ordinary conditions it kept as such indefinitely. Exner found that, if a little of this "suspension" be put in a vessel and water carefully run down over it so as to form a distinct surface of separation between the two liquids, after some days this surface separating the liquids became obliterated, in other words, diffusion took place. Accordingly, finely-divided particles held in suspension in a liquid would seem to have the power of doing work against gravity; for it is only by the expenditure of energy that a particle would pass from a lower to a higher position in the liquid. But Exner found again that, if the experiment be conducted in a room of constant temperature, after three days not only no particles had passed from the lower liquid to the upper, but that, on the contrary, a portion of the gamboge had settled down as a deposit at the bottom of the vessel. The diffusion phenomena observed in the first experiment must then have been due to changes of temperature and jarring. According to the second experiment, emulsions do not possess the property of diffusion; they are only subject to the action of gravity. Muthmann's second experiment also affords additional proof for this conclusion. But solutions of colloids diffuse, as has been shown by Graham in the case of albumin, etc. Here is then a fundamental distinction between a true solution and an emulsion. Diffusion, as has been shown by Nernst,† is due to osmotic pressure. Therefore, we would expect that a solution that diffused, would have an osmotic pressure. Pfeffer, in the course of his researches on osmosis‡ has found the osmotic pressure of a 1 per cent solution of gum arabic to be 7.1<sup>cm</sup> of mercury at 15°. This is the only determination of the osmotic pressure of a colloid that I know to have been made. Gum arabic, from a chemical standpoint of view, is hardly suited for an investigation of this character. Too little is known of the constitution of its molecule, and it is not always a chemical unity. What is wanted for an investigation of the osmotic pressure of colloids is a colloid as simple and stable as possible. The colloid modifications of tungstic and molybdic acids fulfill these conditions very well. A solution of colloid tungstic acid

\* Wiener Ber.

† Zeitschr. f. phys. Ch., ii, 613, 1888.

‡ Osmotische Untersuchungen, Leipzig, 1877.

may be frozen or heated to 150° without alteration. I have therefore made some determinations of the osmotic pressure of solutions of colloid tungstic acid in the hope of obtaining results that may throw some light upon the nature of colloid substances in solution. As osmotic pressure affords a precious means, according to the theory of van't Hoff on dilute solutions, of determining molecular mass, the results should have some interest.

The apparatus used consisted simply of a tube about 8<sup>cm</sup> long and 15<sup>mm</sup> in diameter; one end was well-rounded off in the flame and the other drawn out so as to form a neck. The manometer was a capillary tube with a bore of about 0.5<sup>mm</sup>, passing loosely into the neck of the osmometer. A bit of rubber tubing is used instead of a cork. The manometer should be so adjusted that it may be pushed to and fro in the osmometer. This is accomplished by greasing well the interior of the rubber tubing. By pushing the manometer into the osmometer or by drawing it out, the pressure may be increased or decreased at pleasure. The membrane used was thick parchment paper, which was bound over the wide end of the tube by means of silk thread, perfect contact between the paper and the glass being effected by the use of a solution of good sealing wax in alcohol. A hermetic joint may thus be obtained. Of course, a great degree of accuracy cannot be obtained with an apparatus of the above description, especially when it treats of measuring high pressures. Still with pressures not exceeding 30–40<sup>cm</sup> of mercury quite good measurements can be made. I have modified the apparatus somewhat, so that it is capable of much greater precision. The results obtained with the second apparatus will be published in a succeeding paper.

The osmometer is filled with the solution, the osmotic pressure of which is to be determined and the manometer inserted in the neck, care being taken that no bubbles of air be present. The osmometer is then suspended vertically in a jar filled with pure water.

Two solutions of colloid tungstic acid were prepared, which I will designate by the Roman numerals I and II.

1 c. c. of sol. I contained .02467 grms.  $(\text{H}_2\text{WO}_4)_n$

1 c. c. of sol. II contained .0100 grms.  $(\text{H}_2\text{WO}_4)_n$

The solution of tungstic acid was prepared by adding to a 5 per cent solution of sodium tungstate just enough hydrochloric acid to take up the sodium. The whole was dialyzed until no trace of salt could be detected in the outer liquid.

I filled an osmometer with sol. I, adjusted the manometer so that the pressure was about 20<sup>cm</sup> of the solution, as I did not employ mercury in the manometer in this experiment, and suspended the apparatus in pure water. The solution mounted

steadily in the manometric tube and in four days had reached the height of about three yards. Having thus got an idea of what osmotic pressure the solution would exert, I repeated the experiment, using mercury\* in the manometer. I pushed in the manometer so that the mercury stood at about 40<sup>cm</sup>. In twenty-four hours, it had fallen to 25.3<sup>cm</sup>, and remained at this height for about four days. It then fell slowly and in three weeks had fallen nearly 6<sup>cm</sup>. In another experiment I "set" the osmometer at about 15<sup>cm</sup>, and in a day or so found that the mercury had risen to 25.1<sup>cm</sup>. Taking the mean, a solution of colloidal tungstic acid containing 24.67 grms. to the liter, exerts an osmotic pressure of 25.2<sup>cm</sup> of mercury. The temperature at the time of the readings was 17°. Applying the formula for dilute solutions,  $pv = RT$ , I have  $T = 290^\circ$ .  $R = 84500$ , and, if the molecular mass of colloidal tungstic acid be 250, i. e.,  $H_2WO_4$ ,  $v = 10377$ ,  $p = 2317.6^{\text{grm}}$  per  $\text{cm}^3$  or 170.5<sup>cm</sup> of mercury. But the experiment gave only an osmotic pressure of 25.2<sup>cm</sup> of mercury, which is 6.77 times less than the theoretical. Hence, as molecular mass varies inversely as the osmotic pressure, the molecular mass of  $(H_2WO_4)_n$  must be about 1693 and  $n$  nearly equal to 7.

With sol. II, I obtained as a mean of several determinations an osmotic pressure of 14.1<sup>grm</sup> per  $\text{cm}^3$ . As the pressure with this solution was so feeble I used the solution itself in the manometer, reckoning it as water. This pressure corresponds to a molecular mass of 1718, which corresponds closely with that obtained with sol. I.

In round numbers then the molecular mass of colloidal tungstic acid is about 1700 or nearly seven times 250, and the colloidal molecule consists of seven simple molecules.

All of the phenomena exhibited by colloids may be easily explained on the assumption that the colloid molecule is very large. A solution of a colloid does not seem to lower the freezing point nor raise the boiling point because the molecular mass is so great that it has but little influence. The raising of the boiling point and lowering of the freezing point is a function of molecular mass; the larger the molecule, the less marked these properties of solutions. Colloid solutions do not differ essentially from crystalloid solutions in this particular; and the apparent difference is but one of degree. Colloid solutions lower the freezing point and raise the boiling point only a very little. A 5 per cent solution of colloidal tungstic acid, for instance, would not depress the freezing point more than 0.05°, a depression which could not be accurately measured. I determined the freezing point of sol. I, finding

\* Tungstic acid attacks mercury so that at the surface of contact a blue zone forms, which gradually spreads. Yet, I do not think that it had any influence upon the osmotic pressure.

it to be  $0.1^{\circ}$ , which corresponds to a molecular mass of 456, a number upon which no weight can be laid, as doubtless most of the depression was due to the salt present in the solution.\* The presence of a small amount of salt would have no effect, however, upon the osmotic pressure, since the salt could pass freely through the membrane. Osmotic pressure is then due to the colloid alone. The delicacy of the osmotic pressure method is very great. Using the solution itself to measure the pressure, a molecule 2000 times heavier than hydrogen in 1 per cent solution would support a column more than a yard high.

A colloid solution might be regarded as a step between a true solution and a true emulsion. The colloid molecule is so much larger than the water molecule that it stands to reason that the properties of colloid solutions must differ markedly from solutions of substances which possess a molecule but several times heavier than water. Hence diffusion of colloids takes place slowly; the osmotic pressure is small; and but a slight lowering of the freezing point and raising of the boiling point occurs.

As to the nature of this large molecule and how the simple molecules are combined to form the complex molecules, it is hard to give an opinion. The ease with which colloidal substances are coagulated, i. e., pass into the solid state, indicates that there exist in the solution molecular groupings similar to those existing in a solid. It is generally admitted that in solids the simple molecules unite to form more complex molecules or "tagmas." Similar "tagmas" might exist as such in the solution.

The facts are that solutions of colloids have a definite rate of diffusion and exert a definite osmotic pressure. As osmotic pressure, diffusion, lowering of the freezing point and raising of the boiling point are intimately related, we can say that colloid solutions also have freezing and boiling points differing from those of the solvent. We conclude then that a colloid solution is a solution in the ordinary acceptation of the term and not a "suspension."

I am occupied in making determinations of the osmotic pressure of colloid substances, especially of the albuminoids. Certain albuminoids, as is well known, are insoluble in pure water, but quite soluble in a solution containing a little of some salt. As this salt does not affect the osmotic pressure in the least, its presence does no harm. Thus I hope to get more of an insight into the nature of the complex substances of animal origin.

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\*I might have determined the amount of salt present and thus easily found what depression was due to the acid alone; but as the depression was so small and the solution so dilute, the results would have been worthless.

ART. XXVII.—*Observations upon the Structural Relations of the Upper Huronian, Lower Huronian and Basement Complex on the north shore of Lake Huron*; by RAPHAEL PUMPELLY and C. R. VAN HISE.

DURING the past summer we visited the north shore of Lake Huron in order to find evidence, first, as to whether the Original Huronian of Logan and Murray is divisible into two series as recently advocated by the late Professor Alexander Winchell; and, second, to ascertain more definitely the relations which obtain between the Lower Huronian and the Basement Complex of the region, usually called Laurentian. The term Basement Complex is here preferred in order to avoid a discussion as to any correlation with the original Laurentian rocks.

*Relations of the Upper and Lower Huronian.*

Prof. Winchell found, as he thought, evidence of two series in the Original Huronian near Echo Lake. At this place, according to him, there is in descending order, a slate-conglomerate and quartzite with a dip of about  $20^{\circ}$ . There is then an interval of a third of a mile, after which appears a quartzose slate-conglomerate, followed by quartzite, and this by alternations of quartzite, quartz-schist, and various slates, schists and argillites, the series having a dip of  $75^{\circ}$  to  $80^{\circ}$  southwesterly, and being as a whole more crystalline than the first slate-conglomerate and quartzite. A break is consequently placed between the two, the upper series including all of the limestones and intervening formations of Logan and Murray's Huronian.\*

About two miles east of Garden River is a ridge of banded blue and cream colored limestone fully 200 feet high, which may be easily found as a quarry is here located. Its strike is about N.  $30^{\circ}$  W., and its dip  $\pm 5^{\circ}$  south of west. On its steep northern slope, and underlying the limestone, is found the typical lower slate-conglomerate. The actual contact between the two was not found, although they are separated by only about 50 feet at one place. The lowest layer of limestone is very siliceous, probably indicating that the passage from the conglomerate to the limestone is a gradation such as ordinarily occurs when a change takes place from mechanical to chemical or organic sedimentation. The exposure of lower slate-con-

\* A Last Word with the Huronian; Alex. Winchell: Bull. Geol. Soc. America, vol. ii, pp. 114-124.

glomerate was not sufficiently large to enable one to determine strike or dip.

Passing now a few paces south of the main limestone ledge, i. e., geologically upward, the actual contact between it and the upper slate-conglomerate is seen, although for no great distance. This contact is perfectly sharp. Upon one side of the line is the typical limestone; upon the other is the coarse conglomerate. The bedding of the latter is not sufficiently distinct to determine whether between the two formations there is a discordance. Above the contact occurs a good sized exposure of upper slate-conglomerate. This contains innumerable characteristic fragments of this formation, including besides various granitic fragments those of basic eruptives, of quartzite and of jasper. The distinctive feature of the exposure is, however, the presence of very numerous fragments of limestone, which sometimes reach a foot or more in diameter. These fragments have precisely the appearance of the strongly laminated underlying limestone. The bandings of the fragments lie in various directions, showing that this structure existed in the original rock at the time of the deposition of the conglomerate.

About 40 rods east, while the typical upper slate-conglomerate was not found, at the extreme southernmost part of the limestone bluff is a limestone-conglomerate or recomposed limestone, which is regarded at this point as the base of the upper slate-conglomerate.

A large exposure of lower slate-conglomerate some distance to the west of the locality above described shows the bedding to be vertical. It also has a cleavage in several directions so that large fragments under slight blows break into polygonal blocks. As compared with the upper slate-conglomerate it is much more crystalline. Its finer grained phases pass into a siliceous schist. The outcrop of lower slate-conglomerate adjacent to and north of the limestone has the same lithological character as the large bluff to the west.

It is concluded from the above observations that bearing in favor of a considerable break between the Upper and Lower Huronian are the following points:—There is (1) a difference in degree of metamorphism. The Lower Huronian has been so much altered as to have become semi-crystalline and to take on various cleavages, while the upper slate-conglomerate has no such characters. (2) Blocks of limestone in the upper slate-conglomerate are in exactly the same condition as in the original ledge. (3) Also the jasper fragments here contained were probably derived from the hematitic jaspery formation which is known to occur in the Lower Huronian. This sedimentary formation, like the limestone, belongs to one series, while the

series which contains them as detritus is of later age. The existence of jasper fragments in the Red Jasper Conglomerate was interpreted by Logan as "showing their derivation from a more ancient stratified rock."

Thus, so far as evidence was found by us, it bears in the same direction as the facts cited by Dr. Winchell, except that we would place the unconformity in the Huronian above the lower limestone member, whereas he places it below this formation. The Lower Huronian series would then comprise, in ascending order, Logan and Murray's Nos. 1 to 4 inclusive, the whole being according to these authorities about 5000 feet thick; while the upper series would comprise Nos. 5 to 13 inclusive, the whole being about 13,000 feet thick.\*

*Relations of Lower Huronian to the Basal Complex.*

*Contact near Garden River.*—On the left side of the road leading from the Canadian Sault Ste. Marie, to Garden River, is a huge bluff of lower slate-conglomerate which has a north and south extent of at least an eighth of a mile. This conglomerate has all of the features heretofore described, that is, a vertical bedding, cleavages in various directions, and a semi-crystalline character. In passing from south to north the contained fragments as a whole increase in magnitude, although even after the exposure becomes strongly conglomeratic other layers lower down may be found which are nearly or wholly free from coarse detritus. When the north end of the exposure is reached the rock has become a magnificent basal conglomerate, consisting almost wholly of granite fragments set closely together and forming a stucco. The sparse fine-grained matrix is here composed of materials largely identical with the coarse fragments. Mingled with the numerous great boulders some of which are several feet in diameter are other boulders of intermediate sizes. In the passage from south to north along the bluff there is also noticed a tendency for the boulders to become angular. Turning now around the northwest corner of the ledge, and following along its foot to the east, there appears just north of a sharp ravine not more than 100 steps from the conglomerate a great bluff of massive red granite (the syenite of the early Canadian geologists). On the talus slope of this bluff were found numerous angular blocks which are a genuine recomposed granite. These on their freshly broken surfaces so closely resembled the solid ledge that they can not be discriminated from it, but on the weathered surface their complex character is readily recognized since the discrete fragments of which they are composed stand out

\* Geology of Canada, 1863, pp. 55-57.

sharply. The granite of the ledge, the fragments of the recomposed granite, and the great majority of those of the conglomerate are of identical character. Although the actual contact between the granite and conglomerate was not seen, there can be no doubt that here was an old shore line and that the granitic debris of this lower slate-conglomerate was derived from the granite, this being a pre-existent ledge. A second visit to this place was made by us in the company of Dr. Charles Barrois, Dr. Hans Reusch, Dr. Carl Schmidt and Dr. Th. Tschernyschew. After having carefully examined this and another adjacent locality in which the relations were somewhat obscure, these gentlemen all agreed that the above is a correct interpretation of the facts.

This contact is not between the lowest formation of the Original Huronian of Logan and Murray and their Laurentian, but is at the base of their lower slate-conglomerate, that is, is below a member of the Lower Huronian series. When it is considered that granitic rocks do not originate at the surface, but must have been deeply denuded before they can yield blocks to a basal conglomerate it may be considered a certainty that at Garden River, there is a physical break of great magnitude between the Lower Huronian series and the basement rocks of the region.

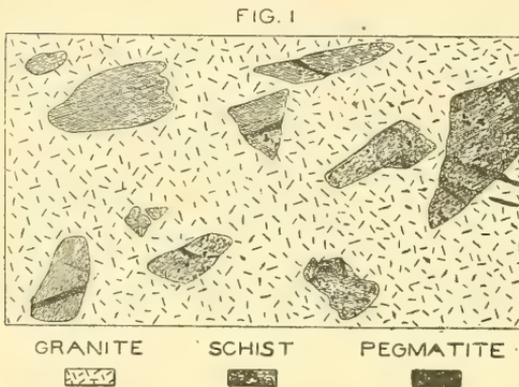
*Contact east of Thessalon.*—A locality four or five miles east of Thessalon visited by the late Prof. Irving and the junior writer in 1883, and described by Prof. Irving in 1887,\* was again visited by the writers last summer. Prof. Irving states that this place shows a true unconformity between the Huronian and the Archean. He describes and figures a granitic and gneissic basement complex upon which rests, with actual contact exposed, a great conglomerate, the debris of which is derived from the immediately subjacent rocks. While in 1883 the basal conglomerate was seen on a magnificent scale, the contact was found only for a few feet at the end of one island.

At our recent visit to this locality the water of Lake Huron was very low, at least three feet lower than in 1883. The contact instead of being exposed only for a few feet at one place was seen all the way across two low, dome-shaped glaciated islands, the length of contact in each case being 40 or more feet. The facts observed are as follows:

The lowest rocks of this vicinity were found not to be simply a granite or granitoid gneiss as might be inferred from the general descriptions of Logan, but are an intricate mixture of granites, granitoid gneisses or foliated granites, and various

\* Is there a Huronian Group? R. D. Irving: This Journal, III, 1887, vol. xxxiv, pp. 207-216.

crystalline schists. A gray granite-gneiss and a red granite occurs in considerable masses, as do also dark colored schistose rocks. Here the fine-grained gneisses and crystalline schists have been most intricately intruded by the granite, and later still both have been cut through and through by pegmatitic granite. In passing from a granitoid exposure to a schist exposure the first evidence of the schists is the appearance of angular and partly rounded inclusions of these rocks. In passing onward there appear very numerous blocks of the schist which have been free to move, and the laminations of



which strike in various directions, although there is often a rough parallelism in their structures. (See figure 1, drawn from a photograph.) The schistose blocks have been more or less absorbed and the whole has a pseudo-conglomeratic appearance which is identical with pseudo-conglomerates of

a similar origin described by Lawson about Rainy Lake.\* In passing onward towards the schistose area the intrusive granite has cut across the lamination of the schists and parallel to them so as to make a network of intrusive dikes; but the schistose material has not greatly moved from its original position, consequent upon which there is a parallelism of structure. In passing still onward the schists are cut by veins or dikes of granite, but in subordinate quantity, and finally the continuous schists are found (lower part of fig. 3.) No observing geologist would take these intrusive relations and pseudo-conglomerates to indicate that the schists are later than the granite-gneiss. Such doubtless are the relations described by Barlow,† as a consequence of which he drew the conclusion that nowhere on the north shore of Lake Huron are any detritals which are later than and rest unconformably upon the basement complex. If we understand his descriptions, he regards the dark-colored crystalline schists as Huronian, whereas they are really pre-Huronian. Seeing facts of one kind and

\* Report on the Geology of the Rainy Lake Region, Andrew C. Lawson, Geol. and Nat. Hist. Survey of Canada, vol. iii, 1887, pp. 130F-139F.

† On the Contact of the Huronian and Laurentian Rocks North of Lake Huron, Alfred E. Barlow: Am. Geol., 1890, vol. vi, pp. 19-32.

failing to find those of another, Barlow erroneously concluded that the latter do not exist.

However, resting upon the crystalline complex east of Thesalon as a basement is the great conglomerate described by Irving. This conglomerate contains numerous bowlders of the red and gray granite, of the pegmatitic granite, and of the various crystalline schists derived from the immediately sub-

adjacent basement complex, as well as other materials not noted as occurring in this vicinity. The character of this conglomerate is shown by figure 2, drawn from a photograph. How different this true conglomerate is from the pseudo-conglomerate may be seen by comparing figures 1 and 2. In

FIG. 2

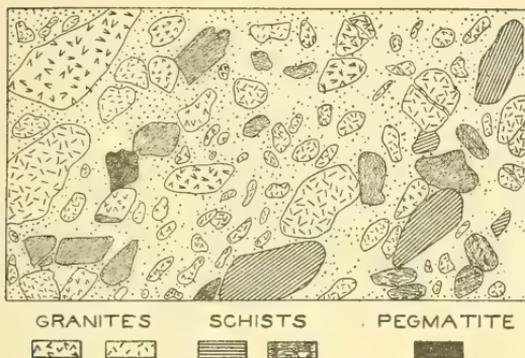
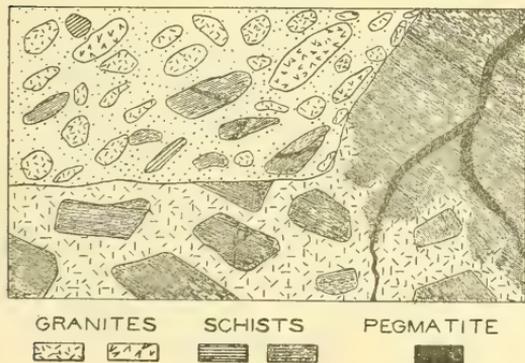


figure 1 the fragments are all alike and the same as the adjacent schist, while those of figure 2 have great variety and are more rounded. Also, although not possible to represent it in figure 2, the matrix is fragmental while in the other case it is crystalline granite.

The line of contact between the true conglomerate and the basement complex across one island is so distinct as to be located to the fraction of an inch. This line is irregular and in one place varies in strike within a foot or two as much as 45° or 50° (see fig. 3).

FIG. 3



At places upon the lower side of this line is the gray granite, at other places are the schists, the two having the relations before described, and both are cut by the pegmatite granite. At one place the foliation of the crystalline schist or gneiss abuts perpendicularly against the line of contact. Along the

line of contact between the basal complex and the true conglomerate, the pseudo-conglomerate also occurs, the fragments being all of one kind, that is derived from the schists intruded.

Above the line of erosion-contact, within an area of a square yard, in the true conglomerate may be seen fragments of the various rocks which occur in the basal complex; granites, gneisses and schists of various sorts, all of them showing the characteristic appearance of water rounding.

Upon the second island the relations are somewhat different from those just described. Here, in passing from the undoubted conglomerate on one side to the granite on the other, is an apparent transition. As the line of contact is neared, the bowlders of the conglomerate which are at first of many varieties gradually become more and more predominantly of the kind of granite which is immediately subjacent. Upon getting closer to the contact these bowlders are found to be angular and finally to have moved but little from their original positions. Finally a transition zone between the conglomerate and the granite-gneiss differs only from the solid mass of the latter in being cut by cracks into which detritus has sifted, and then these gradually die out and we are upon the solid granite. The change from unmistakable conglomerate to the solid granite takes place in about six feet. The facts here are in perfect accordance with those heretofore described, only there is the difference that the forces of erosion were not powerful enough to sweep all the coarse debris sharp and clean away from the shore line at this point, but at the beginning of the deposition of the conglomerate, left the blocks of granite and the perhaps somewhat altered granite practically undisturbed. As the sedimentary deposit increased in thickness, more and more material came in from the outside until the conglomerate took on the ordinary phase.

This contact east of Thessalon is of unusual importance because of two things: First, it is the only locality known to the writers where may be seen together the intrusive relations so well described by Lawson between granite-gneisses and dark colored schists producing pseudo-conglomerates and immediately adjacent to this complex a phenomenon of a wholly different order, a true basal conglomerate which marks the beginning of a new series. Second, this locality is important because the contact is between the lowest member of the original Huronian as described by Logan and Murray and their Laurentian of the North Shore of Lake Huron. Before reaching Thessalon, in going from west to east along the coast, we pass Logan and Murray's lower slate-conglomerate and below this their white quartzite. After passing Thessalon

there appears below these, division 2, from the base upward, of the Original Huronian, the greenish chloritic and epidotic slate group, which has been shown by Irving to be a surface volcanic.\* Below this is found formation 1, the gray quartzite which grades down into the conglomerate just described.

This locality then gives decisive evidence of an erosive unconformity between the lowest member of the Original Huronian and the Basement Complex. The intricate history written in the contorted gneisses and schists, in their intrusions by granites, in the subsequent pegmatization of both, is evidence that a great length of time was taken for the genesis of the basement complex. Then a deep truncation must have occurred before these granites could be found as surface rocks. Finally an orographic movement depressed the crystalline complex below the sea and the basal conglomerate and gray quartzite are the opening chapter of the Huronian. It is then manifest that the time gap represented by the unconformity between the Basement Complex and Huronian is of the first magnitude.

*General.*—As a result of our observations it is evident that at two distant points, one near the west end of the Original Huronian area and the other near the east end, are great physical breaks between members of the lower division of the Huronian and a more ancient crystalline complex which was designated by Logan and Murray as Laurentian. The nature of these breaks is such as to make it impossible that they can have been local, and the conclusion therefore appears warranted that in the typical district mapped in detail by Logan and Murray, between the Huronian and the Basement Complex there was an immense period of time. As further evidence of this break is the very different lithological characters which the Huronian and basal complex have. In the latter are known no rocks which have been demonstrated to be of sedimentary origin or even surface volcanics, while many of them are plainly deep-seated igneous rocks. The major part of the Huronian rocks, on the other hand, are so little altered that their fragmental character is generally seen in the field, and is always evident at a glance when the rocks are examined in thin section. Finally, the igneous rocks associated with these detritals are in large part surface volcanics.

If the foregoing conclusions are correct, it follows that the *pré Keweenawan* rocks of the north shore of Lake Huron are separable by unconformities into three series; a Basement Complex, a Lower Huronian and an Upper Huronian. These

\* Is there a Huronian Group? R. D. Irving. This Journal, III, 1887, vol. xxxiv, p. 210.

divisions in their order, essential characters, and manner of separation, are exactly analogous to those on the south shore of Lake Superior,\* and northwest of Lake Superior at Steep Rock Lake† as shown by Smyth. Is it not then highly probable that the unconformities at these different districts are the same and that the respective series are or once were continuous for the great triangular area between them, including much of the Lake Superior-Lake Huron region.

U. S. Geological Survey,  
Madison, Wis., January, 1892.

ART. XXVIII.—*A Phasemeter*; by JOHN TROWBRIDGE.

CERTAIN investigations in magnetism have led me to adopt an instrument which I have termed a Phasemeter and which, it seems to me, is destined to be of use in determining questions of the phase of alternating electric currents in transformers and in branch circuits. This instrument makes use of the method employed by Lissajous to study the vibrations of tuning forks, and afterwards adopted by Helmholtz in his vibroscope. Two telephone diaphragms are provided with mirrors. A beam of light is reflected in such a manner that the vibration of one telephone diaphragm gives a spot of light a horizontal motion, the second telephone gives the spot of light a vertical motion, and the combination of the movements of both diaphragms gives a figure which indicates the relative amplitude of the motions of the diaphragms and also the difference of phase of the currents which set the diaphragms in motion.

At first I employed a system of levers to amplify the motions of the diaphragms. The liability of the levers to communicate vibrations peculiar to themselves and thus to superimpose sympathetic vibrations on the diaphragms led me to abandon this system, and to affix a stylus to the center of the telephone diaphragm which touched a little mirror which was delicately placed on a hardened steel point on which it could rock. This method of amplifying the motions of a telephone diaphragm was employed by Professor Eli Blake, of Brown University in 1878.‡ It is a very sensitive arrangement, and I soon perceived that the mirror and its supports needed to be care-

\* This Journal, III, vol. xli, pp. 117 to 137, An Attempt to Harmonize some Apparently Conflicting Views of Lake Superior Stratigraphy, C. R. Van Hise.

† This Journal, vol. xlii, pp. 317 to 331, Structural Geology of Steep Rock Lake, Ontario, Henry Lloyd Smyth.

‡ This Journal, vol. xvi, 1878.

fully tuned to the note to which the diaphragm was to respond. Herr Wien, in a late number of Wiedemann's *Annalen*, has adopted practically this method of Professor Blake, in what he terms an optical telephone for the measurement of alternating currents.\* Herr Wien has added peculiar attachments in order to bring the mirror holder into unison with the note given out by the diaphragm. The following arrangement which I have adopted, although it is less sensitive than the arrangement of Professor Blake and Herr Wien, seems better suited to the instrument which I have termed a phase-meter. Two Bell telephones were provided with diaphragms of three inches in diameter; these diaphragms were not clamped equally around their edges, but were tuned to the note given out by the alternating current employed by touching the diaphragm at its edges, at suitable points, by means of clamps which could be moved around the edge of the diaphragm until a mirror attached to the diaphragm showed that the latter moved in unison with the current. By turning the telephones around the axis of their magnets the vibrations of the mirrors are adjusted so that they take place in planes at right angles to each other. Thus when one telephone is cut out of the circuit the other gives a straight line of light, indicating that the mirror is moving in unison with the diaphragm.

As a source of light I have found it convenient to employ the Welsbach burner, which consists of a zirconium gauze mantle placed over the ordinary Bunsen burner. This gives a very steady and intense source of light. A tin chimney is slipped over the glass chimney. In the tin chimney is a circular opening of one half inch in diameter. Over the tin chimney, in turn is slipped, so as to fit it closely, a thin white paper chimney, and a pin hole is made in this paper at the center of the orifice in the tin chimney. This arrangement enables one to see the figures produced by the movement of the two telephones against the cross hairs of the observing telescope. Moreover the field of view being thus illuminated the disturbing phenomena of diffraction are almost completely eliminated and a clear bright image of the pin hole is obtained.

The apparatus can be made very compact, and the two telephones with the observing microscope or telescope can be all contained in a box a foot square. With a screen at a distance of twenty feet the figures can be produced of such a size that an audience in the large lecture room of the Jefferson Physical Laboratory can easily perceive them, and note their changes of phase.

\*Das Telephon als optischer Apparat zur Strommessung. *Wied. Ann.*, xlii, p. 593, 1891.

It is well known that it is necessary to employ two or three electro-dynamometers to detect magnetic lag and changes of phase in the subject of alternating currents of electricity. The phasemeter shows changes of phase which I believe can not be observed in any other way, and I think it will be of especial use in the study of hysteresis. I am employing it at present in the study of the propagation of magnetic disturbances around rings and over straight bars of steel and iron, and have obtained some interesting results which will form the subject of a subsequent paper. The changes of phase which occur on a ring of iron between two magnetizing bobbins with the same or opposite poles, opposing each other and excited by alternating currents of high frequency, are of extremely interesting character, and can as I have already remarked be clearly shown to any audience.

Jefferson Physical Laboratory, Cambridge.

ART. XXIX.—*Preliminary Report of Observations at the Deep Well, Wheeling, West Virginia*; by WILLIAM HALLOCK. (Abstract.)

THE question as to the conditions which exist in the interior of the earth has always attracted much attention. The most important factor in the solution of this riddle is the determination or estimation of the temperatures there existing. The British Association has for years, seized every opportunity to obtain data as to the rate at which the temperature increases as the earth crust is penetrated. The most recent and reliable contributions on this subject are by Mr. E. Dunker of Halle, Germany, and were obtained from a 4170 foot well at Spenberg not far from Berlin, and a 5740 foot well at Schladabach near Leipzig.

These wells are both full of water, the circulation of which vitiates results or renders elaborate apparatus indispensable, and the thermometers must be protected from the pressure.

The Wheeling deep well, sunk by the Wheeling Development Company and by them generously dedicated to science, is 4500 feet deep,  $4\frac{7}{8}$  inches diameter and *dry*; cased only to 1570 feet. The strata there are nearly *in situ*, undistorted and dipping only 50 feet to the mile. More satisfactory geological conditions can scarcely be imagined.

Being dry, ordinary U. S. Signal Service maximum thermometers were used and no especial precaution needed to be taken to prevent circulation of the air. The thermometers

were lowered and raised, and depths measured by a steel wire.  
Results :

TABLE I.

Depth feet.	Temperature Fahr.	Depth feet.	Temperature Fahr.
1350'	68°·75	3125'	88°·40
1591	70·15	3232	89·75
1592	70·25	3375	92·10
1745	71·70	3482	93·60
1835	72·80	3625	96·10
2125	76·25	3730	97·55
2236	77·40	3875	100·05
2375	79·20	3980	101·75
2486	80·50	4125	104·10
2625	82·20	4200	105·55
2740	83·65	4375	108·40
2875	85·45	4462	110·15
2990	86·60	100'	51°·30

These observations when plotted show a slow increase for the upper half of the uncased portion, about 1° F. for 80 to 90 feet, whereas the lower part shows a more rapid increase, about 1° F. for 60 feet. The whole series gives a well defined and regular curve, with a deflection at 2900 to 3000 feet where an oil sand occurs. Practically all the rest of the uncased well is in shale. The increase in the rate at which the temperature rises as the bottom is approached can only be temporary or we should have an inconceivable or improbable state of temperature at comparatively slight depths.

The two distinct series of observations combined in Table I nowhere disagree more than 0°·3 F. and hence are very reliable and accurate.

Table II gives comparison of the results at the three great wells.

TABLE II.

Name of Well and Location.	Feet for 1° F.	Total depth.	Temp. at top.	Temp. at bottom.
Sperenberg, near Berlin,	59·2 ft.	4170 ft.	47°·8	118°·6
Schladabach, near Leipzig,	65·0 "	5740 "	51·9	135·5
Wheeling Development Co.,	-----	4500 "	51·3	110·3
Top and greatest depths,	74·3 "	"		
Mean of lower 3000 feet,	75·4 "	"		
Mean of above two,	74·9 "	"		

Inasmuch as the bottom of the well is some 3700 feet below sea level, it seemed worth while to attempt barometer readings in it. The instruments used proved ill adapted to the work

and the results were unsatisfactory. Samples of air were taken at the bottom but could not be analyzed in time for use.

A series of observations in a coal mine near the well gave as a very probable value of the temperature of the top invariable stratum  $51^{\circ}.3$  F. From the mean annual temperature of Marietta and Steubenville it might be taken at  $51^{\circ}.5$  F.\* Drilling is temporarily stopped, but we hope to go 5500 or 6000 feet. Mr. Anton Reyman of the Development Company has generously guaranteed half the expenses and we are waiting for a lucky man to furnish the other \$3000, and enable the Wheeling well to be lifted from the second to the first place among the deep wells of the world.

The gratitude of the scientific world is due to the Wheeling Development Co. who ordered and paid for the well, to T. S. Kinsey who drilled it, and to Prof. I. C. White who discovered it and induced its owners to dedicate it to science.

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ART. XXX.—*Mount Bob, Mount Ida, or Snake Hill*; by  
T. W. HARRIS.

WHEN a series of stratified rocks, extending over a wide area, is long exposed to the destructive activities of the weather and other erosive agencies, it is gradually removed, first along the courses of the principal streams, then along their smaller branches, and finally, at a decreasing rate, from the back country, on which, however, small scattered outliers may long remain, marking the former extension of the now almost destroyed formation.

In eastern New York, a number of such small outliers mark thus the former eastward extension of the Helderberg limestones, nearly to the foot of the Berkshire Hills. Several of these are mentioned by the State Geologists of New York. Two, lying east of the Hudson River, near the city of Hudson, are given especial prominence by W. W. Mather, in the volume of the Natural History of New York descriptive of the Geology of the First District (Albany, 1842), under the names, respectively, of Becraft's Mountain and Mount Bob. The structure and relations of the former, have also been fully described in this Journal (vol. xxvi, 1883, p. 381) by Mr. W. M. Davis, of Cambridge.

Sometime ago I visited the latter outlier, and found it to be in general of similar character to Becraft's Mountain, as described by Messrs. Mather and Davis, though of smaller area, and simpler structure. Mr. Mather says of it—

\* As reduced by Chas. A. Schott, U. S. Coast and Geodetic Survey.

“Mt. Bob, so-called, is a hill about one hundred feet high, in the north-west part of Claverack, Columbia County. The west side is very steep, and a slope of debris of the blue, compact limestone, conceals a part of the rock of the same kind, which rises about twenty feet in a mural escarpment, and dips to the east, as is represented on Plate 38 [see fig. 1], where (a) is the blue limestone, and (b) and (c) strata of gray fossiliferous limestone like that of Becraft’s Mountain. The slate underlies, apparently unconformably.” (Nat. Hist. of N. Y., Part IV, Geol. of First Dist., p. 351.)

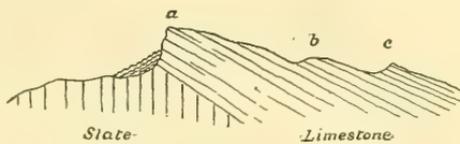
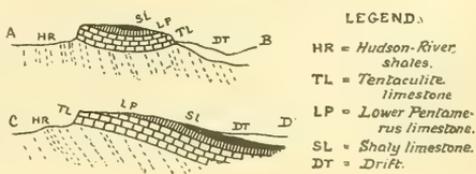
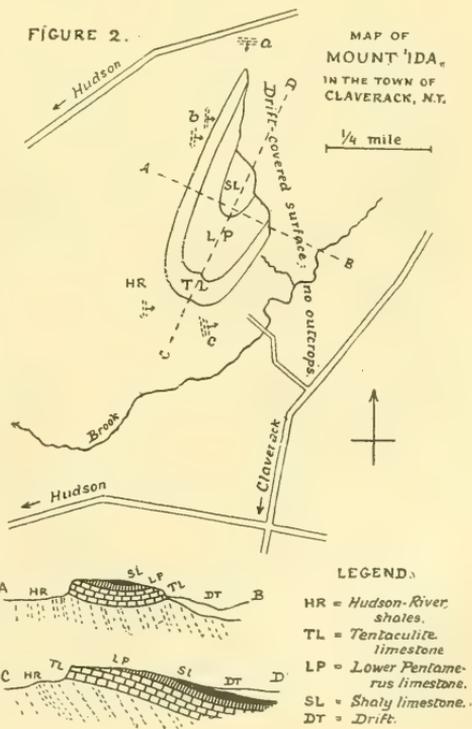


FIGURE 1.

The name, “Mount Bob,” has apparently now gone out of use in the neighborhood, and the outlier is known in Hudson as “Snake Hill,” and among the farmers in the immediate vicinity as “Mount Ida.” The limestones form a wooded elevation about half a mile long by a quarter broad, which rises at the southern end in a steep cliff, one hundred feet or more above the gently rolling, drift-covered plain encircling it, but slopes gently down to the north. In structure, it forms a fragment of a northeastwardly plunging syncline, and consists of the three lower members of the Lower Helderberg group. The great mass of the hill consists of the thin-bedded strata of the Tentaculite or Ribbon limestone, about eighty feet in thickness. No fossils were found in these but a few imperfect *Leperditiae*. Above this, and inside the crest of the cliff, were about twenty feet of the Lower Pentamerus limestone, coarse, gray and irregularly bedded, in which a few specimens of the



characteristic *Pentamerus galeatus* were found. In the center of the hill was a small patch of brownish-gray, shaly material in which a few specimens of *Spirifer macroleura* and *Strophomena rugosa* were found; apparently representing the Delthyris or Catskill shaly limestone. The axis of the syncline courses about N. 35° E., and its plunge is about 20°. To the north it disappears under a heavy mass of drift. The dip on the east side averages 25°; on the west, 20°.

The underlying strata, which appear at several points about the base of the hill, are of a soft gray shale, without fossils, but resembling in appearance the rocks which occur throughout this part of the Hudson valley, and are known as the Hudson River group. The shale has a well-marked cleavage, which appears parallel to the stratification wherever the latter can be distinctly made out. The strike varies from N. 90° E., at the northern end of the hill, to N. 5° W., at its southern end, the dip being always very steep. The question of the conformity of the limestone upon the shale was considered, and a careful search made for their junction; but this was everywhere covered, the nearest approach of the two rocks being about fifty feet, on the west side of the hill, at *b*, fig. 2. Here the limestone had a strike of N. 30° E. and a dip of 22°; the shale, striking N. 8° E., and dipping 60° E. Near the southern end of the hill, the strike of the shale, at *c*, fig. 2, was N. 5° W.; its dip, 45° E. At the northern end of the hill (fig. 2, *a*) the strike of the shale, here very distinct, was about N. 90° E. (varying about 60° from that of the limestone), and its dip 80° S.: but the distance between them being some four hundred feet, it is quite possible that the limestone, if restored, might be found to come into parallelism with the shale within that distance. But although the question of conformity cannot be fully settled from these outcrops, the general lack of accordance between the strikes of the shales and of the limestones, would seem here, as at Becraft's Mountain, rather to favor unconformity, and to suggest that the limestones were laid down upon the upturned and eroded edges of the shales, probably over an area extending far from the outlier in all directions. Since then, erosion has removed most of the limestone, this fragment owing its preservation perhaps to its place in the bottom of a syncline deeper than the average, and hence the last to be reached by the levelling forces; and perhaps also in part to a local increase in the thickness of the hard Tentaculite limestone, if we may take the thicknesses of that member at Catskill (seventy feet) and Becraft's mountain (forty to fifty feet) as average measures.

## SCIENTIFIC INTELLIGENCE.

## I. PHYSICS AND ASTRONOMY.

1. *The Variation in the Density of Water with the Temperature.*—D. MENDELÉEFF in an exhaustive paper discusses the results of previous observers, and points out that the formula  $S_t = 1 - \frac{(t-4)^2}{(A+t)(B-t)C}$  obtained by him appears to embrace all that is known of the variations of the density of water between  $-10^\circ$  C. and  $200^\circ$  C. with the accuracy that is now attainable. He points out that if fresh determinations of greater accuracy should confirm the accuracy of this formula, or lead to a more correct formula, we may hope to arrive at a better understanding of the true law of the expansion of all liquids and also of gases. By means of investigations upon water we may hope to make further progress in the study of matter under the influence of rise of temperature.—*Phil. Mag.*, Jan., 1892, pp. 99-132. J. T.

2. *On a New Method of obtaining a Constant Temperature.*—Mr. HENRY CLEW has employed an electrical current in the following manner. The current from a certain number of storage cells is led through a fine covered wire of high specific resistance, which is coiled about the glass vessel in which the temperature is to be maintained. The glass vessel is contained in a suitable calorimeter. In one experiment the temperature was maintained constant within  $\frac{1}{100}$  of a degree for 40 minutes and the author believes that much greater constancy can be obtained.—*Phil. Mag.*, Jan., 1892, p. 89-93. J. T.

3. *Velocity of Sound in membranous bodies.*—L. MELDE has obtained the velocity of sound in membranes of various natures by taking strips of the membranes. These were fastened at both ends and were rubbed in the middle. A table of the results is given and shows a great difference in the propagation of sound in various substances.—*Beiblätter, Ann. der Physik und Chemie*, No. 11, 1891, p. 756. J. T.

4. *A Surface Bolometer.*—At a meeting of the Physical Society held in Berlin, Jan. 8, Dr. KURLBAUM described a surface bolometer. It is cut out of platinum foil whose thickness is 0.012 mm. and possesses the great advantage of coming to rest quickly. It is a trustworthy instrument for measuring the difference in luminosity of two sources of light.—*Nature*, Jan. 28, 1892. J. T.

5. *Orthochromatic Photography.*—MM. FABRE and ANDOYER photographed the eclipsed moon at the Toulouse Observatory on Nov. 13, 1891. They employed collodion-bromide and collodion-chloride plates which were stained either with eosin or cyanine. The collodion bromide plates were relatively more sensitive to red and yellow than the collodion-chloride plates.—*Nature*, Jan. 21, 1892. J. T.

6. *Prize for Researches in Physics*.—For the year 1894 a prize is offered by “Schnyder von Wartensee’s Foundation for Science and Arts” at Zürich, for the solution of the following problems in the domain of physics: “As the numbers which represent the atomic heats of the elements still show very considerable divergences, the researches conducted by Professor H. F. Weber on boron, silicon and carbon, regarding the dependence of the specific heats upon the temperature, are to be extended to several other elements, prepared as pure as possible, and also to combinations or alloys of them. Further, the densities and the thermic coefficients of expansion of the substances investigated are to be ascertained as carefully as possible.”

The treatises handed in by competitors for the prizes may be in German, French or English, and must be sent in by September 30, 1894, to the address given below. They will become the property of the Foundation. Every treatise must have a motto on the title page, and be accompanied by a sealed envelope bearing the same motto outside and containing the author’s name. The Prize Committee is empowered to award a first prize of two thousand francs, and minor prizes at its discretion to the amount of one thousand francs. *Address*: “An das Praesidium des Conventes der Stadtbibliothek Zürich (betreffend Preisauflage der Stiftung von Schnyder von Wartensee für das Jahr, 1894).”

7. *Astronomical Expeditions to Peru*.—In the annual report for 1891 of the Director of the Astronomical Observatory of Harvard College, an account is given of the expeditions sent to Peru in 1889 and again in 1890, at the expense of the Boyden Fund, as follows: “The expedition sent to Peru in 1889 under the direction of Mr. S. I. Bailey, having successfully completed the observations with the meridian photometer, returned to Cambridge with that instrument, which has been remounted here and will be used for a revision of the Harvard Photometry and for other photometric work. During the two years ending May 1, 1891, Mr. Bailey took 217 series of observations and made 98,756 photometric comparisons of about eight thousand southern stars. These include all the stars of the sixth magnitude and brighter south of  $-30^{\circ}$ , and all known catalogue stars in a series of zones  $20'$  wide at intervals of  $5^{\circ}$  in declination from  $-25^{\circ}$  to  $-80^{\circ}$ ; also all known stars south of  $-80^{\circ}$  and a miscellaneous list of variables, stars having peculiar spectra, etc. The reduction of these observations is nearly completed and their publication will be begun shortly. A large part of the work assigned to the Bache telescope has also been completed, and the instrument has been remounted at Arequipa where its work will be continued.

“An expedition under the direction of Professor William H. Pickering left Cambridge in December, 1890, and established a station about three miles northwest of Arequipa, where the thirteen-inch equatorial has been mounted. This station has an elevation of a little over 8000 feet and has a nearly cloudless sky during a large part of the year. The air is remarkably steady,

the images of the stars are small and round and the diffraction rings, seldom seen with large instruments, are clearly visible. Even with high powers the fluctuations of the images are very slight. In fact, at this station the limit to observation will probably be the size of the instrument, instead of, as at other observatories, the condition of the air. Although the aperture of this instrument is only thirteen inches, it appears to be the largest refracting telescope in use in the southern hemisphere, while about thirty larger telescopes are mounted in the northern hemisphere. Since all of these instruments are north of  $+35^\circ$ , nearly one-quarter of the entire sky, and that containing many objects of the greatest interest, has never been studied by a refractor of the highest grade. For both these reasons an excellent opportunity is afforded to add to astronomical discovery by the erection of a telescope of large size at this station. It is hoped that patrons of astronomy will consider the advantages of erecting a large telescope where it will be kept constantly at work, where the sky is clear a large part of the year, where the condition of the air is probably more favorable than at any other existing observatory, and where a large part of the sky could be examined for the first time under such satisfactory conditions. Photographs have not yet been obtained with the thirteen-inch telescope, but it is hoped that its advantages for this kind of work will be as great as for visual observations."

8. *On the Causes of the Phenomena of Terrestrial Magnetism* and on some Electro-mechanism for exhibiting the secular changes in its horizontal and vertical components, by HENRY WILDE.—This paper from the *Philosophical Transactions* presents the author's views on the nature of terrestrial magnetism. These will be evident from his statement of the three successive stages in the earth's history, which he assumes, and which he illustrates by a large globe with its surface wound with copper wire. These stages are (1) The electro-dynamic condition of the terrestrial globe at a period of its history when the crust from its high temperature was non-magnetic, its surface of uniform curvature and the electro-dynamic foci of the internal sphere of vapors inclined at a definite angle from the poles of the earth's axis.

(2) The electro-dynamic and electro-magnetic condition of the earth when its outer crust was uniform in curvature and had cooled down sufficiently to become permanently magnetic with dual foci of intensity coincident with the poles of the earth's axis and separate from the dual polar foci of the internal sphere of vapors.

(3) The unsymmetrical distribution of the magnetic elements arising from the unequal curvature and foldings of the earth's crust during its secular cooling as indicated by the present distribution of land and water on the terrestrial surface.

As shown in the above, the author finds the seat of the earth's magnetic attraction in the earth's crust and explains the unsymmetrical distribution of the terrestrial magnetism by the irregular configuration of the earth as manifested by the distribution

of land and water on its surface. This was illustrated by experimental methods, the ocean areas of the mapped globe being covered with a thin sheet of iron, roughly contoured to the coast lines of the continental areas; a close agreement with the unsymmetrical lines of declination was obtained. A further cause of magnetic asymmetry is sought for in the diamagnetism of the waters of the globe and of the compounds of the alkaline metals which they hold in solution.

9. *The Astronomical Handbook for the year 1892.* 38 pp. 12mo. Brooklyn, 1892.—This little handbook and ephemeris, prepared under the direction of the Executive Committee of the Department of Astronomy in the Brooklyn Institute of Arts and Sciences, will be found useful particularly by all persons—even if they have not a full scientific training—who are interested, as amateurs, in astronomy and in studying celestial phenomena. It gives information in regard to eclipses, the positions of the planets, notes on the double stars and so on, with suggestions as to special observations which individuals may make with interest and profit. It is also stated that the President of the Department (Garrett P. Serviss, 8 Middagh st., Brooklyn) will give information and advice to those not able to attend the meetings.

## II. GEOLOGY AND MINERALOGY.

1. *Honor to the United States Geological Survey from the French Academy of Sciences.*—The Academy of Sciences of France at its last Annual Session, on the 21st of December, conferred on the United States Geological Survey the Cuvier prize. The commissioners of the Academy—consisting of MM. Gaudry, Fouqué, de Quatrefages, Milne Edwards, with M. Daubrée, Reporter—state in their report with reference to the prize:

“L'œuvre du GEOLOGICAL SURVEY, avec le magnifique ensemble de travaux qu'elle comprend, mérite donc que nous lui rendions un hommage éclatant, pour la lumière si vive et si inattendue qu'elle a jetée sur l'histoire géologique et sur les richesses minérales de l'Amérique du Nord. Le prix Cuvier est décerné à cette grande œuvre collective, non seulement aux collaborateurs actuels, mais aussi à ceux qui ont dû cesser leurs fonctions. Il sera, nous l'espérons, conservé dans les archives du *Geological Survey*, comme un témoignage de la haute estime de l'Académie des Sciences.”

These closing words of the Report are preceded by a review of the geological work carried forward by American geologists in connection with the various State surveys from 1833 onward; by the U. S. Geological and Geographical Survey of the Territories under Hayden, mentioning in detail some of the great results: the expedition of Powell along the cañon of the Colorado; the “study extremely remarkable” of the Henry Mountains by Gilbert; the Exploration and Survey of the 100th Meridian under Lieut. Wheeler, of the U. S. Department of Engineers; the U. S. Survey of the 40th Parallel under Clarence

King; and finally, with more special mention of results and of workers, the existing U. S. Geological Survey, organized by Clarence King in 1879, and placed the following year under the directorship of Major Powell, and from the first carried forward over all parts of the continent "even the most inhospitable," with an energy that "recalls the heroism of an army attacking obstacles the most arduous and most inaccessible."

2. *Geology of the Tonga or Friendly Islands.*—A valuable paper on these islands of the South Pacific, by J. J. LISTER, is published in the Quarterly Journal of the Geological Society, vol. xlvii, p. 590, June, 1891. The region of the group—whose length is about 250 English miles—is remarkable for the great diversity of level in the islands and in the ocean adjoining.

On the west side, along a course nearly N.N.E., the islands, from Amargura in  $18^{\circ}$  S. and  $174^{\circ} 25'$  W. to Honga Tonga in  $20^{\circ} 35'$  S. and  $175^{\circ} 25'$  W. are volcanic, and the heights occur of 1890 feet in Lette I., 151 in Metis I., 3030 in Kao, 1890 in Tofua, and 300 feet in Honga Tonga.

Just east (30 to 40 miles), along an irregularly parallel line, occur: Vavau at the north, in  $18^{\circ} 35'$  S. and  $174^{\circ}$  W., with nothing but coral reef limestone in sight, and having on the N. and N.E. sides the limestone rock in cliffs 300 to 500 feet high; the Hapai Group, consisting mostly of coral reef rock, 20 to 100 feet high; the Nomuka Islands, consisting of tufa, having coral reefs to eastward 30 to 60 feet high; at the south end, Tóngatabú,\* in  $175^{\circ}$  W. and  $21^{\circ} 10'$  S., a coral island with a shallow lagoon, but raised 60 feet above the sea-level on the southeast side.

About 10 miles to the southeast of Tongatabu is Eua, a volcanic island over 1000 feet high at two points, but encased in coral-reef to a height at one point, by estimate, of 300 feet, and another of 500 feet, and having cliffs of the limestone "some 200 feet high" along the eastern and western sides.

Mr. Lister's paper which is illustrated by maps and sections, contains other facts of geological importance. He refers to the great depths of the sea to the southeastward and eastward of the group; to the southeastward 230 miles, in  $175^{\circ} 08'$  W. and  $24^{\circ} 37'$  S., 4428 fathoms, and in  $175^{\circ} 07'$  W. and  $24^{\circ} 49'$  S., 4295 fathoms; to the eastward of Vavau, 150 miles, in  $172^{\circ} 14\frac{1}{2}'$  and  $17^{\circ} 04'$  S., 4530 fathoms. On the bathymetric map in this Journal, vol. xxxvii, and also page 420, and vol. xxxix, p. 412, other soundings in the vicinity are given, but none have been obtained on the direct line between the two deep depressions.

The soundings make the total height of the summit of Kao above the deepest point in the ocean to eastward a little over 30,000 feet. Such depressions are not a result of loading the crust by deposition. The range of facts here reviewed indicate that some profounder method of causing change of level has been at work.

J. D. D.

\* The accent is on the first and last syllables—the latter half being the Polynesian word tabú.

3. *Notes on the Palæozoic Species mentioned in Lindley and Hutton's "Fossil Flora;"* by R. KIDSTON. (Proc. Roy. Phys. Soc. Edinb., vol. x, 1889-90 (1891), pp. 345-391).—The search for and the consultation of type specimens, which have been brought about during the last fifteen years by the renaissance of Paleozoic paleobotany in Europe and the establishment of priority in nomenclature, have keenly emphasized the need of revision of the older works and the frequent redescription of the species. Especially the results of the examination by Zeiller of a large part of Brongniart's material, and by Kidston of so much of the collections of the English authors as can be found, have shown from time to time that a considerable portion of the current identifications after the too brief descriptions and often false figures in the "Histoire" or the "Fossil Flora" not only disagree among themselves, but are totally different from the originals, while the latter, in the case of the English work, are frequently, in the present state of our knowledge, unidentifiable. Mr. Kidston's "Notes" extend his observations, previously recorded in the case of a part of the species, to the entire work, thus placing the existing types of the "Fossil Flora" in their true positions, so far as determinable, according to the judgment of the foremost English authority in this field. Among the more important correlations not so generally anticipated, are the identifications of *Neuropteris Sorettii* and *Cyclopteris dilatata* with *N. heterophylla*, to which also belong the *Pecopteris adiantoides*, and *Neuropteris heterophylla*, made *N. Lindleyana* by Sternberg on account of the incorrect and partially hypothetical figures. *Neuropteris attenuata* is a *Pecopteris* not specifically identifiable, while *Pecopteris Bucklandii* is clearly a *Neuropteris*, probably the *N. rarinervis* Bunb. Thirty-six species founded on, or identifications made from, imperfect specimens are found not to afford the necessary characters for subsequent identification. Mr. Kidston's "Notes" are valuable particularly in pointing out the inaccuracies of the plates, in which the great English work appears much weaker than its contemporaries. D. W.

4. *Correlation Papers: Cambrian;* by C. D. WALCOTT, 447 pp. 8vo. Bull. No. 81, U. S. Geol. Survey. Washington, 1891.—Mr. Walcott has here given, in his very thorough way, a review of the history of Cambrian discoveries, its synonymy, local stratigraphy in each region of its occurrence, general paleontology, subdivisions, and distribution, for North America, with citations from all descriptions or accounts and discussions of the various questions involved, and also with notes on the Cambrian of Great Britain, Europe, China, India, Australia and South America. Following the five chapters dealing with these various subjects, a sixth treats of the general principles of Correlation in geology, as it has been presented by others and as deduced by the author from his own observations.

5. *Index to the known Fossil Insects of the World, including Myriapods and Arachnids;* by S. H. SCUDDER. Bulletin No. 71.

Washington, 1891.—Mr. Scudder's bibliography takes up separately the Paleozoic species, Mesozoic and Cenozoic and gives the references in the briefest form, and still 100 pages are devoted to the Paleozoic species alone, 180 to the Mesozoic, and 500 to the Cenozoic species: so that altogether the entries make a volume of 744 pages.

6. *On the removal of gold from suspension and solution by Fungoid growths.*—Prof. A. LIVERSIDGE, of Sydney, N. S. W., states in a paper read before the Australasian Association for the Advancement of Science at Melbourne in 1890, that, he first observed in 1889 that gold was removed from solution and suspension by fungoid growths, and had since made further investigations. The gold was held in suspension in distilled water, that had been prepared at different times, the gold being reduced from a weak solution of the chloride by means of phosphorus dissolved in ether. A complete precipitation usually takes several years. Examining the bottles which had been settling since 1881, he found that in those having fungoid growths, usually at the bottom of the bottles, the liquid was colorless, but in the others the color was ruby-red or purple, the gold being still in suspension. In one bottle put up in November, 1884, having the liquid colorless, a purple-blue fungoid growth had taken place, which under the microscope was a mass of matted purple-blue filaments; but after being dried over a spirit lamp, the filaments retained their form but acquired the luster and color of gold. In 1889, other experiments were tried with more precise results. But it was found that not only moulds produce the result, but also any organic matter living or dead.

7. *Les Méthodes de Synthèse en Minéralogie* par STANISLAUS MEUNIER. 359 pp. 8vo. Paris, 1891.—The progress made in the subject of mineral synthesis has been remarkably rapid in the last two decades, and the success of the French chemists in this line has been particularly marked. The excellent books of Fouqué and Lévy (1882) and of Bourgeois (1884), which gave a full summary of what had been accomplished in the way of forming artificial minerals, are now followed by a volume by another active worker in the same field, Stanislaus Meunier. This work, however, occupies a place of its own, for it is devoted particularly to an explanation of the methods used and general principles involved. The first part discusses the contemporaneous formation of minerals in nature; and a second part is given to the cases of accidental synthesis, furnace products, etc. The third and most important division describes the method of synthesis proper; first by the dry way involving simple crystallization by molecular change, by igneous fusion and by the intervention of a mineralizer; then simple decomposition; chemical union; precipitation and finally, double decomposition. The methods of synthesis in the wet way are also described with similar system and thoroughness as also those where the method is mixed. This summary will give an idea of the wide range of topics here presented, but the volume calls for the close study that it fully merits.

8. *Brief notices of some recently described minerals: ASTOCHITE.* A kind of amphibole, near richterite, from Långban, Sweden. It occurs as a coarse crystalline, columnar aggregate, of a blue to grayish violet color. Cleavage-angle  $56^{\circ} 27'$ ; extinction  $15^{\circ} 40'$  blue to  $17^{\circ} 15'$  violet; sp. gravity = 3.05, 3.10. Analyses by Mauzelius, are, as follows, 1 for the blue, and 2 for the violet variety:

	SiO <sub>2</sub>	FeO	MnO	MgO	CaO	Na <sub>2</sub> O	K <sub>2</sub> O	H <sub>2</sub> O	F	
1.	56.25	0.15	6.49	21.89	5.44	6.17	1.60	1.56	0.15	= 99.70
2.	54.76	0.21	12.71	17.82	5.83	4.02	1.65	2.77	0.09	= 99.86

This yields a normal metasilicate formula. Described by H. Sjögren in *G. För. Förh.*, xiii, 605, 1891.

**ADELITE.** A basic arsenate from Nordmark and Långban. It occurs in masses of a gray color; hardness = 5; sp. gravity = 3.76. Analyses agree closely with the composition  $H_2O \cdot 2CaO \cdot 2MgO \cdot As_2O_5$ , and a connection with either the olivenite or wagnerite group is suggested. Described by Sjögren, *ibid.*, p. 781.

**SVABITE.** A mineral from the Harstig mine, Pajsberg, referred by Sjögren (l. c.) to the apatite group. It occurs in colorless hexagonal prisms terminated by the pyramids,  $10\bar{1}1$  and  $11\bar{2}1$ ; the vertical axis is 0.7143 (apatite 0.7346). The composition is given by the formula  $H_2O \cdot 10CaO \cdot 3As_2O_5$ .

**BOLEITE.** An oxychloride of lead and copper occurring at the Boleo copper mines, near Santa Rosalia, Lower California. It occurs in cubic crystals of an indigo-blue color, which show anomalous optical phenomena; there are also crystals in tetragonal octahedral forms having the same composition. These are regarded by the describers, MM. Mallard and Cumenge, as identical, but the cubic crystals can hardly be other than perylite, only differing in containing 9 p. c. of silver.—*C. R.*, cxiii, 519, 1891.

**LAUTARITE.** A calcium iodate from Atacama, occurring in large prismatic crystals referred to the monoclinic system. It is colorless to yellow; sp. gravity = 4.59. Composition  $Ca(IO_3)_2$ , and hence belonging to a class of compounds not before represented among minerals. The same region furnishes crystals having a composition approximating to  $Ca(IO_3)_2 \cdot CaCrO_3$ . Described by Dietze, *Zs. Kryst.*, xix, 447, 1891.

**MORINITE.** A phosphate of alumina and soda, not yet analyzed, occurring in monoclinic crystals with the amblygonite of Montebbras, France. Described by Lacroix, *Bull. Soc. Min.*, xiv, 187, 1891.

#### OBITUARY.

**THOMAS STERRY HUNT.**—Mr. Hunt was born at Norwich, Connecticut, in September, 1826, and died in New York on the 12th of February, 1892. The year 1845 and 1846 he spent at New Haven, Conn., in the chemical laboratory of B. Silliman, Jr., who was then assistant to his father in the chemical department of Yale College. He pursued his chemical studies with great

earnestness and success. Already in 1846 he published several short chemical notes in this Journal, and in 1847 reviewed at length Gerhardt's Organic Chemistry, which had greatly interested and instructed him, besides preparing papers on some points suggested by it. The Geological Survey of Canada under Wm. E. Logan, (afterward Sir William) as Director, with Alexander Murray as assistant, had been in progress from the year 1842; and in 1847 Mr. Hunt was appointed its chemist and mineralogist. The Annual Reports for 1849-50 and the following years bear evidence of his activity in analyses of rocks, minerals, mineral waters and materials of economical value. In the Report for 1850-1, he has analyses of the minerals peristerite and bytownite of Thomson and proposes a new species, Loganite; in that of 1851-52 he describes the new species Parophite, and in that for 1852-53, he brings out Wilsonite as a new mineral.\* The results of similar work make large mineralogical and petrological contributions to the succeeding volumes. In the general Report of 1863, chapters 17, 18, 19 and 20, occupying over 200 pages, are by him.

Mr. Hunt took a wide interest in the results of the Canadian Survey, and in 1849 presented at length to the American Association, and again in 1861 and 1868 to this Journal, the conclusion of Logan that the Taconic series of rocks were of Lower Silurian age; and in 1855 there was published in this Journal—anonymously, in compliance with his request—a severe review by him of Professor Emmons's American Geology. He continued his connection with the Survey until 1872, two years after Mr. Selwyn became Director. In the mean time, he also occupied the chair of chemistry at the Laval University, Quebec, from 1856 to 1862, and at McGill University, Montreal, from 1862 to 1868. From 1872 to 1878 he was Professor of Geology in the Institute of Technology, Boston.

\* An error in Appleton's American Cyclopedia of Biography with reference to the introduction of the terms Laurentian and Huronian, should here be corrected in justice to the distinguished head of the Canadian Geological Survey. In the Annual Report for 1852-53, Logan says on this point, on page 8 of his special report, which is 156 pages in length, as follows: "The name which has been given in the previous Reports to the rocks underlying the fossiliferous formations in this part of Canada is the Metamorphic Series; but, inasmuch as this is applicable to any series of rocks in an altered condition and might occasion confusion, it has been considered expedient to apply to them for the future, the more distinctive name of Laurentian Series."

Then follows a list of the geological formations of Canada, in which Laurentian is followed by the Potsdam, showing that it was applied to the rocks older than the Potsdam, all of which he believed to lie unconformably beneath the Potsdam.

The term Huronian first appears in print in the Sketch of Canadian Geology, of 1855, by Mr. Logan and Mr. Hunt, prepared for the Paris Exposition. The preface of the work credits Mr. Logan with all the geological part of the volume, and the text cites from him all the characteristics mentioned of the Huronian Series. The Annual Report of the Survey for 1853-55, published in 1857, in the course of the special report of Mr. Murray for the year 1854, dated June 11, 1855, uses both the terms Laurentian Series and Huronian, in describing the rocks which he had studied the year before and conjointly with Logan in former years.

Among Mr. Hunt's various papers the following have prominence: his Presidential address before the American Association for the Advancement of Science in 1871, in which are the germs of several of his later publication; his address at the Centennial of Chemistry in 1874, on "A Century's Progress of Chemistry;" "The Chemistry of the Primeval Earth;" "The Chemistry of Natural Waters;" "The origin of Crystalline Rocks—the Crenitic Hypothesis;" "The Geological History of Serpentine." Nearly all bear the impress of an able but speculative mind, well stored with knowledge, but not well enough supplied and weighted with geological facts where the subject has a geological bearing, and not always capable of reading rightly the opinions of others when they differed from his own. His late views on the Taconic question have been sufficiently discussed in recent volumes of this Journal. His published volumes are: Chemical and Geological Essays, 1874, 1878; Azoic Rocks, 1878; Mineral Physiology and Physiography, 1886; a New Basis for Chemistry, 1887; "Mineralogy according to a Natural System," 1891.

Dr. Hunt has the credit of bringing before the American Association for the Advancement of Science in 1876, the plan for an International Geological Congress, the fifth meeting of which was held in Washington the past year. At the Bologna meeting in 1881, he was one of the twenty Vice-Presidents. He was made a fellow of the Royal Society of London in 1859, and a member of the National Academy of Sciences in 1873; and in 1881 he received from Cambridge, England, the degree of LL.D.

SIR GEORGE BIDDELL AIRY, for many years Astronomer-Royal of Great Britain, died on January 7, in his ninety-first year. He was graduated at Cambridge as Senior Wrangler in 1823, three years later he was made Lucasian Professor of Mathematics, and in 1828 Plumian Professor of Astronomy; his appointment as Astronomer-Royal was made in 1835. His scientific contributions in the fields of mathematics, physics and astronomy, commencing in 1824, have been numerous and of high merit, and his labors in connection with the Royal Observatory of Greenwich, as well in its development as in his personal scientific work, gave him a position of rare eminence. Few scientific men have the privilege of completing so long a career, and one so rich in profit to science and so full of personal honor.

JOHN COUCH ADAMS, Professor of Astronomy and Geometry at Cambridge, died on the 21st of January, two weeks after the death of his distinguished fellow astronomer, Sir George Airy. He was born June 5, 1819, graduated as Senior Wrangler at Cambridge in 1843, and in 1845 his mathematical discussion of the irregularities in the motion of Uranus led him to the conclusion as to the existence of an outer planet not yet observed—a result reached independently by Leverrier the following year and confirmed by the discovery of Neptune by Galle in 1846. With this early brilliant work his name will be always connected, but hardly less important were his later labors carried on actively until interrupted by ill health a year or two before his death.

## A P P E N D I X .

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ART. XXXI.—*Discovery of Cretaceous Mammalia. Part III*; by O. C. MARSH. (With Plates V–XI.)

IN this Journal for July, 1889, the writer announced the discovery of various remains of Cretaceous mammals in the Laramie of Wyoming, and gave figures and brief descriptions of some of the best preserved specimens. In the following number, the subject was continued, and additional remains were described.\* Since then, systematic explorations have been made in the same and other localities, and, at the present time, more than a thousand specimens are available for examination. These fossils are all fragmentary, but they throw considerable light on this peculiar fauna, showing it to be as yet limited, but more varied than the first discoveries indicated.

All the mammals found are small in size. They are mainly Mesozoic in type, and more nearly related to the Jurassic forms below than to those in the Tertiary above. Carnivores, Rodents, and Ungulates, still appear to be wanting in this horizon, and true Insectivores have not yet been identified with certainty. The *Allotheria* are most numerous, and the evidence that this group is closely related to the modern Monotremes, if not their ancestors, has been strengthened by the discoveries recently made. The *Cimolestidae*, a family allied to the existing Opossums, are especially abundant, and other Marsupials appear to be represented among the remains secured.

In this paper, the third of the series, additional specimens from the same horizon are briefly described, and these and many others are carefully figured. In a later communication, the relations of these forms to each other and to allied Mesozoic and Tertiary mammals will be considered, and the whole subject fully discussed.

\* This Journal, III, vol. xxxviii, pp. 81–92, plates ii–v, July, 1889; and pp 177–180, plates vii–viii, August, 1889.

In the present article, as in the two preceding it, the remains selected as types are all characteristic specimens, which, although fragmentary, will admit of accurate determination whenever more complete material is available for comparison. This is a point of much importance, as paleontology has suffered grievously from descriptions of fossils without characters sufficiently definite to distinguish them from more perfect remains subsequently brought to light. It is a matter of much less importance if such discoveries should prove that two or more specimens described as distinct really pertained to one animal. The advance of the science throughout the world has not been retarded by such preliminary reference, but has often been greatly promoted by making known promptly single facts of importance, leaving their full significance to be determined by later discoveries, made under more favorable circumstances.

The fact, that, for half a century or more, search for mammals in the Cretaceous had been made in vain, indicates the importance justly attached to their recent discovery, and is a sufficient excuse, if any were wanting, for making known the little now accomplished by continued and laborious explorations. The diminutive size of the Cretaceous mammals found, and the nature of the deposits in which they were entombed, readily account for the incomplete and isolated fragments thus far secured. The determination of such remains must of necessity be more or less provisional. It will be seen, however, from the specimens figured and described in the present article, that among the great number obtained, there are some which give valuable information in regard to mammalian life in Cretaceous time.

The geological lesson now taught by these mammalian relics and their associated vertebrate fossils is no less important, but hardly what was expected. These remains are not transitional between Mesozoic and Tertiary forms, but their affinities are with the former beyond a doubt; thus indicating a great faunal break between the time in the Cretaceous when they lived and the earliest known Tertiary, or between the Ceratops horizon and the Coryphodon beds of the Eocene Wahsatch. The lower division of the Coryphodon beds, or lower Wahsatch (Puerco), is clearly Tertiary, and the great break is between this horizon and the Ceratops beds of the Laramie. Each of these faunas is now known by many species of vertebrate fossils represented by hundreds of specimens, and the more the two are compared the stronger becomes the contrast between them. Instead of placing them close together, as some geologists seem inclined to do, it will be more profitable

in future to search for the great series of intervening strata containing the forms that lead from one to the other.

Whether the missing deposits are Cretaceous, transitional, or Tertiary, or all three, they must exist somewhere, for their existence is demonstrated by what is known of vertebrate life below and above them. This knowledge has been mainly secured within the last few years, and has hardly become accessible yet to other departments of science.

Bearing in mind all that is known to-day of the development and succession of vertebrate life in America, from the early Silurian on to the present time, it is safe to say that the faunal break as now known between the Laramie and the lower Wahsatch is far more profound than would be the case if the entire Jurassic and the Cretaceous below the Laramie were wanting. Consequently, every discovery that throws light on this dark region of the geological section has an importance beyond its intrinsic value. In mammalian life, the record here is especially imperfect, and every addition should be welcome.

#### THE ALLOTHERIA.

The most important mammalian remains so far discovered in the Ceratops beds of the Laramie belong to the group which the writer has called the *Allotheria*.\* Members of this group are known also from both the Triassic and Jurassic, and their presence in the Cretaceous was, of course, to be expected. Several hundred specimens have now been found, indicating quite a number of genera and species, but the correlation of these remains is as yet a matter of great difficulty. The individual teeth are most of them in excellent preservation, and, in a few cases, several are in position in the jaw, but accurate determination of many of the forms must depend upon the results of future discovery. The isolated specimens now known, taken together, or the corresponding parts when compared with each other, all prove the abundance and variety of this group during Cretaceous time; yet it seems much more profitable at present to indicate the main variations in these specimens rather than attempt reconstructions of animals to which they may be imagined to belong.

As is usually the case with fragmentary remains of small mammals, the lower jaws are best preserved, and readily recognized. The lower teeth seem less rare in the Laramie than any other portions of the skull or skeleton, and as they are especially characteristic in the *Allotheria*, must be used largely in the present investigation.

\* This Journal, III, vol. xx, p. 239, 1880.

*The Lower Teeth.*

Among the many lower incisors of this group found in this horizon, three well-marked types, at least, may be distinguished, as follows:

The striate forms, which have the inner face flattened to meet its fellow, and the entire crown covered with enamel. This type is figured on Plate III of Part I, and Plate VIII of Part II. Another is shown on Plate VI, figure 5, of the present paper, and there are several others.

The second series is somewhat smaller in size, with the crown also covered with enamel, but it is compressed, and irregularly bevelled on the concave side, somewhat like the lower incisors of *Hypsiprymnus*. One of these teeth is represented on Plate IV, Part I, and another is shown below, Plate V, figure 4. The enamel is very thin, and easily lost.

A third type, smaller than the above, is more abundant. It is slender, considerably curved, and the outer face only is entirely covered with enamel. This type is seen on Plate VIII, Part II, and in figure 4, Plate VI, below.

A fourth type, which may pertain to the upper series, is similar to the second, but has one margin serrate. This form is shown on Plate VII, Part II. A modification of it occurs in smaller forms, one of which is shown in Plate VII, figure 2, below. The lower incisors of some of the existing shrews (*Sorex*) are notched on the outer margin in a somewhat similar manner.

In all the *Allotheria* of this horizon, the first and second lower premolars are apparently wanting. Only the third and fourth have been found in place. The third when present is very small, and cylindrical, with a single root. The fourth is very large, with two unequal roots, and with a compressed, cutting crown. As a rule, this crown is very low, its summit being elevated but little above the true molars behind it. This is an unexpected feature, as the Jurassic forms below and those in the Tertiary above both have the cutting fourth premolar elevated high above the molar series.

In the known Cretaceous forms, the crown of this tooth shows wide variations, indicating several distinct genera and species. In one series, the summit is deeply notched, and strong ridges cover the greater part of the outer and inner faces. In another, the superior notches are smaller or wanting, and the surfaces of the two sides are marked by a larger number of ridges and grooves. In some of these forms, the crown is very low, not more than half as high as long.

In a second series, the whole premolar is smooth, the sides being without distinct grooves or ridges. This type of premolar is found in several forms, which differ much in other features.

The lower molars are as usual two in number, and although differing widely in the form and structure of their crowns, have only two parallel series of crescents or tubercles, an outer and inner row, with a groove or valley between them.

### *The Upper Teeth.*

The upper dental series of the *Allotheria* of this horizon is much more complicated than the lower series, and as the teeth known are nearly all isolated, or with only portions of jaws attached, their relation to the inferior teeth is at present hardly more than a matter of probability. Some of the larger forms certainly have two, if not three, upper incisors, and the main one is deeply notched at one or more points, as in the genus *Allodon* of the American Jurassic.

The upper premolars that can be placed with certainty are in most cases compressed in form, and evidently met the cutting fourth premolar below. Most of these upper cutting teeth secured, however, pertain to the smaller forms, making it very probable, at least, that in the large species, the upper premolars were not much compressed, and had in themselves no cutting function. This was certainly true, also, in some of the smallest forms; as in *Allacodon pumilus*, the premolars are all known, and in one of the specimens figured, three of them are in place (Plate VII, figure 3).

The upper molars of the group now known from this horizon are of special interest. Although not found in position in any one specimen, so many have been secured with portions of the jaw attached, that their place in the dental series has been ascertained in several forms. All these have apparently but two true molars, the penultimate being in some cases of smaller size than the last.

The upper molar teeth may be separated into two series, the first having three longitudinal rows of elevations on the crown, and the second series but two rows. The various modifications of these types are numerous, and certainly indicate many distinct forms. In some of these, the prominences in each of the three rows are conical, and each row is complete, especially in the last molar. Another type has the three rows complete also,

but the elevations are crescentic, with the convexity forward. In a third series, the two outer rows are composed of tubercles, and the middle one of crescents only. In the smaller upper molars, the middle row and the outer one are complete, but the inner row is less developed. In the second series, where the true molars have but two rows of elevations, these are either conical, or distinctly crescentic, the former being especially seen in the smaller forms.

Among the very large number of *Allotheria* teeth found in the localities explored, not one has yet been secured corresponding to the molar described by Cope, and referred with the type to *Meniscoessus*. The nearest approach to it is the upper molar described by the writer in Part II, as the type of *Selenacodon brevis* (Plate VII, figures 9–12), and this tooth is smaller in size. The two specimens are from widely distant localities, and perhaps from distinct horizons. In the molar described by Cope, one end of the crown was lost, and this fact was stated in the original description, and shown in the first figure published.\*

The various *Allotheria* remains represented in the accompanying plates include several that appear to be different from those previously described, but in view of their fragmentary nature, some have been referred to species already named. The material now secured, when fully investigated, will test the accuracy of these references. A few of the smaller forms which appear to be quite distinct are briefly described below, and their main characteristics shown in the plates; accurate figures being the best description, as every paleontologist knows.

*Cimolodon parvus*, sp. nov.

One of the smallest forms of this genus is represented by various isolated remains, among which is the anterior portion of a lower jaw with the incisor in place, which may be regarded as the type. This specimen is shown on Plate VI,

\* Prof. H. F. Osborn has since given a figure of this tooth, which represents the crown as complete (Am. Nat., July, 1891, p. 598). In the same paper, he has a figure of the skull of *Bolodon*, of Owen, which is even more misleading. This figure is made by putting together two different specimens not found associated, and adding a strongly marked suture, which neither shows. Nothing is said in the text in explanation of these indefensible reconstructions, which are mild examples compared with other composite work in the same article, made out of specimens I have described. Such use of my original figures, without permission, while my preliminary work was still in progress, cannot be justified.

On the same page with the *Bolodon* figure is another of a supposed premolar, which, as I have shown elsewhere (Proc. Ac. Nat. Sci. Phila., 1891, p. 240), is almost certainly made up of portions of *Hybodus* fish teeth. Additional evidence on this point makes it sure that other similar specimens are in existence, and also suggests that the type of *Triglyphus* may be a like production.

figure 4. A number of separate incisors and molar teeth, some with pieces of the jaw attached, were found at the same locality, and one of the molars is represented on the same plate, figure 6. The incisor in the type is much compressed, and has its inner face concave. The symphysis of the jaw is very small, and situated on a distinct elevation. The molar tooth shown in figure 6 is from the lower series, and apparently the penultimate. The cusps are tubercular, and there is a deep median groove between the two rows.

This species is about half the size of *Cimolodon nitidus*, a molar of which is shown on the same plate, figure 7, and a lower jaw, in figure 9. The latter specimen is of special interest, as it shows the smooth fourth premolar in place, with the summit of the crown on a level with the two molar teeth behind it.

These specimens are all from the Laramie of Wyoming.

*Cimolodon agilis*, sp. nov.

The smallest species of this genus is represented by various remains, the most important of which is the left lower jaw, shown on Plate VI, figure 8, which is here taken as the type specimen. The penultimate molar is in place, and its position is so far back that its posterior margin is opposite the front of the coronoid process. The last molar, when present, was entirely concealed by this process when seen from the outside. The molar preserved has the two rows of tubercles close together, with only a valley between them.

This specimen, which belonged to an animal the size of a mouse, was also found in the Laramie deposits of Wyoming.

*Allacodon fortis*, sp. nov.

Since the genus *Allacodon* was established by the writer, in Part II, many additional specimens have been secured, so that the entire upper series of molars and premolars, at least, is believed to be known. Of these teeth, there are three distinct sizes, representing as many species. The largest of these is undescribed, and the tooth shown in Plate VII, figure 4, one of the most characteristic, may be taken as the type. It is evidently an upper premolar corresponding to the middle one in the jaw of *Allacodon pumilus* represented on the same plate, figure 3.

The upper teeth in this genus, besides those figured, have either five or six cones on the crown, and are evidently molars, showing that this genus is closely allied to *Allodon* of the Jurassic, described by the writer.

The lower teeth of the present genus are not known with certainty. The specimens here figured are from the Laramie of Wyoming.

*Allacodon rarus*, sp. nov.

Among the specimens above described a few isolated teeth were found, one of which is represented in Plate VII, figure 5, and may be provisionally referred to the genus *Allacodon*. It is a molar tooth, with four rounded tubercles on the crown, yet these are not crowded together as in the known species of this genus, but the anterior and posterior pairs are separated by a deep transverse groove, showing a distinct type of tooth. This is well shown in the figures given. Additional specimens must determine its nearer affinities.

*Oracodon comulus*, sp. nov.

The teeth of this genus have well marked characters, but none have yet been found in position, or so associated with other remains as to afford any evidence of where they really belong. Although their general features are distinctive, there are various forms and sizes among those now known. The two teeth shown on Plate VII, figures 6 and 7, agree substantially with the type specimen of *Oracodon anceps*, described in Part II. A somewhat larger form, represented in Plate VII, figure 8, appears to be different, and is taken as the type of the species here regarded as new. Its important characters are well shown in the figure.

The teeth figured appear to be upper premolars, and one of them shows a worn surface on the inner side of the crown. They are here placed with the *Allotheria*, and a fortunate discovery may at any time prove their proper position among the varied remains of this group.

*The Stagodontidæ.*

A large number of specimens belonging to this family have been discovered since the first were described. These are quite distinct from any other remains from this horizon, and several of them are figured on Plate VIII, with the type specimens of the two species of *Stagodon* previously made known. Some of the new fossils indicate the largest mammal yet found in the Laramie, and this is described below.

*Stagodon validus*, sp. nov.

The type of the present species is the anterior portion of a right lower jaw represented on Plate VIII, figure 7. This shows alveoles for three incisors closely crowded together, the

first, or inner one, being much the largest. A very stout canine (fig. *a, c*) was present, and behind it, in close contact, follow two premolars, the second being the larger. These are both much worn, but the surface of the crowns preserved is coarsely striate, or rugose, thus permitting a comparison with various isolated teeth of similar size and structure found in the same deposits. Two of these teeth are shown in the same plate, figures 4 and 5, while a separate canine referred to this species is represented in figure 6.

These specimens taken together indicate a carnivorous animal, which apparently has its nearest living ally in the genus *Sarcophilus*, the only representative of which is the "Tasmanian devil" (*S. ursinus*, Cuvier). The resemblance of the present type specimen to the corresponding part of this living marsupial is close.

The teeth of the smaller species of *Stagodon* shown on the same plate appear to be all upper premolars, and each has two roots. The crowns of those best preserved show indications of the same rugose markings seen on the larger lower teeth, and all other features prove their close affinity with them.\*

#### *The Cimolestidæ.*

The remaining specimens figured on the accompanying plates (IX–XI) include various fossils belonging to the family *Cimolestidæ*, which appear to be certainly marsupials more or less related to the modern opossums. Beside these, however, there are quite a number of remains which show features of the *Insectivora*, but until more perfect specimens are obtained, their true affinities must remain in doubt. Under these circumstances, some of these fossils have been referred to forms previously made known in Parts I and II, and only the most distinct and best preserved specimens are described as new. It is believed that the material already secured, when properly worked out of the matrix and investigated, will remove most of the uncertainty now remaining in regard to several typical forms already in part made known.

The larger forms most nearly allied to the genus *Didelphys* are not abundant, but their size has kept some of the remains in good preservation. There are several distinct species of these, but at present they are known only from imperfect material, mostly isolated teeth.

\*Prof. Osborn in the paper already quoted has questioned the mammalian nature of the type of this genus, without giving any evidence for such an opinion. In a later paper (*Am. Nat.*, p. 780, 1891), he has even placed in the *Stagodontidæ*, as my types, figures of quite different fossils. No reply is necessary, as the specimens shown on Plate VIII tell their own story to every anatomist.

The smaller forms, including the genus *Cimolestes* and its near allies, are less rare, and thus admit of more accurate determination. Of these forms, there are at least three genera, which may be readily separated from the specimens now known. *Cimolestes*, which has in the lower jaw seven teeth behind the canine, forming a close series without diastema; *Batodon*, with four premolars separated from each other; and *Telacodon*, an allied form, with five lower premolars. The upper molar teeth referred provisionally to these genera have also marked characters, as shown in the various figures representing them, but more perfect specimens must settle the question of their exact relations to each other.

*Telacodon lewis*, gen. et sp. nov.

The type specimen of this genus is the right lower jaw figured on Plate IX, figure 3. It contains three premolars in good preservation, and has alveoles for two more between these and the canine. An upper premolar referred to this species is shown in figure 2, and an upper molar, also referred provisionally to this form, is given on Plate XI, figure 1. Their exact relation to each other is, of course, uncertain. They are all from the same locality, although not found closely associated.

A second species, somewhat larger in size, is represented by several specimens, one of which, the lower jaw shown on Plate IX, figure 4, may be taken as the type. The lower molar represented on Plate XI, figure 8, is referred to the same species with doubt. This species may be called *Telacodon præstans*.

All the remains of this genus so far as known are from the Laramie of Wyoming.

*Batodon tenuis*, gen. et sp. nov.

The present genus is represented by several specimens, of which the lower jaw on Plate XI, figure 5, may be regarded as the type. In this specimen, the canine is in position. It is comparatively large, and directed well forward. Just behind the canine, there was a very small premolar, not preserved. Following this are two others with low compressed crowns pointing forward. The fourth premolar is quite large, with the crown standing high above the jaw, as shown in the figure. In Plate X, figure 6, a right lower jaw is shown, which may be referred to the same species. It has the last two molars in place, well preserved. An upper molar shown on Plate XI, figure 2, is likewise referred to the present species.

All the known remains are from the Laramie of Wyoming.

One of the most interesting isolated teeth found is represented on Plate XI, figure 9. Several others with the same structure of crown have been secured, but most of them are much more worn. All are evidently deciduous, and they were associated with the teeth of *Didelphops*. There can be little doubt that they are the milk-teeth of the last premolar, and probably pertain to that genus. The discovery of these teeth is of special interest, as it connects the Cretaceous forms with existing Marsupials.

The only specimens described in this series of papers in regard to the nature of which any reasonable doubt can be suggested are the small *Platacodon* teeth the crowns of which are figured in Part II, Plate VIII. In form, these are certainly like the crowns of some fish-teeth, but the best authorities on the subject who have examined them do not consider them such. They were found associated with characteristic mammal teeth, some of which they closely resemble, especially various small incisors, one of which entire is represented on Plate XI, figure 7. A microscopic examination will determine the true nature of the type.

The specimens described and figured in the present article all belong to the skull, the teeth being especially characteristic, and best preserved. Associated with these, likewise, were many parts of the skeleton, especially vertebræ, and bones of the limbs and feet. Some of these specimens were illustrated in Part I, Plate V, and many others will be discussed in a later communication. The bones of the skeleton now known confirm the conclusion derived from the teeth, that many genera and species are represented in the collections made. Some of the broader generalizations suggested by the preliminary study of these remains are of special interest in connection with those already presented, but cannot be given here. One or two facts, however, may be mentioned. All the pelvic bones thus far found have been separate. This is true not only of those of young animals, but of some others apparently adult. The bones of the feet, moreover, indicate that the specialization so marked in the dentition of some of these early mammals was not confined to the skull, but in one or more forms, at least, had made equal progress in the extremities.

For the rare and important material on which the present communication is based, the writer is again mainly indebted to his able assistant, Mr. J. B. Hatcher, whose field-work in vertebrate paleontology has never been surpassed, and will be appreciated more fully as the results of his explorations are placed on record.

## POSTSCRIPT.

After Parts I and II of the present series were published, I made a communication on the subject before the British Association, at the Leeds meeting, Section D, September 5, 1890. The title of the paper was "On the Cretaceous Mammals of North America." These were fully discussed so far as then known, and a series of specimens of the principal forms discovered was exhibited to the section, and shown to many other members interested in the subject. An abstract of this paper will be found in the Report of this meeting, p. 853, 1891.

The first announcement of Mammals in the Cretaceous of Europe has recently been made before the Zoological Society of London, November 17, 1891, by Smith Woodward, of the British Museum, who described a single molar tooth from the Wealden of Hastings, under the name *Plagiaulax Dawsoni*. An abstract is given in *Nature*, p. 164, December 17, 1891. It seems strange that discoveries of similar remains have not been made before in the Wealden, but now others will probably follow. A more promising field is in the fresh-water Gosau beds of Austria, where the *Ceratopsidae* occur, and other fossils allied to those in the Laramie. When a student in Germany, years ago, I searched in them myself for mammals, without success, but have ever since been expecting that some one would announce the discovery.

In this country, the discoveries of Cretaceous Mammals as announced by me in 1889 were not altogether approved by Prof. H. F. Osborn, who, while my investigation was still in progress, wrote a criticism of the two parts already issued, although he had seen none of the specimens described. This review was read before various scientific bodies, among them the Philadelphia Academy of Natural Sciences, to which it was presented January 20, 1891. Part of it was accepted for publication, and appeared in the *Proceedings*, pp. 124-135, 1891. I received a separate copy March 13, 1891, but had previously heard the review read by Prof. Osborn at the Biological Society of Washington, February 7, 1891. At this meeting, I exhibited a series of specimens of Cretaceous mammals that disproved the main points then asserted by Prof. Osborn, but he declined to examine them.

The review as subsequently published was discourteous, unjust, and erroneous in so many points, that I prepared a short reply under the title "Note on Mesozoic Mammalia," and sent it to Dr. Leidy, President of the Philadelphia Academy, who presented it to that society April 14, 1891, and informed me that it would soon be printed. As chairman of

the committee of publication, he gave me full permission to publish it separately, duly credited to the Academy, and a few copies were thus printed, and sent to Europe. The sudden death of Dr. Leidy delayed publication by the Academy, but the paper appeared in the Proceedings, pp. 237-241, 1891, essentially as presented, the main alterations being verbal changes, the result of editorial supervision. Separate copies had previously been printed by the Academy, and distributed by me.

Prof. Osborn next had his original review as offered to the Philadelphia Academy published in full in the American Naturalist for July, 1891, and with it my reply as presented to the same Academy, except under a somewhat different title. To the latter article, he prepared the rejoinder read before the American Association at Washington, August 21, 1891, published it in the American Naturalist for September, 1891, and issued revised, separate copies. In this paper, Prof. Osborn attempts to answer the criticism upon his review and previous work on Mesozoic mammals, and repeats a number of statements made in his original review, and since shown to be erroneous. The value of such extensive publications without examination of a single specimen described may be fairly questioned. The record of them above presented is for the benefit of those especially interested in the subject.

New Haven, Conn., Feb. 23, 1892.

## EXPLANATION OF PLATES.

### PLATE V.

- FIGURE 1.—Upper cutting premolar of *Cimolomys gracilis*, Marsh.  
 FIGURE 2.—Upper molar of *Tripriodon caperatus*, Marsh.  
 FIGURE 3.—Right upper molar of *Tripriodon calatus*, Marsh.  
 FIGURE 4.—Left lower incisor of *Halodon sculptus*, Marsh, in position in jaw.  
 FIGURE 5.—Right lower fourth premolar of same species.  
 FIGURE 6.—Worn molar of *Dipriodon lunatus*, Marsh.  
 FIGURE 7.—Right lower jaw of *Dipriodon lunatus*, with third and fourth premolars and first molar in place. Natural size.

### PLATE VI.

- FIGURE 1.—Upper incisor of *Dipriodon lunatus*.  
 FIGURE 2.—Upper premolar of *Nanomyops (Nanomys) minutus*, Marsh.  
 FIGURE 3.—Upper molar of *Cimolodon nitidus*, Marsh.  
 FIGURE 4.—Left lower incisor of *Cimolodon parvus*, Marsh, in position in jaw.  
 FIGURE 5.—Lower incisor of *Selenacodon*.  
 FIGURE 6.—Molar of *Cimolodon parvus*.  
 FIGURE 7.—Molar of *Cimolodon nitidus*.  
 FIGURE 8.—Lower jaw of *Cimolodon agilis*, Marsh, with penultimate molar in place.  
 FIGURE 9.—Right lower jaw of *Cimolodon nitidus*, with cutting premolar and last two molars in place.

Note.—In all the plates, Figure *a* is natural size. The figures enlarged have the increase in size given in diameters over each cut.

PLATE VII.

- FIGURE 1.—Incisor of *Cimolomys gracilis*.  
 FIGURE 2.—Incisor of *Cimolomys bellus*, Marsh.  
 FIGURE 3.—Upper jaw of *Allacodon pumilus*, Marsh, with three premolars in place.  
 FIGURE 4.—Upper premolar of *Allacodon fortis*, Marsh.  
 FIGURE 5.—Upper molar of *Allacodon rarus*, Marsh.  
 FIGURE 6.—Upper premolar of *Oracodon anceps*, Marsh.  
 FIGURE 7.—Upper cutting premolar of same species.  
 FIGURE 8.—Upper premolar of *Oracodon conulus*, Marsh.

PLATE VIII.

- FIGURE 1.—Premolar of *Stagodon nitor*, Marsh. (Type.)  
 FIGURE 2.—Premolar of same species, with roots more distinct.  
 FIGURE 3.—Upper premolar of *Stagodon tumidus*, Marsh. (Type.)  
 FIGURE 4.—Premolar of *Stagodon validus*, Marsh.  
 FIGURE 5.—Premolar of same species.  
 FIGURE 6.—Left lower canine of same.  
 FIGURE 7.—Right lower jaw of *Stagodon validus*, showing canine and two premolars in place.

PLATE IX.

- FIGURE 1.—Two right upper molars of *Didelphops vorax*, Marsh, in position in jaw.  
 FIGURE 2.—Upper premolar of *Telacodon levis*, Marsh, in jaw.  
 FIGURE 3.—Lower jaw of *Telacodon levis*, with three premolars in place, and alveoles for two others.  
 FIGURE 4.—Lower jaw of *Telacodon præstans*, Marsh.  
 FIGURE 5.—Left lower jaw of *Cimolestes incisus*, Marsh; outside view.  
 FIGURE 6.—The same jaw; inside view.  
 FIGURE 7.—Right lower jaw of *Didelphops ferox*, Marsh; seen from above.  
 FIGURE 8.—The same jaw; seen from the inside. Both figures natural size.

PLATE X.

- FIGURE 1.—Upper molar of *Didelphops comptus*, Marsh.  
 FIGURE 2.—Upper premolar of same species.  
 FIGURE 3.—Upper molar of *Pediomys elegans*, Marsh.  
 FIGURE 4.—Premolar of same species.  
 FIGURE 5.—Lower molar of *Cimolestes incisus*.  
 FIGURE 6.—Lower jaw of *Batodon tenuis*, Marsh, with last two molars in place.  
 FIGURE 7.—Left lower jaw of *Pediomys elegans*, with last molar in place.

PLATE XI.

- FIGURE 1.—Upper molar of *Telacodon levis*.  
 FIGURE 2.—Upper molar of *Batodon tenuis*.  
 FIGURE 3.—Lower molar of same species.  
 FIGURE 4.—Canine tooth of *Cimolestes*.  
 FIGURE 5.—Lower jaw of *Batodon tenuis*, with premolars and canine in place.  
 FIGURE 6.—Tooth of *Platacodon nanus*, Marsh.  
 FIGURE 7.—Lower incisor of same species.  
 FIGURE 8.—Lower molar of *Telacodon præstans*.  
 FIGURE 9.—Milk-tooth of *Didelphops*.

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# A. E. FOOTE,

4116 Elm Avenue,

Philadelphia, Pennsylvania, U. S. A.

## CALIFORNIA RUBELLITES.

We have just received from a new locality in California some remarkable specimens of **Rubellite**. The well defined, columnar crystals, many of them from one to two inches long and showing distinct terminations, occur principally in radiated aggregates imbedded in a **Lepidolite** rock. These specimens are exquisitely beautiful, all of them presenting the same uniform shade of rose-pink in a pale lilac setting of **Lepidolite**, forming a combination of colors rarely equalled.

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Polished sections of **Jasperized Wood** from Arizona. Rare and interesting crystallized **Gold** on **Galenite** from Colorado. **Cobaltite**, **Linnæite**, **Stannite**, **Euchroite**, **Libethenite** and many others.

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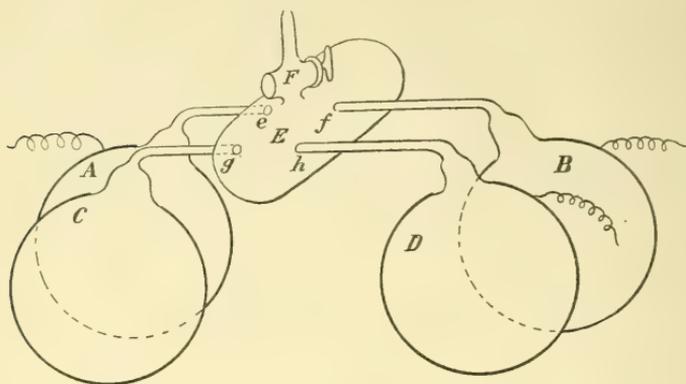
ART. XXXII. — *On the Action of Vacuum Discharge Streamers upon each other*; by M. I. PUPIN, Ph.D., of Columbia College. With Plate XII.

VARIOUS phenomena which I observed in the course of an investigation on the coronal effects produced by electrical discharges through rarefied gases, led me to the belief that under certain conditions two electric current filaments in a rarefied gas may act upon each other oppositely to the direction of their mutual electrodynamic action, and that this additional action may sometimes be far predominant over the electrodynamic action; that is to say, we have a strong repulsion where electrodynamic action would produce an attraction. A brief account of these investigations was given on Feb. 8th, before the Astronomical Section of the New York Academy of Sciences. The following paper is limited to the description of the experiments by means of which the existence of the above mentioned action was definitely proved.

Fig. 1 represents the apparatus first employed. Four glass bulbs, A, B, C, D, each having a capacity of about a liter, are connected by four glass tubes of small bore to a glass reservoir E. A stopcock F serves to connect the apparatus to a mercury pump. The reservoir has a diameter of 10<sup>cm</sup> and a length of 22<sup>cm</sup>. The mouths *e*, *f*, *g*, *h*, of the four narrow-bore tubes form a square whose side is 10<sup>cm</sup> long. The bulbs are covered with tinfoil and the tinfoil is then well coated with paraffin.

Each tinfoil covering has a well insulated copper wire attached to it.

*Fig. 1.*



After producing a  $2^{\text{mm}}$  vacuum in the apparatus the bulbs A and B were connected to the secondary poles of a small Ritchie induction coil, whose primary was fed by an alternating current of 125 periods per second. The electromotive force in the secondary coil was varied by varying the current in the primary; this was done by means of a resistance box in the primary circuit. The electric flow between the bulbs is, of course, due to the condenser effect between the tinfoils and the vacuum.

At the pressure of  $2^{\text{mm}}$  the discharge was easy, steady and very diffuse along its path through the reservoir. Disconnecting AB and connecting CD to the induction coil the discharge was the same in character as before. Connecting both pairs of bulbs in parallel to the induction coil, that is, the bulbs A and C to one pole and B and D to the other pole, the two discharges, going on simultaneously, were the same in character as before, except that they were somewhat convex towards each other.

The pressure was then increased by turning the stopcock once around and allowing some air to get in. The discharges were less diffuse but more luminous, and less convex toward each other.

With the increase of pressure the discharges became less and less diffuse and their convexity towards each other diminished until, when a certain gas pressure was reached, it disappeared. At this point the discharges were very little diffuse and when allowed to pass through the reservoir simultaneously they remained rectilinear, but somewhat unsteady, oscillating quite appreciably about their rectilinear paths through the reservoir,

but the oscillations were always in the plane common to their rectilinear paths.

The pressure was still increased by turning the stopcock once around and allowing some more air to get in. The discharges became still less diffuse along their path through the reservoir and when allowed to pass one at a time they were quite steady and rectilinear. Both being allowed to pass through the reservoir simultaneously they were appreciably concave toward each other, but the concave arcs were in the plane passing through their shortest path in the reservoir. There was evidently a repulsive force acting between the discharges. This repulsive force increased continually with the increase of pressure in the vacuum, but with the increase of the force the steadiness of the discharges along their paths through the reservoir when they were both passing simultaneously gradually diminished. Fig. 3 (Plate XII) is a photograph of the discharges when taking place simultaneously in a vacuum in which the repulsive force just described was moderate. Fig. 2 is a photograph of the same discharges, but when taking place one at a time. Fig. 2 indicates that there is a repulsion between the discharge and the nearest wall of the reservoir, but this repulsion is very small in comparison to the repulsion acting between the streamers, when they take place simultaneously, as fig. 3 indicates. The photographs were taken by very short (1 to  $1\frac{1}{2}$  second) exposure, so strong is the luminosity of these discharges. They were taken when the repulsion was moderate, because when the repulsion is very strong the discharges oscillate very rapidly, so that they could not be well photographed with the apparatus employed. When the repulsion was so strong as to cause the streamers to curve way out and from time to time strike the nearest wall of the reservoir, the vibrations became very violent every time the streamers struck against the walls. They rebounded against the walls just as if they were luminous vibrating strings.

At this pressure in the vacuum it was very difficult to start the discharge and I had to strain the alternating machine and the induction coil to their utmost to make the start.\* But when once started the discharge continues without any interruption even if the potential at the tin foils is lowered 15 to 20 per cent.

The rate at which the temperature of these discharges increased with the increase of pressure in the vacuum seems to be much more rapid than the increase of the pressure; (the impressed *e. m. f.*, of course has to be increased with the pressure) and with the increase of the temperature the luminosity

\* A gentle touch of the apparatus with a conductor will sometimes start the discharge at once when all other means of making this start fail.

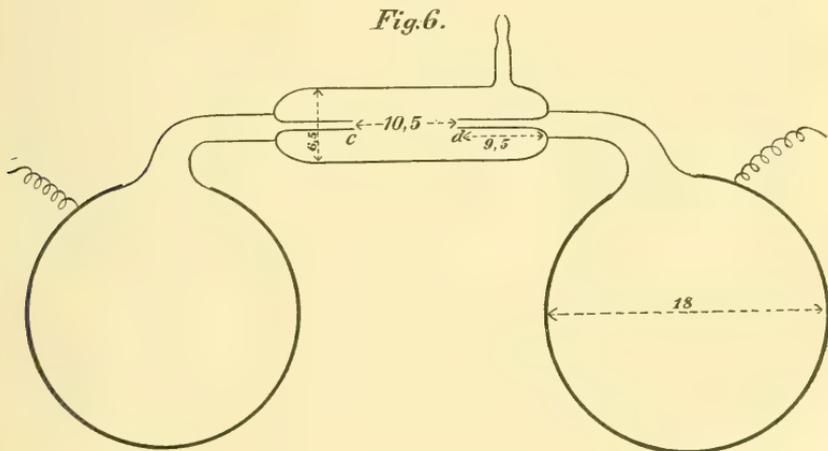
of the discharge increased also. With the increase of luminosity the color of the discharge changed from the pink color, which is the characteristic color of the ordinary Geissler tube discharges through rarefied air, to a color which inclined more and more toward the white. With the increase of the pressure the diffuseness of the discharge disappeared, but instead of the diffuse pink color there appeared a beautiful green phosphorescent light which filled the whole reservoir. This phosphorescent light is so strong, that even an almost instantaneous exposure is sufficient to give it time to act upon the sensitive plate, as appears from the photographs in figs. 2 and 3. At some future date I shall describe experiments which seem to be a strong proof that phosphorescence produced by electrical discharges depends on the temperature and only in so far on quantity of the discharge and on the vacuum, as the temperature of the discharge depends on them. The investigations of Crookes, Goldstein, and others lead to the conclusion that a high vacuum with its cathode rays is most favorable if not indispensable to the development of strong phosphorescence. In my experiments a good vacuum (of about  $2^{\text{mm}}$ ) gave no phosphorescence whatever, whereas a poor vacuum (even with as high a pressure as  $100^{\text{mm}}$ ) gave very strong phosphorescence, and that too not only in places where the discharge struck the walls of the vessel but also in places which were far away from the discharge. Presently I shall describe an experiment which shows that the gas as well as the glass becomes strongly phosphorescent. My observations cannot, therefore, be well reconciled to those of Crookes, Goldstein, etc., unless the cathode rays be supposed to be very thin and very hot discharge filaments. I have several experimental facts which speak in favor of this hypothesis, but a discussion of them would lead me beyond the limits of this paper.

I find that some astrophysicists assume the existence of a repulsive force acting between the streamers of the solar corona; it was the peculiar behavior of the corona-like vacuum discharges which, in addition to other phenomena that came under my observation, forced me to assume that repulsive forces must be active between the filaments of these discharges, although at that time I was perfectly ignorant of the details of the various electrical theories of the solar corona. The streamers of these discharges are very unsteady and very much split up when the vacuum is poor. A photograph of a discharge of this kind is given fig. 4. As the vacuum improves the corona-like discharges become a great deal steadier, less torn up and quite diffuse, but never uniformly distributed over the whole spherical electrode. Fig. 5, represents the photograph of a discharge in the vacuum of about  $20^{\text{mm}}$  pres-

sure. These photographs belong to my collection of photographs of corona-like vacuum discharges, an account of which I expect to give at some future time.

The question arose then, naturally, what is the cause of this repulsion? Electrostatic action suggested itself first, of course. But various observations which I made during my investigations on vacuum discharges made me favor another view, the view namely that the repulsive force between vacuum discharge streamers is due to a strain in the vacuum produced by the peculiar distribution of the gas pressure resulting from the peculiar distribution of temperature. If this view is correct then there should be no action between two vacuum streamers passing in two separated vacua. This suggested the following experiment:

Investigate the action of two discharge streamers upon each other when two separate discharge reservoirs are employed. Fig. 6, represents the apparatus (with its dimensions in cm.



marked), containing one of the reservoirs, two of which were placed side by side in the experiment. The bore of the capillary tubes  $e$ ,  $c$ ,  $d$ ,  $f$ , was about  $1.5\text{mm}$ . The bulbs  $AB$  were coated with tinfoil and the whole arrangement was the same as in the experiments with the apparatus given in fig. 1. The two apparatus communicated with each other by means of a stopcock, so that the pressure was the same in each. The discharge in one apparatus did not influence the discharge in the other, no matter what the pressure was, up to the limit at which I could still obtain a discharge, which was about  $60\text{mm}$ . From this I conclude that the repulsion which I observed in the previous experiments was probably not due to electrostatic

action. The probability of the correctness of the other view is therefore considerably strengthened.

The apparatus for this experiment was constructed with two other objects in view, which ought to be mentioned here.

1st. To locate the phosphorescence. In this I was quite successful. It surrounded the hottest parts of the discharge, and therefore it was most intense in the narrow parts of the apparatus. Within the reservoir it extended from *c* to *d* in form of something like an ellipsoid of revolution, with the extremities of its longest axis at *c* and *d*, and at times this ellipsoid did not fill out the reservoir at all, which proves that the phosphorescent light in this part of the apparatus is due to the phosphorescence of the rarefied air and not to the phosphorescence of the glass, although in the narrower parts of the apparatus where the hot discharge was very near the glass the glass was also phosphorescent.

2d. To study what I call the ramification of the discharge. As soon as the pressure reached a certain limit the luminosity in the bulbs (which at low pressures was more or less uniformly diffused throughout the bulbs) became streaked, and at still higher pressures the whole discharge in its path through the bulbs divided itself into a number of distinct streamers, the number of streamers diminishing with the increase of pressure; given pressures produced invariably the same number of streamers. In this experiment I did not succeed in reducing the number of these streamers to less than two. The streamers rotated more or less uniformly in one direction or the other. The angular velocity of rotation seemed to increase considerably with the current of the discharge.

An exhausted glass bulb without electrodes when brought into the vicinity of these discharges emits a faint yellowish light which looks very much like the light of some forms of the aurora borealis. The bulb seems to remain perfectly cool. Lack of time and facilities have prevented me from determining the spectrum of this cold glow.

My thanks are due to Professors W. P. Trowbridge and J. K. Rees for the interest which they took in my work; also to Mr. Mann, of the Astronomical Observatory, for the very valuable service which he rendered to me in photographing these discharges.

I hope to continue this work with improved facilities as soon as time will permit.

Department of Electrical Engineering, Columbia College, February 28th, 1892.

ART. XXXIII.—*On a Melilite-bearing Rock (Alnoite), from Ste. Anne de Bellevue near Montreal, Canada; by FRANK D. ADAMS.*

AT the extreme southwest corner of the Island of Montreal and about twenty miles from the city of the same name, is the village of Ste. Anne, sometimes called Ste. Anne de Bellevue to distinguish it from a number of other places of the same name in the Province of Quebec. Here both the Grand Trunk and Canadian Pacific Railways cross the Ottawa river on bridges but a few yards apart, while under these and directly in front of the village is a short canal constructed to avoid the rapids which impede navigation at this point. Owing to the difficulty of navigating the Ottawa below this canal during times of very low water, it was decided to remove a ridge of rock in the river bed opposite the lower end of the village of Ste. Anne, and in this way to open up communication with a deeper channel on the opposite side of the river. In the summer of 1877 accordingly the Dominion Government put down cofferdams and having laid the bed of the river bare at this point blasted out the obstruction.

While this work was in progress, the locality was visited by Dr. B. J. Harrington, at that time connected with the Geological Survey of Canada, who found the bed of the river to be composed of well bedded sandstones and conglomerates of Potsdam age dipping to the south at an angle of  $3\frac{1}{2}$  to 4 degrees, cut through by a nearly vertical dike three feet thick and running N.  $20^{\circ}$  W. At one point a branch was observed running off from the larger dike. Much of the rock was entirely decomposed but a number of comparatively fresh specimens were obtained and notes on the mode of occurrence of the dike were published by Dr. Harrington in the Report of the Geological Survey of Canada for 1877-78, page 39 G, and also in the *Canadian Naturalist*, vol. ix, p. 253.

The rock however was fine grained and for the most part much decomposed, so that its true character was not recognized until the discovery by Törnebohm in 1882 of a melilite-bearing rock which he termed a melilite basalt\* on the Island of Alnö in Sweden, which rock in hand specimens so closely resembled that from Ste. Anne, that Prof. Rosenbusch of Heidelberg to whom a specimen of the latter had been given was led to carefully reëxamine the sections of it for melilite. One or two crystals of this mineral found in one of the sec-

\* A. E. Törnebohm: Melilitbasalt från Alnö, Geol. Fören. i Stockholm Förel., 1882, p. 240.

tions served to indicate the relationship of the rock although in this particular specimen the melilite had been almost entirely destroyed by decomposition. This rock was therefore in the last edition of Prof. Rosenbusch "Massigen Gesteine," page 809, classed with that from Alnö as Alnoite, a dike rock corresponding to melilite basalt among the effusive rocks. As a new occurrence of a rare and curious rock it seemed worthy of careful study, the more so as it is, so far as I am aware, the first melilite rock that has been found on this continent.

The locality has therefore been revisited and a number of specimens of the fresh rock obtained from several large blocks which were thrown out on the slopes of the cribwork defining the channel. The dike itself of course cannot be seen, as it lies in the bed of the river and is now under several feet of water and but little fresh material can be obtained even from the blocks, as these are for the most part much decomposed. The strike of the dike would carry it through the village of Ste. Anne, but although the Potsdam sandstone is exposed in a number of places in the village no trace of the dike could be found, nor could any similar rock be found elsewhere in the vicinity.

The rock has a fine grained grayish-black groundmass through which are usually distributed large phenocrysts of biotite, olivine generally of a bright red color but sometimes green and black pyroxene. These are generally plentiful and sometimes so abundant as to constitute the greater part of the rock, giving it a very striking appearance. Some of the rock is almost free from these phenocrysts and consists of the fine grained groundmass alone, which in such cases is almost invariably much decomposed. It was impossible to ascertain whether this variety of the rock is confined to any particular part of the dike. The phenocrysts sometimes measure as much as 4 or 5 centimeters across but are generally somewhat smaller,  $2\frac{1}{2}$  centimeters being the usual size. The biotites are frequently arranged in a rudely parallel position coinciding, as in the Swedish rock, with the direction of the walls of the dike, thus giving the rock a sort of schistose structure in this direction. The groundmass, which can only be studied properly in thin sections of the freshest material, is composed of smaller biotites, olivines and pyroxenes between which lies a still finer grained aggregate made up of individuals of melilite and little pyroxene spicules, the relative proportions of the two minerals varying considerably in different parts of the rock. Magnetite often in little cubes and octahedra occurs somewhat abundantly in the groundmass as well as in the form of inclusions in almost all the other constituents of the rock. Pyrrho-

tite is also present in small amount and can be separated from the powdered rock by means of a magnet. Apatite as well as perowskite, which is so constantly associated with melilite, is found in small amount in all the sections, while a little nepheline is probably present intimately associated with the melilite. Although some thirty-five thin sections have been prepared and carefully studied, no feldspar could be detected as a constituent of the rock. Curious angular fragments of a rather coarsely crystalline rock, composed in some cases almost entirely of plagioclase and in other cases of a granite or gneiss are not uncommon as inclusions. These are bounded by curious little contact zones and are evidently fragments of wall rock which have been brought up by the molten rock probably from the underlying Laurentian. Cavities, partially or completely filled with secondary minerals are also of frequent occurrence. The specific gravity of three average specimens of the rock was found to be as follows: 3.020, 3.013, 2.955.

For an analysis of the rock I am indebted to Mr. P. H. Le Rossignol of this University. In order to obtain as far as possible an average, a large number of fragments were broken from a series of the freshest hand specimens, and having been reduced to powder the whole was carefully mixed together and a portion taken for analysis. The results of the analysis of this Alnoite from Ste. Anne are given under I below, while under II the analysis of the melilite basalt from Hochbohl is reproduced from Prof. Stelzner's paper\* for purposes of comparison. No analysis of the rock from Alnö has as yet been published.

	I.	II.
SiO <sub>2</sub> .....	35.91	33.89
TiO <sub>2</sub> .....	0.23	0.64
Al <sub>2</sub> O <sub>3</sub> .....	11.51	9.93
Fe <sub>2</sub> O <sub>3</sub> .....	2.35	15.63
FeO .....	5.38	----
CaO .....	13.57	15.19
MgO .....	17.54	16.14
K <sub>2</sub> O .....	2.87	----
Na <sub>2</sub> O .....	1.75	2.86
P <sub>2</sub> O <sub>5</sub> .....	not det.	1.41
CO <sub>2</sub> .....	} 9.40	1.41
H <sub>2</sub> O .....		2.90
	<hr/> 100.51	<hr/> 100.00

The large amount of water and carbonic acid present in the rock shows that even the freshest specimens have undergone

\* "Ueber Melilith und Melilithbasalte," Neues Jahrbuch für Mineralogie, etc., 1882, Beil. Bd. II, 398.

very considerable alteration. The comparatively large percentage of potash in the Canadian rock is probably derived principally from the biotite which is present in large amount, while the Hochbohl basalt is nearly free from it. This biotite which is of a rich brown color occurs in individuals which although occasionally presenting a good crystalline form are usually irregular in shape. The basal sections are black or nearly so between crossed nicols and in convergent light show a cross, the arms of which separate somewhat when the section is revolved, indicating that the mineral is biaxial with a small axial angle. The lateral sections show the usual eminent basal cleavage with parallel extinction and a strong pleochroism, pale yellow sometimes nearly colorless, to deep yellowish brown. When a percussion figure is obtained and the optical orientation of the mica studied it is found to be different from that of ordinary biotite and like the mica in the Alnö rock,\* to belong to Tschermak's first series. It is therefore anomite.

Around the biotite phenocrysts a narrow zone somewhat deeper in color but similarly orientated is often seen. It is distinguished from the inner portion of the crystal, not only by its color, but frequently also by the presence of minute inclusions, for the most part little pyroxenes like those of the groundmass, which are wanting in the inner portion. This zone is sharply defined against the inner portion and is frequently seen to build out the more or less rounded core into a more perfect crystalline form. The outer edge, although frequently minutely serrated, displays crystalline outlines. There has evidently been, first a separation of biotite in large phenocrysts, followed by a partial re-absorption and then a second crystallization of biotite, occurring partly in the form of zones about the remnants of the biotites of the first generation and partly as smaller individuals both in the form of phenocrysts and in the ground mass. The biotite of the first generation is lighter in color and free from pyroxene inclusions, while these occur abundantly in that of the second generation.

*Olivine.*—In the hand specimens the mineral is sometimes pale green but more frequently of a beautiful bright red color. It is usually well crystallized, especially the smaller phenocrysts and is traversed by a multitude of irregular cracks in addition to the lines of imperfect cleavage. When examined in thin sections by reflected light the color of the red olivine crystals is seen to be due to the presence of irregular wavy lines of ferric oxide of a brilliant red or orange color. That the ferric oxide, however, is present in but small amount is seen from the accompanying analysis I; of this red olivine by

\* F. Eichstädt: "Anomit från Alnö, Vesternorrlands län," Geol. Fören. i, Stockholm Förh., 1884, No. 87, 194.

Prof. B. J. Harrington.\* An analysis of the olivine from the Hochbohl Melilite Basalt, II, made by Mr. Meyer is reproduced from Prof. Stelzner's paper for comparison. The olivine from the Ste. Anne rock is seen to be a variety much richer in magnesia and poorer in iron than that of the rock from Hochbohl.

	I.	II.
SiO <sub>2</sub> -----	38.560	41.90
MgO -----	44.369	28.48
FeO -----	12.649	29.16
Fe <sub>2</sub> O <sub>3</sub> -----	1.361	----
MnO -----	0.112	----
H <sub>2</sub> O (ign.)-----	2.914	----
	<hr/>	<hr/>
	99.965	99.54

The oxide of manganese contains a little oxide of cobalt. The olivine is remarkable however chiefly on account of the very peculiar character of the alteration which it has undergone. The product of this alteration is in some cases the usual decomposition product serpentine, but in other cases a highly feriferous magnesite (Breunerite). These minerals sometimes occur separately, one olivine crystal being altered to serpentine while another near it is changed to magnesite but they are more usually found together as alteration products of the same olivine individual. The serpentine is green in color and is developed as usual along cracks and cleavage lines often extending inward from these, a perfect pseudomorph being finally produced. The magnesite occurs as a cryptocrystalline or very fine microcrystalline aggregate also working its way into the olivine along the cracks and cleavage lines or else eating its way in from the exterior of the crystal in masses having a peculiar scalloped outline. When developed as a narrow edging along cracks, it is seen to have a somewhat fibrous structure in a direction at right angles to the crack but the fibers are not arranged in a sufficiently parallel position to afford a dominant extinction. When occurring in larger grains the fibrous structure is not seen and the mineral becomes compact, often indicating however by its structure the position of the cracks in the olivine along which it was developed, just as serpentine usually does. Occasionally it shows a very imperfect spherulitic structure. It is transparent to translucent in thin sections, and although the individuals are minute is seen to have a high index of refraction and strong double refraction. By reflected light it has a dull white or yellowish white color.

\* B. J. Harrington: "On the occurrence of Olivine in Canada," Report of the Geological Survey of Canada, 1877-78, page 39 G.

When thin sections are treated with cold diluted hydrochloric acid the magnesite remains unaltered, even cold concentrated hydrochloric acid does not dissolve it. When however the acid is warmed the greater number of the magnesite pseudomorphs are completely dissolved, others however, are only partially dissolved, or are dissolved only in certain places, owing apparently to the fact that in these cases the alteration into magnesite is not yet complete or is complete only in certain parts of the pseudomorph. By carefully searching a large number of hand specimens it was found to be possible to obtain a sufficient amount of the magnesite apparently quite pure, to enable its blowpipe characters to be determined and also for chemical analysis. Before the blowpipe it decrepitates somewhat and blackens but does not fuse even on the thin edges. After ignition it shows an alkaline reaction with turmeric paper and in its other blowpipe reactions, which it is unnecessary here to detail, agrees with magnesite. A small fragment placed in cold concentrated hydrochloric acid gives off a few minute bubbles but goes into solution only with extreme slowness. The specific gravity of four little fragments was taken by the aid of Thoulet's solution and a Westphal's balance and was found to range from 3.062 to 3.072 at 19.5° C.

The following analysis of the apparently pure material referred to above, dried in vacuo over sulphuric acid, was kindly made for me by Dr. B. J. Harrington.

MgO .....	32.68
CaO .....	0.93
FeO .....	16.24
CO <sub>2</sub> .....	44.61
SiO <sub>2</sub> .....	3.38
H <sub>2</sub> O .....	2.13
	99.97

When the combinations are calculated the percentages of the carbonates are found to be as follows:

MgCO <sub>3</sub> .....	64.83
FeCO <sub>3</sub> .....	26.16
CaCO <sub>3</sub> .....	1.66

This leaves an excess of 1.81 p. c. of magnesia, which is probably present as a hydrous silicate. The silica, which remains behind in a flocculent condition when the mineral is treated with hot hydrochloric acid, is probably derived in part from a little serpentine present as an impurity.

When both serpentine and magnesite are present as alteration products in the same olivine individual their boundaries against one another are sharply defined and the two minerals do not occur mixed together. The magnesite seems to have been formed before the serpentine, as it frequently occupies the outer part of the crystal while the inner portion is altered to serpentine. In these cases the alteration to magnesite appears to have gone on to a certain point and then ceased, while the rest of the olivine was subsequently altered to serpentine in the usual manner. Two of these altered olivine crystals are represented in the accompanying figure (fig. 1). In one of them magnesite alone is present as a decomposition product, while the other is altered to magnesite and serpentine.

It is believed that this peculiar alteration of olivine has not been hitherto observed. A very similar if not identical alteration product, however, is seen in the olivine occurring in certain fine grained nepheline-bearing dykes from the Montreal mountain, and in Sagvandite\* we probably have a somewhat similar alteration of bronzite to magnesite.

*Pyroxene.*—The pyroxene which is one of the most abundant constituents in the rock is also in many respects remarkable. Two varieties are present, one forming the large phenocrysts and the other occurring very abundantly in the groundmass. The phenocrysts which, as mentioned above, are often very large, are usually well crystallized but sometimes have more or less rounded forms. The mineral is fresh and unaltered even when the other constituents have undergone considerable decomposition even where cavities filled with secondary minerals have eaten their way into its substance the pyroxene around their border is quite fresh. When crystallized, basal sections present eight sided forms showing a development of both prismatic and pinacoidal forms, with good cleavage parallel to the former and extinction parallel to the latter. It is monoclinic and the maximum extinction observed in the zone of the orthopinacoid and clinopinacoid was  $42^{\circ}$ . It is colorless and never shows more than mere traces of pleochroism, it has however a strong dispersion of the bisectrices so that when a thin section is revolved between crossed nicols until the point of maxi-

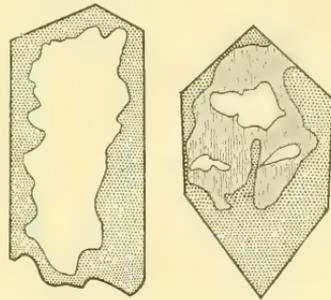


FIG. 1. Alteration of olivine to magnesite (stipple) and to magnesite and serpentine (vertical lines). The white spaces are unaltered olivine.

\* H. Rosenbusch: "Ueber den Sagvandite," Neues Jahrbuch für Mineralogie, etc., 1884, p. 195.

When darkness is reached a slight revolution of the stage in one direction will cause the pyroxene to assume a light brown tint, while a movement of a few degrees in the reverse direction will cause it to appear of a grayish-blue color, the section never becoming black and the contrast of color often being very marked.

This same dispersion is seen in the pyroxene occurring in the alnoite from Alnö, in the melilite basalt from Hochbühl, as well as in many of the nepheline bearing rocks found in the vicinity of Montreal. It is believed to be a variety containing a considerable amount of titanitic acid but it has not as yet been analyzed. Almost every one of the larger phenocrysts has a narrow border or zone, well defined against the inner core, but differing from it both in color and angle of extinction. This zone, which can sometimes be seen even in hand specimens, is light brown in color in the thin sections and probably has the same composition as the pyroxene occurring in the groundmass and forming the smallest phenocrysts, which have no core, seeing that it resembles this in optical properties. This zone has a larger extinction than the inner portion, the difference frequently amounting to  $16^\circ$  and even more. The crystalline outline of the pyroxene phenocrysts is frequently seen to be much more perfect than those of the inner core, the latter often having a distinctly rounded form while the former present true crystalline outlines. The zone moreover, although sharply defined against the inner core along a curved line frequently has a somewhat serrated outer limit showing like the biotite many little projections running out into the groundmass. The same phenomenon is noted by Törnebohm in the pyroxene in the alnoite from Alnö. It would thus seem that the pyroxene like the biotite had first been crystallized out as large phenocrysts, that these had been partially reabsorbed giving to them rounded contours and that subsequently pyroxene had again been crystallized out of the magma, forming the zones about these larger phenocrysts, tending to restore to them their original crystalline forms and also at the same time forming the smallest phenocrysts and all the little pyroxene crystals in the groundmass which, as above mentioned, resemble in character that of the zones.

The pyroxene occurring in the groundmass takes the form of swarms of minute elongated often acicular crystals of a light brown color. In some sections they constitute the greater part of the groundmass. They have a high index of refraction, are not pleochroic and sometimes occur twinned parallel to  $\alpha P\bar{\alpha}$ . They occur very frequently penetrating the biotite and other constituents of the rock and are often embedded in them.

*Melilite.*—This mineral which gives to the rock its distinctive character is well characterized and is quite abundant in some of the sections, while in others it occurs more sparingly. It is found almost invariably as flat tabular crystals shortened in the direction of the vertical axis. Basal sections of these crystals have rectangular or eight sided outlines and are isotropic, while prismatic sections present lath shaped forms which between crossed nicols show parallel extinction. Sometimes however the crystals are not so flattened but have the form of short stout prisms while frequently they are irregular in shape. The individuals ordinarily range in size from  $\cdot 016^{\text{mm}}$  to  $\cdot 046^{\text{mm}}$  in thickness and from  $\cdot 07^{\text{mm}}$  to  $\cdot 17^{\text{mm}}$  in length. The largest of a considerable number which were measured was  $\cdot 46^{\text{mm}}$  by  $\cdot 057^{\text{mm}}$ , this however is unusually large. Törnebohm says that in the rock from Alnö the melilite crystals are seldom over  $\cdot 1^{\text{mm}}$  in length. The mineral is usually colorless but often has a slight but distinct yellowish tint. It has a much higher index of refraction than nepheline but the double refraction is weak, the polarization colors in good sections varying from very dull blue to bluish gray. In the lath shaped sections a basal cleavage can often be distinctly seen and in such cases the extinction is of course parallel to it, as it is parallel to the sides of the lath shaped sections when the cleavage is not seen. At right angles to this cleavage and therefore parallel to the vertical axis, what Stelzner has called "peg structure," which is so characteristic of melilite is often excellently developed. This cleavage with the "peg structure" at right angles to it, when well seen indicates with certainty the orientation of the melilite individual and the study of a large number of such grains in slides prepared from several hand specimens, with the aid of a gypsum film giving between crossed nicols red of the first order, shows that in all cases the vertical axis is the axis of greatest elasticity, that is to say that the mineral is negative. When both minerals are developed in crystals giving lath shaped sections, the gypsum plate affords a ready means of distinguishing melilite, from nepheline, seeing that in the latter mineral the longer axis of the oblong sections is parallel to the vertical axis.

In basal sections the "peg structure" appears as little dots. The melilite is often traversed by irregular cracks in addition to the basal cleavage. The accompanying figure (fig. 2) drawn from one of the thin sections of the rock, shows the mineral with better crystalline outlines than it usually possesses, associated with biotite, magnetite and apatite and surrounded by a mass of decomposition products consisting of the most part of calcite.

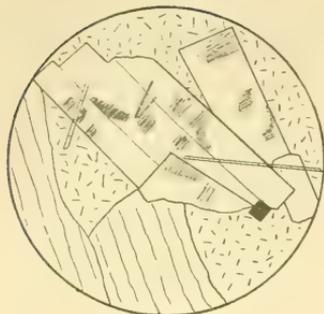


FIG. 2. Melilite showing "peg structure" associated with biotite, magnetite and apatite.

An attempt was made to separate the melilite from the groundmass of one of the freshest and most coarse grained specimens by means of heavy solutions but it was found to be impossible to do so, the average melilite individuals being too small and the mineral being impure on account of the presence of inclusions and decomposition products. The melilite is well seen only in sections of the fresh rock, when the rock is decomposed to any considerable extent the mineral is replaced by alteration products and no longer

easily recognizable. When a portion of the groundmass is finely powdered and boiled for a short time with hydrochloric acid a slight gelatinization can be observed sufficient to cause the powder to adhere to the sides of the tube but not sufficient to make a jelly. When a section is treated with hydrochloric acid and then with fuchsine the melilite is seen to be distinctly stained.

*Nepheline.*—In addition to the melilite and in much smaller amount, there is in many sections a clear colorless mineral occurring in little corners in the groundmass which resembles the melilite, but seems to have a much lower index of refraction and never shows "peg structure." This is probably a little nepheline, but after carefully studying a large number of thin sections no positive proof on this point could be obtained as the mineral has not a good crystalline form. The other constituents of the rock exhibit no peculiarities deserving of further mention.

The order of crystallization of the principal constituents is as follows: First, the magnetite, then olivine, biotite and pyroxene of the first generation in the order named, then probably another generation of olivine, followed certainly by a second generation of pyroxene and biotite while the melilite has crystallized last of all.

The secondary minerals filling the cavities before mentioned are quartz and calcite. The former mineral is represented for the most part by microcrystalline and cryptocrystalline varieties. The calcite occasionally shows excellent pleochroism, yellow and colorless. A little opal and a small quantity of some zeolite are probably also present in a few cases. These are not primary but true secondary cavities eaten out of the various constituents of the rock.

This alnoite from Ste. Anne differs from the original alnoite from Alnö, in containing much more olivine and in being free from plagioclase, a mineral which can be frequently observed in sections of the Alnö rock. Otherwise they resemble one another very closely. Although there is no way of ascertaining the age of this dike it is probably connected with the great volcanic center at Montreal which constitutes the elevation known as Mount Royal, from which the city takes its name. This is formed of a theralite, cut through by a later eruption of elaeolite syenite, both rocks breaking through and altering the Trenton limestone of the vicinity, the whole being traversed by several series of dikes, tinguaites, bostonites and other rocks to which a definite name cannot at present be given but which probably originally held some melilite although they are now as a general rule much altered. Dr. Harrington has been for several years collecting material and data for an accurate description of the whole complex and we hope before long to have the work sufficiently advanced for publication. The present paper may be considered as a first contribution toward an accurate knowledge of these rocks.

McGill University, Montreal.

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ART. XXXIV.—*On an Azure-blue Pyroxenic Rock from the Middle Gila, New Mexico*; by GEORGE P. MERRILL and R. L. PACKARD.

AMONG a lot of ores and other materials donated to the Museum some months ago by Prof. J. H. Huntington then at Silver City, New Mexico, was a hand specimen of a finely saccharoidal rock of a beautiful light azure-blue color with spots of serpentine, and which was stated to have come from a point on the Gila River some 40 miles west of that city. The striking beauty and color of the rock at once excited our interest, and arrangements were made for analysis and microscopic study. Meanwhile business called Mr. Merrill to Silver City, and while there he took pains to visit the locality and learn for himself the source and geologic character of the rock. The results of our combined investigations are given in the following notes.

In the field the rock was found to occur in sporadic nodular masses of rarely 100 pounds weight, imbedded in a granular crystalline serpentinous limestone which in the form of a nar-

row, nearly vertical bed, enclosed between granitic and basic eruptives, forms a continuation of the peculiar banded serpentinous rock commercially known as *nicolite* and which has been put upon the market as an ornamental stone.

Under the microscope, in thin sections, the rock is seen to consist wholly of short and stout colorless granular pyroxenes interspersed with occasional small areas of interstitial calcite. None of the pyroxenes show idiomorphic forms but the structure is eminently granular, the individual crystals varying in size up to 1 mm. in greatest length. Cleavage is very poorly developed, but an occasional basal section shows a nearly rectangular parting and gives a biaxial interference figure with the optic axis lying in the plane of symmetry. The blue color so striking in the hand specimens is naturally quite lacking in the section, nor is there evident pleochroism. As is often the case with rocks of this class a serpentinous alteration has set in giving rise to a beautiful compact oil-yellow and greenish serpentine with the liberation of abundant free calcite, but so far as observed no chalcedonic or other form of free silica. The absence of secondary silica in alterations of this kind, has been noted by Mr. Merrill in previous papers,\* as in marked contrast with serpentines resulting from the alteration of rocks of the peridotite group which are nearly always traversed by strings and veins of chalcedony.

A piece of the blue rock free from serpentine was pulverized, treated with warm hydrochloric acid to remove calcite and then boiled in an alkaline carbonate. The analysis gave:

		Molecular ratio.
SiO <sub>2</sub> .....	54.30	.905
MgO .....	18.33	.458
FeO .....	1.11	.015
CaO .....	25.00	.446
	98.74	

This reduces to the formula,  $\text{CaMgSi}_2\text{O}_6$ , which is that of malacolite.

The striking blue color of the mineral would appear to be due wholly to iron protoxide as careful tests fail to indicate the presence of other metallic substances nor is the color changed by the action of strong acids or moderate heat.

National Museum, Feb., 1892.

\* On the Serpentine of Montville, New Jersey. Proc. United States National Museum, 1888, p. 105; Notes on the Serpentinous Rocks of Essex Co., New York, etc., *ibid.*, vol. xii, 1889, p. 595; and On the Ophiolite of Thurman, Warren Co., New York, this Journal, vol. xxxvii, March, 1889, p. 189.

ART. XXXV.—*On the Correlation of Moraines with Raised Beaches of Lake Erie*; by FRANK LEVERETT.

THE observations recorded in this paper, and its accompanying maps, were made for the United States Geological Survey during the field seasons of 1889, 1890 and 1891, and are here published by permission, in advance of the official report. In the prosecution of the work I have had the constant supervision of Pres. T. C. Chamberlin to whose guidance in the study of the glacial phenomena I am greatly indebted. I have also received valuable suggestions from Mr. G. K. Gilbert which have been of service in the study of the beach lines.

Before entering upon the discussion of the beaches and their correlative moraines a few remarks are necessary as to the evidences of lakes or inland seas in the drift covered portions of Ohio, south of the well defined beach lines, during the closing stages of glaciation. In early publications on the drift of Ohio, and also of adjacent States, glacial phenomena such as osars, kames, moraines of gravelly constitution, and overwash gravel aprons bordering moraines, were appealed to in support of a hypothesis of submergence of the land during the closing stages of the glacial epoch, and a recent publication in this Journal includes with the beaches of Michigan, certain moraines and their overwash gravel aprons.\* That such phenomena do not demand a submergence is now quite generally conceded by glacialists, and in the district in question they have been found to be independent of lacustrine conditions.

Throughout the part of Ohio along and south of the continental watershed, and in northern Indiana and southern Michigan where these deposits of assorted drift occur, the moraine-headed terraces, which follow the principal streams, show clearly that the land had such an altitude at the time the ice was forming its moraines as to afford good drainage for the waters issuing from the ice margin.

Instead of a depression of the land in the later episodes of the drift deposition in the eastern Mississippi basin, such as is taught by the early writers, there was a greater altitude than in the earlier stages. This subject has been thoroughly considered by Pres. Chamberlin in a paper before the A. A. A. S. at the recent meeting in Washington, and his paper is already published in full in the *American Geologist*.†

\*High Level Shores in the region of the Great Lakes and their Deformation, J. W. Spencer, this Journal, March, 1891, pp. 209-10.

†The altitude of the eastern and central portions of the United States during the Glacial Period, T. C. Chamberlin, *Am. Geol.*, Nov., 1891.

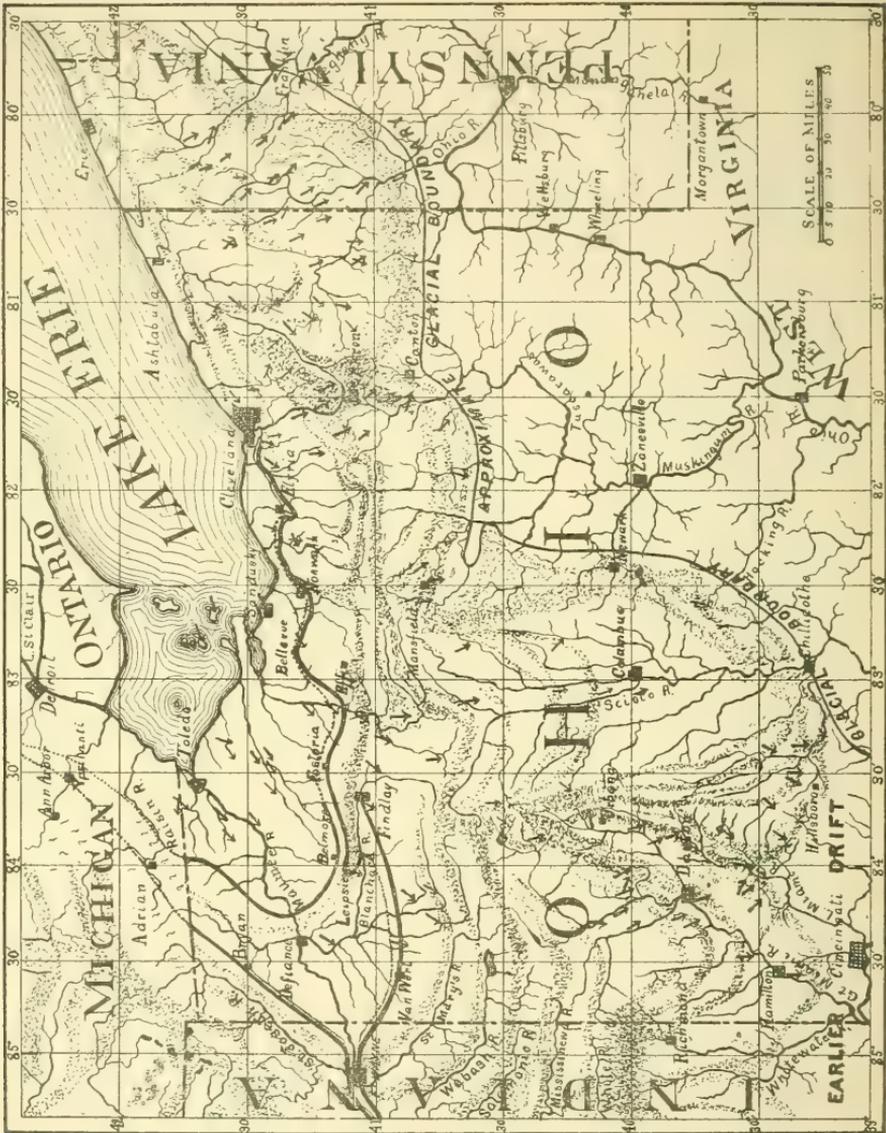


FIG. 1. Map of the Western Erie Basin and Adjacent Territory.

*Explanation of Map.*—The shaded portions represent moraines. Their mapping is incomplete in southeastern Michigan. Interrogation points are used to indicate the probable position of moraines not yet traced. Striae are represented by arrows and indicate the general divergence from the axes of the ice-lobes. The continuous lines around the western end of the Lake Erie basin represent the beaches which have been traced. The dotted lines represent their conjectured continuation. The lower beaches (between the Belmore and the present beach) are omitted. There are usually two well defined ones, throughout the portion of the basin shown on this map but their distribution is accurately known only in the eastern portion of the basin. The "Earlier Drift" area in the southwest corner of the map lies outside the moraines of the later ice-invasion. The glacial boundary is probably less regular than indicated by the line on the map. The drift is too thin and discontinuous near the margin of the glaciated district to admit of exact mapping of the boundary.

It is a common belief that when the ice-sheet had made its final retreat to the slope north of the continental watershed in Ohio, even though the altitude remained high, lakes would be formed in front of it which would stand at a higher level than the Ft. Wayne outlet, and discharge through passes in the watershed at altitudes as great as 350 to 400 feet above Lake Erie. Dr. Newberry speaks of these passes as water-gaps and waste weirs.\* Prof. E. W. Claypole has indorsed this view and carried the idea further by outlining on a map several theoretical lakes on the north slope of the watershed.† The studies of the past season do not, however, support this mapping. The actual outline of the ice-margin at that stage in its retreat is far from coincident with Prof. Claypole's theoretical outline. It will be seen from the moraines shown on the accompanying map (fig. 1) that as soon as the ice had withdrawn from the watershed in northern Ohio it had withdrawn so far in northwestern Ohio that there was adequate outlet for the discharge of its waters past Ft. Wayne down to the Wabash river. This outlet being much lower than the passes on the watershed eastward from there, the necessity is removed for the existence of extensive lakes at levels sufficiently high to discharge through these passes. It is true that quite heavy deposits of silt occur in the Cuyahoga valley and slight deposits in the valleys which lead to Lake Erie west from that valley, but they are all of earlier date than the latest of the ice advances. While examining the Cuyahoga valley I was accompanied by Prof. Claypole who recognized, with me, as *glacial* the deposits that cap the silts along the valley. The glacial deposits referred to consist of till along the greater part of the valley, but west of Akron they consist of gravel. The till is aggregated in places into morainic ridges and knolls, and the outer of these ridges has an overwash gravel apron leading from it across the watershed to the Tuscarawas valley, and that too where there are deposits of silt 100-200 feet or more in thickness below both the till and the gravel. This is a clear indication of the presence of land ice in these valleys subsequent to the deposition of the silts. The probable age and conditions of deposition of these silts constitute a question of much interest, but beyond the scope of this paper, since it does not pertain to the closing stages of glaciation.

The result of investigation has been therefore to reduce the noteworthy lakes connected with the closing stages of glaciation in Ohio to the one bounded by the beach lines which were recognized by the Ohio Geological Survey.

\* Geol. of Ohio, vol. i, pp. 43-45; vol. ii, pp. 46-48, 51-53.

† Lake Age in Ohio, E. W. Claypole, Trans. Edinb. Geol. Soc., 1887.

Some years ago Mr. Gilbert discovered that several of the raised beaches of Lake Erie do not completely encircle that body of water but terminate in a successive series from higher to lower in passing eastward from northern Ohio to southwestern New York. The results of his study are unpublished, but through his kindness I have been supplied with the principal data. In explanation of the termination of these beaches. Mr. Gilbert has entertained the theory that they represent successive positions of the ice-front in its northeastward retreat across the Lake Erie basin, but has held that the complete verification of this theory depends upon the occurrence of moraines which are demonstrable correlatives of the beaches. Such moraines have now been discovered and traced into connection with the eastern ends of the three beaches which terminate in Ohio. The glacial phenomena in the vicinity of the termini of the lower beaches (in southwestern New York) have not yet received attention.

The characteristics and limitations of the several stages of the lake whose presence is known by these raised beaches, are but partially determined, my investigations being confined to its south shore. The data already obtained are, however, believed to be adequate to show that the higher beaches are of the same age as certain moraines, and to warrant the conclusion that the higher stages of the lake occurred as a result of the occupancy of the eastern portion of the basin by the retreating ice-sheet.

The facts I wish to present are naturally grouped under three heads: (I) The Van Wert or upper beach and its correlative moraine the Blanchard ridge: (II) The Leipsic or second beach and its correlative moraine: (III) The Belmore or third beach and its correlative moraine. The names here adopted are those suggested by Prof. N. H. Winchell.\*

### *I. The Van Wert or Upper Beach and its Correlative Moraine.*

(a) *The Van Wert or Upper Beach.*—The distribution of this beach in Ohio and Indiana is well shown in maps published many years ago by Mr. Gilbert.†

From Mr. Gilbert's description in the *Geology of Ohio*, (pp. 549-550) we take the following account of this beach and the outlet of the lake.

"The Maumee valley is well adapted to the display of these beaches since on its easy slopes they are so broadly separated that they can be traced without confusion, and in its soft drift

\* *Proc. Am. Assoc. Adv. Sci.*, 1872, pp. 171-179. *Geol. of Ohio*, vol. ii, p. 56.

† *This Journal*, May, 1871, p. 341. *Geol. of Ohio*, vol. i, 1873, p. 540.

they were inevitably modeled at every stage of the water's lingering. Four shore lines above the present are distinguished. The first marks a water level at 220 feet, the second at 195 feet, and the third at 170 feet above the Lake, while the fourth records a slow descent from 90 feet to 65 or 60.

West and north of the first beach—that is, above it—the Erie clay lies undisturbed, with the rolling surface it received from the unequal heaping of the iceberg loads of which it is largely composed. Upon such a surface the result of shore action could not escape notice, and the evidence of its absence is not merely negative in its character. I feel warranted in saying that from the northwest corner of the State to the upper beach (a horizontal distance of twenty miles with a fall of 200 feet), the waters of the glacial sea did not linger in their descent.

The Upper Beach consists in this region of a single bold ridge of sand, pursuing a remarkably straight course in a northeast and southwest direction, and crossing portions of Defiance, Williams and Fulton counties. It passes just west of Hicksville and Bryan; while Williams Centre, West Unity and Fayette are built upon it. When Lake Erie stood at this level it was merged at the north with Lake Huron. Its southwest shore crossed Hancock, Putnam, Allen and Van Wert counties, and stretched northwest, in Indiana, nearly to Fort Wayne. The northwestern shore line, leaving Ohio near the south line of Defiance county, is likewise continued in Indiana, and the two converge at New Haven, six miles east of Fort Wayne. They do not, however, unite, but instead, become parallel, and are continued as the sides of a broad water-course through which the great Lake basin then discharged its surplus waters southwestward into the valley of the Wabash river, and thence to the Mississippi."

In so far as it deals with *phenomena* the above description is graphic and valuable for our purpose, but the references to glacial seas and iceberg drift the author himself would doubtless throw out were he to revise his paper. Whether or not this glacial lake was merged with Lake Huron at the time this beach was forming is, I think, undetermined, since the moraine that lies between it and Lake Erie has not, so far as I am aware, been traced through southwestern Michigan. It is quite possible that the ice-sheet occupied the Lake Huron basin at the time as it is known to have occupied the Lake Erie basin. In that case the two basins would not have been united by lake water to the extent suggested by Mr. Gilbert.

Tracing the Van Wert ridge westward to the outlet from its eastern terminus near Findlay, we find it passing through the following villages and cities in the order named: Findlay,

Benton Ridge, Webster, Pandora, Columbus Grove, Alnora, Delphos, Middlepoint and Van Wert, Ohio, and through Zulu P. O., Indiana, to the outlet at New Haven. The north shore, according to Mr. Gilbert's tracing, leads northeast from New Haven, Indiana, and passes just west of Hicksville and Bryan, Ohio. Dr. J. W. Spencer identifies it in Michigan at Adrian, Ypsilanti and Berville.\* It is not improbable, however, that this beach terminates before reaching Ypsilanti and if so correlation should be made there with the second beach.

Mr. Gilbert's estimate of the height of this beach is based upon its altitude where crossed by the L. S. & M. S. R. R. near Bryan,† where it is about 220 feet. The altitude is slightly lower along the south shore than at Bryan, as shown by several independent railway surveys. It is evident, however, from the variations displayed by these surveys that accurate leveling and a critical study of the beach with reference to its usual stage of water will be required, before any conclusions can be drawn as to differential crust movement between Findlay and Fort Wayne. The beach here apparently stands about 210 feet above Lake Erie. In the table given below, the lower altitudes are slightly below the usual stage of water. In Michigan there is, according to Dr. Spencer, a marked northward differential uplift between Ypsilanti and Berville.

*Table of altitudes along the Van Wert Ridge.\**

\*The altitude above Lake Erie is 573 feet above tide.

Stations.	Altitude Ab. Lake Erie.	Remarks.
Findlay, O., L. E. & W. R. R.	209 feet.	Vol. vi, Geol. of Ohio.
" " " "	205 "	Dict. of Altitudes.
Pandora, O., P. A. & W. R. R.	202 "	Taken from profile.
Columbus Grove, O. " "	202 "	" " "
Alnora, " " "	203 "	" " "
Delphos, " " "	214 "	" " "
" Miami canal.	211 "	Dict. of Altitudes.
" P. F. W. & C. R. R.	208 "	Surface of Miami canal.
Middlepoint, O. " "	211 "	Vol. vi, Geol. of Ohio.
Van Wert. " " "	211 "	Dict. of Altitudes.
New Haven, Ind. (beach S. of),	205 "	Bar. from N. Y. C. & St. L. R. R.
Bryan, Ohio, (ridge W. of),	220 "	From profile L. S. & M. S. R. R.
Adrian, Mich.	216 "	Am. Journ. Sci. (Spencer.)
Ypsilanti, " (terrace)	211 "	" " "
Berville. " "	244 "	" " "

The Van Wert ridge so far as I have examined it consists in the main of a deposit of sandy gravel though for considerable distances it presents only a wave-cut bench free from gravels. It is not a strong bench, its usual height being 3-5 feet and its breadth but 10-12 rods. Occasionally, however,

\* This Journal, March, 1891, p. 209.

† This Journal, May, 1871, p. 343.

opposite the place where streams tributary to the lake had their *debouchure*, it is much larger, standing 12–15 feet above the plains either side of it and having a breadth of 20–40 rods or even more.

The beach apparently terminates at a cemetery near the south bank of Blanchard river in the western part of Findlay. It is here in the midst of a plain that rises gradually toward the north, the east and the south, so that the lake at its eastern terminus was a mere point and its waters quite shallow. The beach is about as well developed at its eastern terminus as it is, on the average, west from there, so there is no difficulty in tracing it. Along the north side of Blanchard river, west from Findlay, no well defined beach of corresponding age with the Van Wert ridge appears. It is evident that the plain between the river and the Blanchard moraine was submerged, for it is coated in places with sand and gravel, and much of it is as low as that between the river and beach on the south. Sand also sets in on the outer (south) slope of the Blanchard moraine, a few miles west from Findlay, and reaches altitudes as great as on the beach south of the river, but I could trace no shore lines.

The strength of the beach at its eastern terminus raises the suspicion that the ice may have been more remote when the principal work was done on the beach and afterwards re-advanced to the position indicated by the moraine, for the water between the beach and the moraine constituted a narrow pointed bay and as a rule the beach following the side of such a bay is not as strong as the beach facing a broad sheet of water. However no conclusive evidence of such a re-advance of the ice-sheet was discovered. The phenomena along the moraine as shown below seem to indicate that the ice-sheet overhung it while the lake was still occupying the Van Wert beach and thus prevented the waves of the glacial lake from making their impress on the moraine.

(b) *The Blanchard Moraine.*—The Blanchard is the latest moraine of the series in Ohio that can be traced around the western end of Lake Erie. Its course may be seen on the accompanying map (fig. 1). Westward from Findlay the moraine is on the whole a less conspicuous feature than eastward from that city, but may be easily traced in a curving course northwestward to the Maumee just below Defiance, and thence north into Michigan. The portion of it west from Findlay was discovered and mapped by Mr Gilbert more than twenty years ago.\* It is therefore one of the earliest recognized moraines on this continent.

\* This Journal, May, 1871, pp. 339–342.

The moraine rises and falls in its course across Ohio showing but little dependence upon levels, though there is usually a slight southward curve at the lowlands and a reëntrant or northward curve on the highlands crossed by it. The following table of altitudes will illustrate its great range. It embraces the portion between the Maumee river and the interlobate tract in Geauga county, Ohio.

*Table of Altitudes along the Blanchard Moraine.*

Stations.	Altitude A. T.	Remarks.
Near Defiance,	730 feet.	Wabash R. R. profile.
Pleasant Bend,	742 "	T. St. L. & K. C. profile.
Summit S. of Leipsic,	780-85 feet.	Bar. from W. Leipsic.
Summit S. of McComb,	795-800 "	" " McComb.
Summit N. of Findlay,	840-850 "	" " Findlay.
Alvada,	850 "	Geol. of Ohio, vol. vi.
Sandusky river bluff,	830 "	Bar. from Tiffin.
Near Rockaway,	900 "	Bar. from Attica.
Attica, B. & O. R. R.,	963 "	Dict. of Altitudes.
Near Chicago Junction,	950 "	Bar. from Chicago Junct.
Near New London,	1050 "	" " New London.
2 mi. N. E. of Troy (Nova P. O.),	1182 "	Pre. Surv. P. A. & W. R. R.
Lodi,	910-925 "	Bar. from station.
Chatham (1 mi. N. of Center),	1120 "	Bar. from Litchfield Sta.
Near Medina,	1100 "	" " P. A. & W. R. R. Sta.
Near Remson's Corners,	1200 "	" " Medina.
Cuyahoga river bluff,	950 "	" " Peninsula.
Eastern Cuyahoga and western Gauga Counties,	1000-1250 "	" " various stations.

From the interlobate tract in Geauga county westward to a few miles beyond the meridian of Findlay this moraine, in its topography and general appearance, is like other moraines south of it, consisting of a broadly ridged and slightly undulating tract of till standing 20-40 feet or more above the plain south of it, and having a breadth of  $1\frac{1}{2}$ -3 miles. Near the meridian referred to it assumes a very different appearance having a knob and basin topography of subdued type in which knolls of conical form rise abruptly 5-10 feet and cover an acre or less each, and among which are sharp basins occupying usually but a small fraction of an acre each, though frequently several feet in depth. The crest of the moraine is no longer well defined though it continues to be a watershed between tributaries of the Maumee all the way to that stream near Defiance. On the accompanying map (fig. 2) an attempt is made to represent this change in the topography.

The structure presents as marked a change as the topography. Instead of a uniform deposit of till at the surface there is a variety of formations remarkable for the abruptness of their alternations. In one knoll a fine sand may occur

while its neighbors are composed of clay, or a portion of a knoll may be sand and the remainder clay, the whole being molded together into a symmetrical knoll like the gravel and till in ordinary kames. A few knolls contain gravel but as a rule pebbles are rare and no surface boulders or large pebbles are observed. The clays are very calcareous and abound in nodules in nearly every exposure. This variable structure characterizes the superficial portion of the ridge only. At a depth of about 15 feet stony till sets in which does not differ perceptibly from that in the portion of the moraine further east which was formed above the level of the lake water.

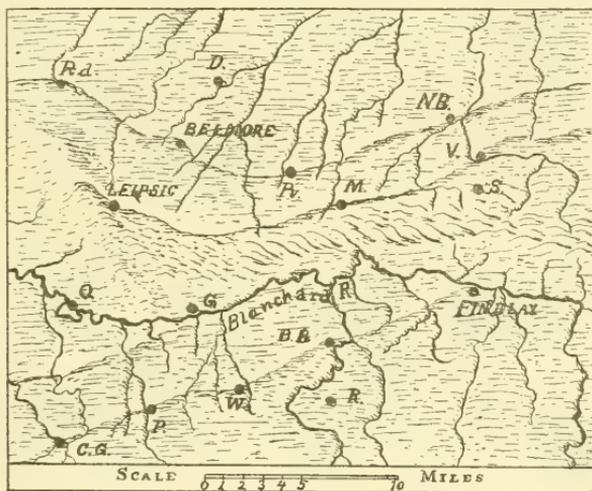


FIG. 2. Map of a portion of Hancock, Putnam, Henry and Wood Counties, Ohio, showing the junction of the Van Wert beach and its correlative, the Blanchard moraine

*Explanation of Map.*—An attempt is made to represent the topography graphically, the beaches being indicated by steps or benches cut in the plain, and the moraine by curved lines representing its billyowy and irregular surface. The letters indicate villages and cities as follows: (Rd.) Ridgeland; (D) Deshler; (NB.) North Baltimore; (V) Van Buren; (S) Stuartville; (M) McComb; (Pv.) Pickensville; (O) Ottawa; (G) Gilboa; (CG) Columbus Grove; (P) Pandora (Pendleton); (W) Webster; (R) Rawson; (BR) Benton Ridge.

Such is the character of the moraine for a distance of ten or twelve miles. About three miles northwest from Leipsic the Leipsic or second beach crosses the moraine and from there northwestward the moraine has a comparatively smooth surface the result of wave action subsequent to the retreat of the ice.

The portion of the moraine of especial interest is the knob and basin tract, above described. If my interpretation be cor-

rect this owes its peculiar topography and structure to the presence of lake water beneath the ice-margin. This portion of the moraine has an altitude but slightly below the level of the Van Wert beach, consequently the water was shallow and incapable of buoying up the ice-sheet and producing icebergs. The result was what might be anticipated under such conditions of deposition, a variable structure produced by the motion of waters under the edge of the melting ice-sheet, and an uneven surface molded by the inequalities of its base and margin. It may be suggested that the moraine received its sandy deposits from a lake that covered it after the ice had retreated. It seems improbable, however, that such was the case, (1) because the sandy deposits are not in the form of a beach nor in any way connected with a well defined beach, but are in sharp knolls similar to the clay knolls of the moraine; (2) because the sand in places graduates into clay of glacial origin showing contemporaneous deposition with it; (3) because the basins and depressions are so sharp and of such a form and arrangement as to forbid the idea that the wave action had been long exerted on them; (4) the portion of the moraine northwestward from where the Leipsic beach crosses affords a clear illustration of the effect of an open lake on the moraine, its surface being smooth and its sand either a uniform coating or aggregated into forms clearly referable to wave or wind action. It is fortunate that the lake in its later stages fell short a few feet of reaching its earlier maximum stage and thus left unmodified a portion of what appears to be a lake-deposited moraine. So far as I am aware no cases of a moraine demonstrably formed in lake water have been reported from other parts of the glaciated district, but it is not improbable that other instances will be found when attention is directed more closely to this subject, if they have not already been observed by other students. It is quite probable that in portions of this moraine farther north, there will be found other places similar to that just described. My studies were not carried north of the Putnam and Henry County line.

Summing up the phenomena of this district it appears (1) that the Van Wert ridge terminates near Findlay, Ohio, and that east from there the Blanchard moraine is its correlative; (2) that the Blanchard moraine from near the meridian of Findlay northwestward, was deposited in lake water. The beach as well as the morainic phenomena therefore support the hypothesis that the lake bounded by the Van Wert beach was of *glacial* age.

## II. The Leipsic or Second Beach and its Correlative Moraine.

(a) *The Leipsic or Second Beach.*—From the meridian of Findlay eastward to its eastern terminus at North Linndale there is no beach higher than the Leipsic, but from that meridian west this beach stands second in the series. Careful search between Findlay and North Linndale not only failed to reveal a beach outside of this one, but convinced me that no effective wave action was there exerted, there being present in large numbers the small knolls of till and other irregularities of contour produced by the glacier which would have been rendered obscure and perhaps effaced had there been wave action on it for any prolonged period. Moreover, no deposits of sand, gravel, or silt were observed that could be referred to lake action.

Tracing the beach from its eastern terminus westward it leads us through the following cities and towns in the order named: North Linndale, Rockport, Fields Corners, La Porte, Carlisle Center, South Amherst, Axtell, Berlin Heights, east part of Norwalk, Pontiac, Bellevue, Lowell, Tiffin, Bascom, Fostoria, Van Buren, McComb, Leipsic, and West Leipsic. From McComb to West Leipsic the lake washed the north slope of the Blanchard moraine. About three miles northwest of West Leipsic the beach crosses the moraine and swings south following nearly the southwest or outer border of the moraine to the Blanchard river at Crawfis college, just below Gilboa. From Blanchard river it is reported to pass south of west leaving Ottawa about three miles to the north, but I have not traced it beyond that stream. This beach is probably the correlative of Mr. Gilbert's second beach that passes through Hicksville and Bryan, Ohio.

*Table of Altitudes along the Leipsic Beach.*

Stations.	Altitude Ab. L. Erie.	Remarks.
North Linndale, C. C. C. & St. L. R. R.	196 feet.	Notes from Chief Engineer.
Rockport, L. S. & M. S. R. R.	200 "	From profile.
2 miles E. of Shawville.	200 "	L. S. & M. S. profile.
Carlisle Center.	204 "	Geol. of Ohio, Vol. II.
Huron County Infirmary.	203.5 "	Notes from County Surveyor.
Pontiac, B. & O. R. R.	190 "	Top of beach, 195 feet.
2-4 miles E. of Bellevue.	208-12 "	L. S. & M. S. profile.
2 miles W. of Bellevue.	208 "	" " "
Tiffin.	210 "	Bar. from B. & O. R. R.
Bascom, B. & O. R. R.	209 "	Top of beach 215 feet.
Fostoria, L. E. & W. R. R.	209 "	Geol. of Ohio, Vol. VI.
Van Buren, T. & S. R. R.	209 "	" " " "
McComb, N. Y. C. & St. L. R. R.	195 "	Notes from Chief Engineer.
West Leipsic, " " "	192-5 "	" " " "
Crawfis College, F. Ft. W. & W. R. R.	197 "	" " " "
Hicksville, B. & O. R. R.	188 "	Dict. of Altitudes.
Bryan, L. S. & M. S. R. R.	191 "	" "

The principal embayments in the ancient shore are at Black, Huron and Sandusky rivers. At Vermillion river there was scarcely any embayment. These embayments do not owe their existence to different rates of erosion of the shore under wave action, but were probably produced by the ice-sheet previous to the occupancy by the lake, the effect of the ice-sheet being to broaden the mouths of old valleys which it entered. The lake nowhere cut back its shore a mile, and usually but a few rods while it occupied this beach, as may be determined by a restoration of the original slope on which it was carved.

It is not improbable that the terrace noted by Dr. Spencer at Ypsilanti, Michigan, should be correlated with the second beach instead of with the Van Wert ridge, for the next lower beach observed by him near that city is below the level of the Leipsic beach, the altitude being but 161 feet above Lake Erie or about the altitude of the third or Belmore beach of north-western Ohio. If the Ypsilanti terrace proves to be the correlative of the second beach there is a differential uplift of 20 feet between Bryan and Ypsilanti, a distance of about 50 miles.

Certain altitudes in the above table will no doubt raise the question as to the possibility of correlating this beach with the Van Wert ridge. From Van Buren to Bellevue it has apparently as great an average altitude as the Van Wert ridge. Since the stations included between these towns have altitudes obtained from several independent surveys and show essential harmony it is unlikely that they contain great errors or exaggerations of the altitude of the beach. A beach formed subsequent to the retreat of the ice, as the Leipsic beach was, cannot be correlated with one formed while the ice-sheet still occupied the Blanchard moraine. Reasons have already been given for considering the Van Wert ridge the correlative of the Blanchard moraine, and to my mind they hold good even though portions of the Leipsic beach be as high as the Van Wert ridge. The Leipsic beach certainly fluctuates in altitude. I have followed it continuously from Van Buren to McComb and made certain that it represents but a single stage of the lake; yet there is a difference of 14 feet in the altitude of these stations (seven miles apart). The altitudes being obtained by independent surveys it is possible that a portion of the difference may be due to their not checking in their results, but probably only a small portion. A study of the profiles of the L. S. & M. S. R. R. reveals the fact that the beach is at least 10 feet higher at Bellevue than it is between Cleveland and Elyria, and its survey is carefully checked since it comes down nearly to lake level both at Sandusky and Cleveland. It is, therefore, well established that in the vicinity of Bellevue the beach has suffered a slight differential elevation. This elevation may

cover the whole interval from Bellevue to Van Buren where the table shows its highest altitude to be.\*

The general appearance of this beach is much like that of the Van Wert, though it is on the whole somewhat stronger. Throughout much of its course it stands 6-8 feet above the plain north of it, and in places 15-20 feet. In the vicinity of Vermillion river and thence west nearly to Norwalk, and again in the cape-like projection in the vicinity of Bellevue it is quite sandy, but as a rule it contains but little sand. In pits at Bascom, a village between Tiffin and Fostoria where the beach attains the extraordinary height of 215 feet above Lake Erie, the gravel contains a remarkably large percentage of angular or but slightly worn pebbles, and elsewhere along the beach the rounding of the pebbles is slight compared with that in the present beach of the lake. This beach, in common with the upper and third beaches, contains much poorly assorted material and where the deeper parts of the beach contain well assorted gravel, there is usually a capping of clayey gravel two feet or more in thickness in which boulders are sometimes imbedded. The beaches were apparently short lived and rapidly formed otherwise the pebbles would be more water worn and the clayey ingredients less conspicuous. It is not improbable that throughout much of the year the borders of the lake were fringed with floe ice and the presence of boulders in the beaches may be due to this agency.

The view that the waters of the lake at the time it occupied these raised beaches were cold, seems sustained by the extreme rarity of the remains of Molluscan life in its beaches. Careful observation and inquiry while on the ground failed to bring to light any evidence of such life, but after leaving the field I was told by a farmer who formerly lived on the upper beach a few miles east from Van Wert that he had seen "clam shells" in its sands. This observation needs verification, however, by some competent student before much weight can be attached to it, for untrained observers often call the brachiopod shells of the quarries "clam shells." These beaches contain such shells that were washed up from the glacial drift, which includes material derived from the neighboring rock formations. Since the absence or scarcity of fossils is not always due to the

\*This portion of the beach characterized by high altitudes, is on the crest and eastern slope of the "Cincinnati axis," which leads from the Ohio river near Cincinnati northerly across the western part of Lake Erie, (Geol. of Ohio, vol. vi, map opposite p. 48.) It will be a question of some interest to determine whether or not this coincidence is due to recent uplift of this axis. I have not sufficiently full data on the altitudes of lower beaches than the Leipsic to enable me to determine whether or not they also show a rise in passing over the Cincinnati arch. In case they do it is to be presumed that the arch has been slightly uplifted since the beaches were formed.

original absence of life but often to the lack of conditions for preservation, this evidence should be taken with caution.

Horns of elk and deer have been obtained from the Leipsic beach in the railway gravel pit near Crawfis college between Gilboa and Ottawa. They were imbedded in undisturbed beach gravels at a depth of eight or nine feet below the surface, and are therefore as old as the beach itself.

As previously stated, the Leipsic beach has its terminus at North Linndale. The beach here connects with the western end of a moraine. By reference to the accompanying map (fig. 3)

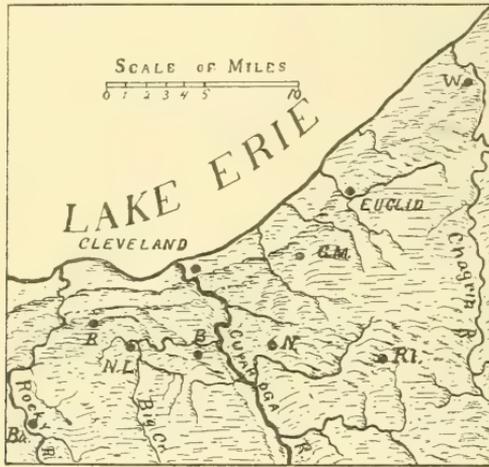


FIG. 3. Map of Cleveland and vicinity showing the junction of the Leipsic and Belmore beaches with their correlative moraines.

*Explanation of Map.*—The beaches are represented by a series of benches cut in the bluffs and plains. The Leipsic beach comes to the bluff of Big creek at North Linndale (NL) the Belmore beach near Brighton (B). The terraces in East Cleveland are to be seen between Newburg (N) and the Garfield Monument (GM). Two lower beaches are indicated. Their exact position in the city of Cleveland was not mapped but is probably within a mile of the position indicated in the map. These lower beaches alone occur east from Euclid. The moraines are indicated by curved lines representing the billowy and uneven surface which they present. The letters indicate villages as follows: (W) Willoughby; (GM) Garfield Monument; (RL) Randall; (N) Newburg; (B) Brighton; (NL) North Linndale; (R) Rockport; (Ba) Berea.

it will be seen that the beach just east of Rockport swings from a course north of east to a southeasterly course, and is there made up of a series of ridges of nearly uniform height which are united at the curving portion of the ridge but diverge into distinct ridges toward the southeast so that their ends are spread out over a space of nearly one-half mile. The outer ridge comes to Big creek bluff in North Linndale.

There is outside of these beach ridges a peculiar ridge which appears to be a compromise between a beach and a moraine. At its western end, near the inner bend of a tributary of Big creek, a mile or so west of North Linndale, it is composed of gravel and resembles in every way the beaches just north of it, but upon tracing it eastward the gravel changes to till, giving it the appearance of a low glacial ridge. This low till ridge may be traced through North Linndale to the bluff of Big creek near the bend of that stream, and upon crossing the creek we find a much larger ridge of till, one worthy the name moraine. This large ridge is separated from the eastern end of the beach proper by the narrow valley of Big creek, one fourth mile or less in width. I was unable to find beach gravel along the inner (north) slope of the morainic ridge farther east than the terminus of the beach ridge, but this inner border district is very flat and its clays contain few pebbles compared with the clays of the moraine. These features apparently indicate that the lake water covered the tract north of the moraine, either while the ice overhung it or subsequently.

From Newburg northward to the Garfield Monument there are two terraces along the east bluff of the Cuyahoga, which may possibly be correlated with the Leipsic and Belmore beaches. It is however doubtful if the correlation of the upper terrace with the Leipsic beach is legitimate, since the terrace stands slightly higher than the beach at its eastern terminus in North Linndale, being 210-220 feet above Lake Erie as determined by Dr. Newberry,\* while the Leipsic beach is but 196 feet. Dr. Newberry recognized the difficulty of making this correlation and suggested that the lower terrace which stands 165-170 feet above Lake Erie, is the correlative of the upper beach at North Linndale, "since a terrace is cut by shore waves somewhat below the water level, while on a gently inclined surface of loose material the waves raise a beach above the water" (p. 182). My examination of the upper terrace failed to disclose beach deposits on it or other decisive evidence that it was occupied by the lake, but the decision as to whether or not it is a lake terrace should be left to one more familiar than I with the various phases such terraces may present. Dr. Newberry suggests that the upper terrace may find its correlative west of the Cuyahoga in some undiscovered shore line south of the Leipsic beach, but since, as previously stated, the districts south of the beach do not afford distinct evidence of any such shore line, this view does

\* Geol. of Ohio, vol. i, pp. 181-182.

not seem to be sustained. I am inclined to correlate the lower of the two terraces, with the Belmore beach, since the altitude is not too great for that stage of the lake, and to leave the question open as to whether or not the lake extended back to the upper terrace at the time it was forming the Leipsic beach. That the lake at the time of the Leipsic beach did not extend farther east than Cleveland has been determined by Mr. Gilbert who has given the beaches of the eastern end of the Erie basin careful study.

(b) *The Correlative Moraine of the Leipsic Beach.*—This moraine as indicated above is traceable no farther west than North Linndale. Both north and west from there the surface, aside from the low beaches, is a monotonous plain with scarcely any undulation. The disappearance of the moraine at the point where the beach appears, leaves little room for doubt that the ice-sheet here terminated in a lake and that the beach is of glacial age. The portion of the moraine west of the Cuyahoga does not show evidence that it was deposited in lake water, on the contrary its structure so far as exposed opposes such a theory of deposition, the mass of the ridge being ordinary till without capping of sand or other water deposits. But since the descent is rapid toward the Lake Erie basin from the junction of the beach and moraine, there was sufficient depth of water to cause the ice-sheet to break up into bergs at its margin instead of resting upon the lake bottom and forming such a moraine as it did in the western Erie basin northward from the junction of the Van Wert beach and Blanchard moraine.

Tracing the moraine eastward we find it passing just south of the village of Brighton near which it is interrupted by the Cuyahoga valley. It reappears on the east side of the river in Newburg and is traceable from there eastward through Randall and Warrensville to the Chagrin river below Chagrin Falls. Its farther course may be seen on the general map (fig. 1). West of the Cuyahoga it is a single gently undulating ridge about 80 rods in width and 20–30 feet in height. East of the river it consists of many short ridges and conical swells 10–25 feet in height and has a width of 1–2 miles or more. In places there is a well defined crest but as a rule the crest is wanting.

The range of altitude is considerable. West of the Cuyahoga the moraine stands about 800 feet A. T. East of the river it rises from 800 feet at Newburg to 1050 feet at Randall (only six miles distant), and ranges up and down 200–250 feet in eastern Cuyahoga and Geauga counties in crossing ridges and valleys, its highest points being about 1250 feet A. T.

The thickness of drift as shown by its relief above border districts is only 20–30 feet, but spread out as it is over a width of 1–2 miles it represents a vast accumulation compared with that of the correlative beach. The moraine is composed principally of till, though in places it has gravelly knolls (kames). Pockets of gravel and sand occur in the till and beds of assorted material are occasionally interstratified with it. In short, the moraine in its topography, range in altitude, bulk and constitution, is so different from the beach that the two formations cannot be confused, and yet there seems to be no question that the moraine of the eastern Erie basin has, in the western Erie basin, a beach for its correlative.

### *III. The Belmore, or Third Beach, and its Correlative Moraine.*

(a) *The Belmore Beach.*—This beach was not traced continuously from Belmore to its eastern terminus, but standing as it does third in the series, and having an altitude about 30 feet below the Leipsic beach, there is but little possibility of error in correlation. From the Cuyahoga river westward it resembles the Leipsic beach so closely in size, form and structure that further description seems unnecessary. From Cleveland nearly to Tiffin it is seldom more than two miles from the Leipsic beach, and much of the way but a mile or less. From near Tiffin to Belmore it is 3–5 miles north of the Leipsic beach. Between Belmore and the Michigan line its course is directly away from the Leipsic beach, northwesterly, through Ridgeland, New Bavaria and Ayersville to the Maumee river at Independence, as indicated on Mr. Gilbert's map.\*

Beyond this stream its course is east of north into Michigan. In Michigan it is correlated by Dr. Spencer with the Ridge-way beach of that State.†

Careful leveling will be necessary to determine the amount and direction of deformation, if any has occurred along the Ohio portion of this beach, since it was formed. The few altitudes obtained show the beach to be between 160 and 170 feet above Lake Erie. The highest point known to me is at the crossing of the C. C. C. & St. L. railway between Cleveland and North Linndale where it is 170 feet, but there may be points further west equally high. Dr. Spencer's data indicate a northward rise in Michigan, the altitude east of Ypsilanti being 161 feet, at Berville 180 feet, and at Emmett 197 feet above Lake Erie.

This beach if my interpretation be correct is represented east of the Cuyahoga by the lower of the two terraces in the

\* Geol. of Ohio, vol. i, p. 548.

† This Journal, March, 1891, p. 207.

east part of Cleveland, previously mentioned, which stands about 165 feet above Lake Erie. From Cleveland eastward Mr. Gilbert has given the raised beaches of Lake Erie critical study and finds no beaches there that can be correlated with the Leipsic and Belmore beaches. Before discussing further the termination of this beach, it will be profitable to consider its correlative moraine.

(b) *Correlative Moraine of the Belmore Beach.*—There is along the south border of the Lake Erie basin from the eastern end of the lake, nearly to Cleveland, a well defined moraine which lies nowhere more than eight miles, and in places but two or three miles, from the present shore of the lake. It lies along the escarpment south of the lake, and occupies a belt a mile or more in width. Its inner border comes down to within 250–300 feet of the level of the lake, and is usually less than 100 feet above the highest of the raised beaches in that part of the lake basin. Its outer border varies greatly in altitude on account of the form of the escarpment along which it lies. In southwestern New York and northwestern Pennsylvania where the escarpment is abrupt it reaches altitudes nearly 1000 feet above Lake Erie, but in northeastern Ohio the outer border is but little above the inner. I have examined the moraine no farther east than Lake Chautauqua in southwestern New York. From Lake Chautauqua westward to Painesville, Ohio, some 30 miles east from Cleveland, the moraine exhibits considerable strength. It has a nearly continuous main ridge, on whose slopes and borders knolls are disposed in morainic fashion. From the vicinity of Painesville westward to its terminus the moraine is much weaker. It seldom has a well defined crest but consists of low knolls, isolated or in groups, among which are quite extensive nearly plane tracts. The moraine is traceable westward to Euclid, a small village about ten miles northeast from the center of Cleveland (see fig. 3). West from Euclid the old shores of the lake turn southward and cut off any continuation toward the west which the moraine may have had. The moraine is however so feeble at Euclid that it seems improbable that the ice-sheet extended much farther west at that time. This moraine along the shore of the lake basin is lateral rather than terminal to the ice-sheet, the terminal portion being in the midst of the lake basin. Judging from the feebleness of the moraine west of Painesville it is improbable that it has sufficient strength to be traceable on the lake charts across the lake bottom, and a moraine may not have been formed there, since the water was apparently of sufficient depth to break up the ice-sheet into bergs near its margin.

Parts of this moraine have been classed with the beaches by early writers.\* This confusion appears to have arisen mainly from the imperfect knowledge of the phases of structure which a moraine may present, especially in its gravelly and sandy portions, though in one of the instances above cited a large till ridge is called a beach. In the profile section from Lake Erie to Grand river (Geol. of Ohio, vol. ii, p. 62) the southernmost of the four ridges, there shown, is this moraine. The highest beach is there about 150 feet above Lake Erie while the moraine is 260 feet. The beaches are narrow ridges only a few rods in width, while the moraine has a width of one-half mile or more. The beaches are composed of sand and assorted material, the moraine of till, with occasional developments of gravelly knolls. In places in Ashtabula county the moraine and beach are closely associated, and beach sand appears on the moraine, but through much of its course in Ashtabula county as well as elsewhere the moraine is quite distinct from the beach and free from such deposits. Sand occasionally caps the moraine in places where it was not encroached upon by the beach, and that too at higher altitudes than portions not thus coated. In such cases it may have been drifted back from the shore by the wind. Some of it may however have been deposited by waters attending the melting of the ice-sheet, and be similar in origin to kames, rather than to dunes or beaches.

The Belmore beach has not been traced into close connection with this moraine, but if we consider the lower terrace in East Cleveland its correlative, the gap is nearly filled. In my opinion there is no objection to this correlation since the height of the lower terrace is slightly below that of the portion of the Belmore beach immediately west of the Cuyahoga, being about 165 feet, while the beach at the crossing of the C. C. C. & St. L. R. R. is 170 feet above Lake Erie. It seems therefore that in this, as in the next older moraine, a moraine of the eastern Erie basin, has in the western Erie basin, a beach for its correlative.

In the earlier beaches there is no question that the Lake Erie basin has a southwesterly outlet into the Wabash river, their altitude being slightly above that of this outlet, and the beaches being open there, but the Belmore and later beaches are below that level and do not open toward the outlet. We must therefore look elsewhere for their outlet. It is evident that it was not along the present route, nor by the Mohawk valley, since the ice-sheet filled at this time the western portion

\* Second Geol. Surv. Penn., Q<sub>4</sub>, pp. 38, 39. Geol. of Ohio, vol. i, pp. 488-90, 518; vol. ii, pp. 60-63.

and perhaps the whole of the Ontario basin and the eastern Erie basin. The only outlet remaining is through the Lake Huron and Lake Michigan basins to the Chicago outlet. The distance to which the ice-sheet had retreated in the Lake Erie basin seems to warrant us in believing that the Huron and Michigan basins may have been so far cleared of ice as to afford an outlet in this direction, either around the north end of the Southern Peninsula or across it via Saginaw Bay and Grand river valley.

#### *Summary and Conclusions.*

From the data above presented it appears that Lake Erie in its earlier stages was but a small body of water, its size being conditioned by the position of the retreating ice-sheet and by the height of the western rim of the basin it occupied. It at first occupied only a portion of the district between the outlet and the western end of the present lake, the remainder of the basin, including the whole of the area of the present lake, being occupied by the ice-sheet. Its south and north shores were then at the Van Wert ridge, while its eastern border was at the Blanchard moraine.

By a recession of the ice-sheet northeastward to about the meridian of Cleveland, the lake became much expanded and its level was lowered a few feet, though the outlet still continued down the Wabash. Its north and south shores then occupied the second or Leipsic beach, while on the east the waves beat against the ice front. The ice-sheet itself seems to have broken into bergs at its margin, and to have formed no terminal moraine at that time though its lateral moraine is well developed.

A subsequent recession resulted in the lowering of the lake below the level of the Ft. Wayne outlet probably by opening a passage to the Chicago outlet for no other outlets were open to this lake at that time through the Huron and Michigan basins. The north and south shores of the lake were then occupying the Belmore beach, while the east shore was unrecorded because the waves beat against a vanishing sheet of ice, and the ice itself, as in the preceding stage seems to have failed to form a terminal moraine, though its lateral moraine is strong.

From the phenomena attending the replacement of the three beaches in Ohio by moraines we are led to suspect that two later beaches which die away in southwestern New York are there connected with moraines, and that similar moraines will be found to connect with the beaches of Lake Ontario, at

points where they disappear on its eastern and northern borders.

Differential uplift was slight in the western Erie basin compared with what it was in the eastern Erie basin and the Ontario, in Michigan, and on the Canadian shores of Lake Huron and Georgian Bay. The data at hand indicate that it amounts to scarcely more than ten feet in the whole area of the portion of the Erie basin west of Cleveland, and has therefore played an insignificant part in causing the three stages of the lake herein described.

The bulk of the moraines is many times that of the beach deposits, though no longer time was involved in their deposition. The ice-sheet was therefore a much more efficient transporting agency than the lake waves.

The extreme scarcity of evidence of life in these waters, though negative in its nature, and therefore to be taken with caution, is quite accordant with the theory deduced from the relation of the beaches to the moraines, viz: that the beaches are of glacial age.

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ART. XXXVI.—*Magnesium as a Source of Light*; by  
FREDERICK J. ROGERS, M.S.

[Contributions from the Physical Laboratory of Cornell University, No. 9].

I.

*Quality of Magnesium Light.*

THE light produced by the combustion of magnesium is brilliantly white. It is whiter than the arc light and almost rivals sunlight itself. When the spectrum of the magnesium light is formed side by side with that of ordinary gaslight, the former is immediately seen to be relatively much stronger in the more refrangible rays. It gives a continuous spectrum, superimposed upon which are the ever present sodium lines  $D_1$ ,  $D_2$  and the magnesium lines  $b_1$ ,  $b_2$ ,  $b_4$  as well as four or five oxide bands.

In the experiments to be described in the first part of this paper the brightness of magnesium light in different parts of its spectrum was compared with the corresponding components of gaslight from an Argand burner by means of the "horizontal slit" photometer.\* This is a spectrophotometer movable along a photometer bar. It furnishes, side by side, spectra of the two sources of light to be compared, the two

\* Described by Dr. E. L. Nichols, in *Trans. Am. Inst. of E. E.*, vol. vii.

spectra being viewed in the usual manner by means of an observing telescope. The advantage of this form of spectrophotometer is that there is no polarizing device, equality of the particular portions of the spectra compared being obtained by movement along the photometer-bar.

The light to be studied was produced by the combustion of magnesium-ribbon  $2\frac{1}{2}^{\text{mm}}$  wide, supplied at a uniform rate by means of clock-work. The light was very variable, a fact which greatly increased the difficulty of determining its quality. Even when a diaphragm with an opening of  $2 \times 5^{\text{mm}}$  was placed immediately in front of the burning ribbon this variation in intensity was quite marked. The best that could be done was to take the mean of a large number of observations. The comparison was made at eight points very nearly equidistant in the normal spectrum. Five sets of observations were made making in all fourteen readings for each of the eight points in the spectrum. Table I gives the ratios, magnesium light: gaslight, reduced to unity at the D line, as obtained by taking the mean of these five sets of observations.

TABLE I.

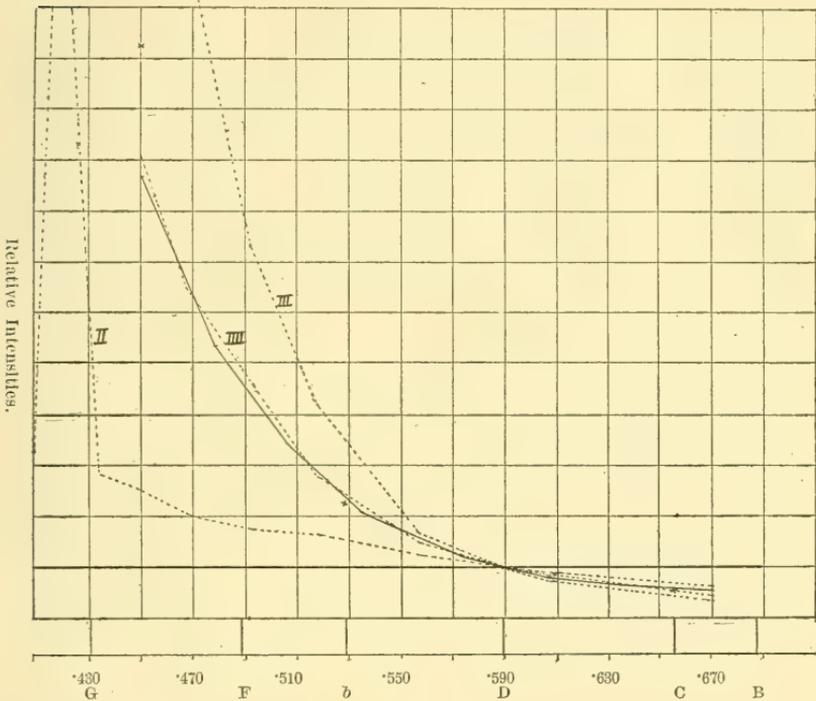
Wave-lengths.	Mg. light. gaslight.	Wave-lengths.	Mg. light. gaslight.
·450	8·77	·574	1·21
·479	5·33	·606	0·83
·506	3·43	·635	0·66
·536	2·07	·670	0·53

The full curve in fig. 1 represents graphically the relation between wave-lengths and relative intensity in the case of the magnesium light. The standard gaslight is arbitrarily taken to be unity in all parts of the spectrum. Curve II\*, fig. 1, represents the relative intensity of the arc light for different wave-lengths as obtained by Dr. Nichols in 1888. Curves III and IV, fig. 1, represent the relative intensity of daylight as compared with the standard. III represents daylight from a cloudless sky and IV, daylight from a heavily clouded sky. In the latter case the cloudiness happened to be just sufficient to make daylight almost identical in character with the magnesium light. For these dotted curves the standard light was a sixteen candle power incandescent lamp which, however was found to give a light nearly identical in quality with the light from an Argand gas burner. The stars in the figure for  $\lambda = \cdot656, \cdot527,$  and  $\cdot450$  represent the values for magnesium light obtained by Prof. Pickering in

\* This Journal, vol. xxxvii, p. 100.

1879.\* It will be seen that the results from Table I, are quite in accordance with those of that observer and sustain his statement that of all artificial illuminants the magnesium light approaches sunlight much more nearly than does any other.

1.



II.

*Temperature of Burning Magnesium.*

An important question in regard to the magnesium light is that of the temperature at which combustion takes place. Flame temperatures are not well known. Rossetti† has found 1350° for the hottest part of a Bunsen flame and 640° to 940° for a stearine candle flame. As I knew of no experimental data whatever on the subject of the temperature of burning magnesium, I attempted to measure it by means of the E. M. F. produced in a thermo-element composed of platinum and platinum-iridium, when the element was placed in the flame. A thermo-element of those materials had been previously cali-

\* Proc. Am. Acad. of Arts and Sciences, 1879-80, p. 236.

† Annalen der Physik, Beiblätter, I, p. 615, II, p. 333.

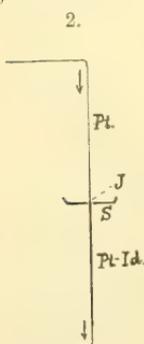
brated\* using as known temperatures the melting points of metals, for high temperatures,† silver 954°, gold 1035°, copper 1054°. As the melting point of copper is far below the temperatures to be measured it is necessary to prolong the calibration curve beyond the points determined by observation. But as this curve is almost exactly a straight line from 700° to 1050° it is probably safe to prolong it to, at least within 200° or 300° of the melting point of platinum.

It was soon found that burning magnesium almost instantly destroyed the small platinum wire used (.01 inch diameter), apparently by some chemical action, as there was no evidence of fusion. To determine the temperature in the ordinary way, by noting the permanent deflection of a galvanometer needle when the thermo-junction was held in the magnesium flame, was clearly impossible. To obviate this difficulty several indirect methods were employed, in all of which the temperature of burning magnesium was determined by comparison with other flame temperatures.

The temperatures of the flames to be used as standards in this work, were determined by the writer by means of the E. M. F. produced by them in the above mentioned thermo-junction. These flames were air blast flame, Bunsen flame, luminous gas flame (Bunsen burner with the air holes closed) and candle flame. In all cases the object was to get the temperature of the hottest part of the flame. No galvanometer readings were taken, until by repeated trial, the deflection was as great as could be obtained. The final results of three sets of observations are given in Table II.

Three methods employed in the estimation of the temperature of combustion of magnesium are described below.

*First method.*—The wire of the thermo-element was passed through a small hole in a porcelain screen which protected the junction as shown in fig. 2. The platinum-iridium wire was then heated as closely as possible to the screen by the different flames, including the magnesium flame and the corresponding galvanometer "swings" were noted. Three determinations by this method are given in Table II.



*Second method.*—It was found that after the platinum-iridium wire had been heated a short time by the magnesium-flame, a *negative* deflection of the galvanometer was obtained. An investigation proved that the burning magnesium formed a black compound with the wire and that this substance formed with the platinum-iridium a thermo-element whose

\* By Mr. Ernest Merritt in the course of an investigation not yet published.

† "Physikalische-Chemische Tabellen." Landolt und Börnstein.

E. M. F. was negative, the E. M. F. in the original element being considered positive. To eliminate this accidental E. M. F., the thermo-junction was made in the form of a **T** as in fig. 3 and the projecting portion which passed through a porcelain screen was heated as before by the different flames. Two determinations by this method are given in Table II.

*Third Method.* — In this case a rather large bead of metal was formed at the junction. The junction was then *directly* heated by the different flames, last of all by the magnesium flame, and the galvanometer "swings" were noted as before. The thermo-element was not so quickly destroyed as before; nevertheless, only one reading for the magnesium flame could be obtained before making a new junction. Two determinations were made by this method.

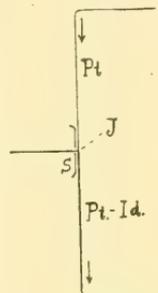
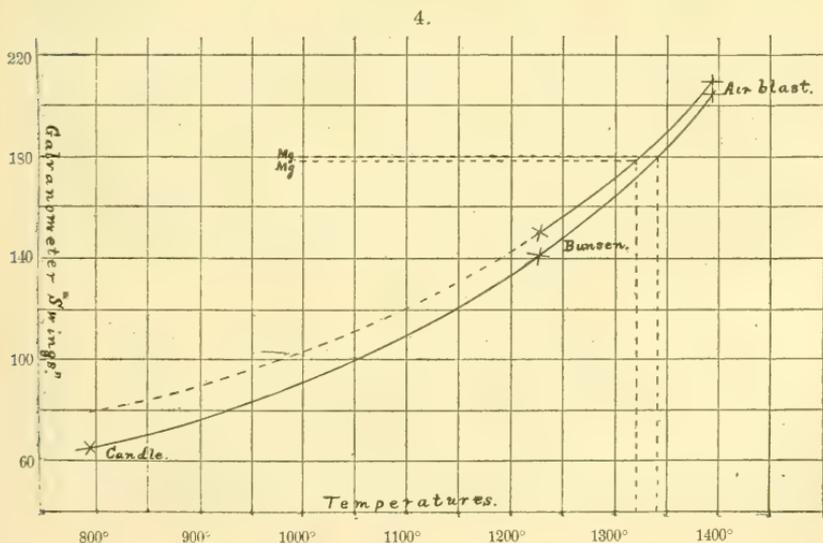


TABLE II.

Candle flame.	Luminous gas-flame.	Bunsen flame.	Air blast flame.	Method.	Magnesium flame.
827°	----	1227°	1398	First	{ 1345° 1375 1333° 1280
765	992°	1233	1382	Second	{ 1350 1333 1342
792	1018	1222	1404	Third	{ 1320 1345 1332

The values for the flame temperature of magnesium, given above, were obtained by a graphic method which is illustrated



in figure 4. The previously determined temperatures of the other flames were plotted as abscissæ and the corresponding galvanometer "swings" as ordinates. The ordinate on these curves, corresponding to the "swing" due to the magnesium flame was taken as indicating the position of that flame upon the curve. The abscissa reading of this point gave the flame temperature to be inserted in the table. In figure 4 are given the curves for the third method. The galvanometer "swings" for the same flame in the two cases were not exactly the same on account of the bead of metal at the junction being larger in one case than in the other.

Whatever question may be raised touching the accuracy of the absolute values of the above determinations of flame temperatures; there can be little doubt that they are relatively nearly correct; and we may be sure that the temperature of burning magnesium is a little below that of the hottest part of an air blast flame.

When the quality of the light from sources of different temperature is examined, it is almost uniformly found that the light from the sources of higher temperature is richer in the more refrangible rays. Prof. Pickering, in the course of the series of investigations on the quality of the light from different sources already cited, has made use of this fact to calculate flame temperatures. The following passage from his paper will serve to indicate the basis of his estimates: "Then if the temperatures we adopted were correct, this would give us a very simple empirical law, viz: The temperature is always proportional to some function of the ratio of any two assumed wave-lengths. For artificial sources for the wave-lengths  $\cdot585$  and  $\cdot455$  it varies directly as this ratio. . . . . Upon this principle the temperature of the magnesium-light, perhaps the highest terrestrial temperature we have yet attained, would be  $4900^{\circ}$  C." As direct measurement shows this estimate to be altogether too high, it might be inferred that the magnesium light, unlike that of most sources, is not solely due to incandescence, but that it is in part due to something like fluorescence by heating. Further evidence in favor of this view will be presented in the course of the following study of the efficiency of the magnesium light.

### III.

#### *Radiant Efficiency of Magnesium light.*

By radiant efficiency of a source of light I mean the ratio of *luminous energy* to total *radiant energy*. This ratio has often been rather ambiguously called, *net efficiency*.

The method employed for the determination of this ratio was to note the galvanometer deflections produced by the direct radiation of the source upon the face of a thermopile in circuit with a galvanometer, and then the effect of radiation from the same source when the "dark" heat is cut off by a glass cell containing a saturated solution of alum. Two alum cells were used in all cases. The second cell eliminated the effect of the warming up of the first one due to the absorption of radiant heat. The total thickness of the two alum cells was 72<sup>mm</sup>. The E. M. F., produced in a thermopile by radiation on its face, varies directly as the intensity of the radiation. Therefore the ratio of the galvanometer deflection obtained when the alum cells are interposed, to the deflection produced by the unobstructed radiation, properly corrected if there has been a change in the resistance of the galvanometer circuit, gives the ratio of the radiation through the alum cells to the total radiation. When this ratio is corrected for the light absorbed and reflected by the alum cells and for the "dark" heat which passes through them, we have the radiant efficiency of the source of light.

The amount of light absorbed and reflected by the alum cells was determined photometrically. The candle power of a constant source of light was measured both when the two alum cells were and were not interposed between it and the photometer, and it was found that .641 of the light incident upon the face of the first alum cell passed through both. The "dark" heat transmitted by the alum cells was measured with the aid of a cell containing an opaque solution of iodine in bisulphide of carbon. This transmitted the "dark" heat but intercepted the light. In the case of a gas flame .004 of the incident "dark" heat was transmitted through both alum cells.

For the sake of comparison the radiant efficiency of candle light and gaslight was determined. The final results of a number of measurements are as given below.

TABLE III.

Radiant efficiency of candle-light,		.0153
“ “ “ gaslight,	{ Bat's wing burner,	.0128
	{ Argand “	.0161

Julius Thomsen\* found the efficiency of petroleum flame to be about .02. His method was similar to the above except that he used distilled water instead of a solution of alum and disregarded the heat transmitted. S. P. Langley† by a very different method, namely by measuring the intensity of the

\* Poggendorff's *Annalen*, cxxv, p. 348.

† *Science*, vol. i, p. 483.

radiation for the different wave lengths of the luminous and heat spectrum, found the radiant efficiency of gaslight from an Argand burner to be .024.

Considerable difficulty was experienced in measuring this ratio for magnesium light on account of the great variability of the magnesium flame. The galvanometer needle instead of moving steadily or by steps to a maximum and then remaining there, was almost constantly in motion. Furthermore the radiation with and without the alum cells had to be measured successively, and there was no certainty that the condition of the flame was the same in the two cases. The best that could be done was to take a large number of observations and discard a few that were very far from the mean.

TABLE IV.

No. of Experiment.	Galvanometer deflections. Two alum cells R. of circuit =808.	Direct radiation R. of circuit=8080.	Light transmitted through alum cells divided by total radiation.	Preceding ratio corrected for heat transmitted.	Radiant efficiency (preceding ratio corrected for light reflected and absorbed.)
No. 1	67.4	76.5	.088	.085	.133
" 2	77.5	83.5	.093	.090	.140
<i>Same as above but with diaphragm.</i>					
No. 3	16.5	17.9	.092	.089	.139
" 4	21.7	22.7	.095	.092	.144
<i>Same as above but with galvanometer No. 2.</i>					
	R. of circuit=37.46	R. of circuit 147.46			
No. 5	18.0	48.6	.094	.091	.142
" 6	17.8	49.1	.092	.089	.139
" 7	12.4	40.8	.077	.074	.115
" 8	14.1	41.2	.087	.084	.131
<i>Same as above, sensitiveness of galvanometer changed.</i>					
	R. of circuit=20.46	R. of circuit 207.46			
No. 9	31.0	40.5	.076	.073	.114
Average by method of permanent deflections,					.133

In Table IV, are given nine determinations of the radiant efficiency of magnesium light. In the first two no diaphragm was used, but in every other case a diaphragm of  $10 \times 15^{\text{mm}}$  opening was placed in front of the ribbon of burning magnesium. This reduced the fluctuations caused by the varying length of the incandescent strip of magnesia.\*

It has been proved† that when a galvanometer and thermopile are used together the "first swing" of the galvanometer

\* It is perhaps a misnomer to call this strip of incandescent magnesia a "flame." Neither the combustible nor the product of combustion is a gas and the burning magnesium unlike a flame hangs downward.

† Ernest Merritt, note on galvanometer used with thermopile, this Journal, xli, p. 417.

needle due to the face of the thermopile being suddenly exposed to a source of radiation is proportional to the final permanent deflection. Use was made of this fact in obtaining the results given in Table V. In this case there was no difficulty in determining the limit of the "first swing." The difficulty still remained, however, that the magnesium might be giving out a maximum of radiation at the instant of exposing the thermopile to it while at the next exposure it might be far from a maximum. A mean of the results by the method of permanent deflections and "first swings" gives .135 as the radiant efficiency of magnesium light. The only artificial light whose efficiency is greater than this is the light from a Geissler tube\* of which the radiant efficiency is about .34. L. B. Marks† finds the radiant efficiency of the arc light to vary from .08 to .127 depending upon the character of the carbons.

TABLE V.

No.	No. of Experiment.	Galvanometer "swings."		Light transmitted through alum cells divided by total radiation.	Preceding ratio corrected for heat transmitted.	Radiant efficiency (preceding ratio corrected for light reflected and absorbed.)
		Two alum cells. R. of circuit 7.46	Direct radiation R. of circuit 7.46			
No.	1	3.8	47.0	.081	.078	.122
"	2	3.5	40.0	.088	.085	.133
"	3	2.9	31.8	.092	.089	.139
<i>Sensitiveness of galvanometer changed.</i>						
No.	4	4.9	55.1	.089	.086	.134
"	5	5.2	57.0	.091	.088	.137
"	6	5.0	48.3	.103	.100	.156
"	7	5.4	56.3	.096	.093	.145
"	8	4.6	54.9	.084	.081	.126
"	9	4.3	45.3	.095	.092	.144
Average by the method of "first swings."						.137

H. Nakano,‡ in a series of experiments to determine the relation of the size of carbons to efficiency, found that in the case of carbons .25 in. in diameter and a potential difference of 38 volts the "spherical efficiency" was .166 but with carbons of the usual size the efficiency was about .10.

The radiant efficiency of incandescent lamps is much less than that of the arc light. Ernest Merritt§ found the radiant efficiency of incandescent lamps under the best conditions compatible with their continued existence to be about .06.

In all the experiments above referred to, the efficiency was measured in the same way, viz: by taking the ratio of the

\* Beiblätter zu den Annalen der Physik, xiv, page 538.

† Am. Inst. of E. E., 1890, vol. vii.

‡ Am. Ins. of E. E., vol. vi, p. 308.

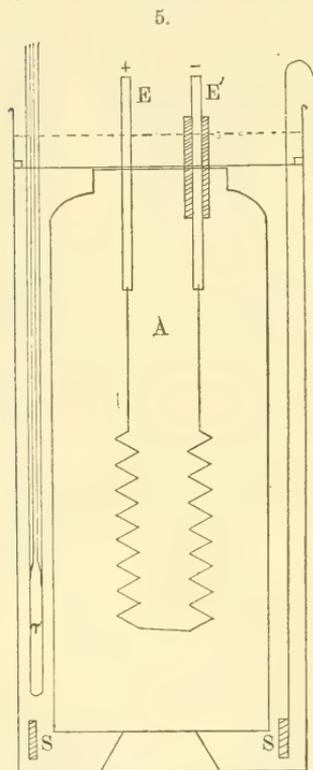
§ This Journal, vol. xxxvii, p. 167.

radiation through an alum cell to the unobstructed radiation and correcting for light absorbed and heat transmitted.

## IV.

*Heat of Combustion of Magnesium.*

In order to determine the total efficiency of magnesium light it is necessary to know its heat of combustion. In determining this quantity a new form of calorimeter was used. In this



case the magnesium ribbon was burned in an entirely closed vessel containing oxygen, not allowing *any* of the products of combustion to escape. Figure 5 represents a vertical section of the calorimeter. The smaller vessel, A, holds something over half a liter. This vessel is provided with an air-tight cover through which pass two electrodes E, E', one of which is insulated from the calorimeter. The outside vessel is just large enough to allow room between it and the inner vessel for a stirrer, S, and a thermometer T.

The process was as follows: About three fourths of a gram of magnesium was coiled into a spiral and a very small quantity of phosphorus fastened to it. The terminals of the spiral were then connected to the electrodes. Before putting the magnesium into the vessel, A, the latter was filled with oxygen. After the inner vessel had been closed, water was poured into the calorimeter until it was a centimeter deep over the top of the former vessel. The ribbon was then ignited by the instantaneous application of a current of electricity. This calorimeter gave quite uniform results. In Table VI, are given

TABLE VI.

No.	Lesser calories per g. of Mg.	No.	Lesser calories per g. of Mg.
1	6246	5	6020
2	6081	6	6072
3	5760	7	6011
4	5878	Average	6010

the results of seven determinations by this method. A mean of these gives 6010 lesser calories as the heat developed by the combustion of one gram of magnesium in oxygen.

Julius Thomsen\* gives 6077 as the heat of combination of magnesium and oxygen. He arrived at this result indirectly by means of the heat developed in the formation of the hydrate.

## V.

*Total efficiency of magnesium light.*

By total efficiency is meant the ratio of luminous energy to the total energy expended in the production of the light. In order to determine this ratio it is necessary to know the ratio of radiant energy to total energy of combustion. The method of obtaining the energy of combustion of a gram of magnesium in lesser calories, has just been described, and next must be indicated that of obtaining the radiant energy from a gram of burning magnesium in the same units. The method of obtaining this result was by calibrating the galvanometer and thermopile for lesser calories of spherical radiation from a source 24<sup>cm</sup> from the face of the thermopile. The known source of heat was a spherical brass vessel coated with lamp black and filled with hot water. Its loss of heat was known by its fall in temperature. The loss by convection and conduction was determined by noticing the rate of cooling in air and in a vacuum, under otherwise similar circumstances. By this means it was found that a galvanometer "swing" of one scale division corresponded to a spherical radiation of 2.53 calories per minute. Next the thermopile was exposed to the radiation from burning magnesium, the ribbon being supplied at a uniform rate. From a mean of 24 observations it was found that the burning of one gram of magnesium produced 4630 calories of radiant energy. As above shown .135 of this radiant energy is light. The total energy of combustion of one gram of magnesium is 6010 calories, therefore the total efficiency of magnesium as a producer of luminous energy is  $\frac{.135 \times 4630}{6010} = .1025$ .

It is assumed in this computation that the radiation from burning magnesium is of the same intensity in all directions. Experiments were made for determining the validity of this assumption, in which it was found that the candle power showed but little diminution up to 70° from the horizontal plane.

It is very remarkable that nearly .10 of the total heat of combustion of any artificial illuminant is expended in producing light. The radiant efficiency of magnesium, as we have

\* Journal für praktische Chemie, 1875.

seen, is very high and what is still more surprising, the ratio of radiant energy to total energy is not far from .75. The small loss by convection which renders this ratio possible is partially explained by the fact that the product of combustion is a solid. It may be also that this unusually high percentage of radiation is in some way related to the fact that so large a proportion of the radiant energy itself is luminous.

The final experiments in my study of magnesium as a source of light consisted in the determination of the amount of light produced by burning one gram of the metal. Measurements were made by means of the "horizontal slit" photometer. The standard for four determinations was an Argand lamp with a Methven slit, which allowed two candle power to pass through. In these measurements the comparison was made at the D line. In four other determinations the standard was an incandescent lamp; in which case the measurements were made at two points on opposite sides of the D line and their mean taken. In Table VII are given the final results of these eight determinations.

TABLE VII.

Standard=Argand lamp.		Standard=Incandescent lamp.	
No.	C. p. minutes per g. of Mg.	No.	C. p. minutes per g. of Mg.
1	248	1	233
2	252	2	236
3	228	3	288
4	250	4	272

A mean of the above eight measurements gives 251 candle-power-minutes produced by the combustion of one gram of magnesium.

This measurement of the candle-power-minutes produced by one gram of magnesium may serve as a check on the determination of the total efficiency. Assuming that the efficiency is .10, one gram produces 601 calories of luminous energy; therefore the thermal equivalent of one candle-power-minute of magnesium light is  $\frac{.10 \times 6010}{251} = 2.39$  calories. Even in the most unfavorable circumstances, namely, by using the maximum heat of combustion from Table VI and the minimum candle power minutes from Table VII we have, thermal equivalent  $= \frac{.10 \times 6246}{228} = 2.74$  lesser calories. In 1865 Julius Thomsen\* published some determinations of the thermal equivalent of light, which he found to vary from 4.4 calories in the case of

\* Annalen der Physik und Chemie, vol. cxxv, page 348.

a sperm candle to 3.7 calories in the case of gas. His values are too high, for he used distilled water to absorb the radiant heat instead of an alum solution, and made no correction for the heat transmitted. Dr. Nichols\* puts the thermal equivalent of the light from an incandescent lamp at 3.6 calories. Magnesium-light is much richer than gaslight in those rays (green) which are most effective in producing vision. Nevertheless it is highly improbable that its thermal equivalent is much less than two-thirds that of the incandescent lamp or in other words, that it is much less than 2.4 calories. But if the total efficiency of magnesium light is considerably less than .10 then its thermal equivalent must be considerably less than 2.4 calories.

It may be interesting to compare magnesium with gas as a producer of luminous energy. The radiant efficiency of gaslight is about .015; but of the total energy of combustion in the case of gas only .15 or .20 is radiant energy. Therefore the total efficiency of gaslight is .0022 or .003. This means that potential energy in the form of uncombined magnesium and oxygen is from 30 to 40 times more effective as a producer of luminous energy than the same quantity of potential energy in the form of illuminating gas and oxygen. Even this statement does not give the full measure of the superiority of magnesium light. If the thermal equivalents of gaslight and magnesium light are 3.6 and 2.4 respectively, the same quantity of luminous energy in the form of the latter will produce 50 per cent more candle power than if it were luminous energy in the form of gaslight.

The results of this investigation may be summed up as follows:

1. The spectrum of burning magnesium, as has already been pointed out by Pickering, approaches much more nearly that of sunlight than does the spectrum of any other artificial illuminant.

2. The temperature of the magnesium flame, about 1340° C., lies between that of the Bunsen burner and that of the air blast lamp, although the character of its spectrum is such as would correspond to a temperature of nearly 5000° C. were its light due to ordinary incandescence.

3. The "radiant efficiency" is 13½ per cent; a value higher than that for any other artificial illuminant (excepting perhaps the light of the electric discharge in vacuo for which Dr. Staub of Zürich has found an efficiency of about 34 per cent.

4. The radiant energy emitted by burning magnesium is about 4630 calories per gram of the metal burned or 75 per

\* American Inst. of E. E., vol. vi, p. 173.

cent of the total heat of combustion; as compared with 15 per cent to 20 per cent in the case of illuminating gas.

5. The thermal equivalent of one candle-power-minute of magnesium light is about 2.4 lesser calories, as against 3.5 to 4.0 for other artificial illuminants.

6. The total efficiency of the magnesium light is about 10 per cent; as compared with .25 per cent [a quarter of one per cent], for illuminating gas.

7. Taking into consideration the greater average luminosity of the rays of the visible spectrum of the magnesium flame, it is certain that *per unit of energy expended, the light-giving power of burning magnesium is from fifty to sixty times greater than that of gas.*

Physical Laboratory of Cornell University, June, 1891.

ART. XXXVII.—*A method for the quantitative separation of Barium from Calcium by the action of Amyl Alcohol on the Nitrates*; by P. E. BROWNING.

[Contributions from the Kent Chemical Laboratory of Yale College—XII.]

THE fact that strontium can be separated quantitatively from calcium by boiling the nitrates with amyl alcohol, as I have recently shown,\* naturally suggested a similar separation of barium from calcium by the same general treatment. Solutions of specially purified barium and calcium nitrates were prepared and standardized, either by the evaporation or filtration of definite portions after treatment with sulphuric acid. The mean of several closely agreeing results, both by evaporation and filtration, was taken as the standard. The method followed was essentially the same as described in the method for the quantitative separation of strontium from calcium referred to above. The first series of experiments was directed toward an investigation of the action of amyl alcohol upon barium nitrate alone. Accordingly definite amounts of the barium salt were measured into Bohemian beakers of about 100cm<sup>3</sup> capacity and weighed. The water was then evaporated over a water bath, and the dry salts dissolved in a few drops of water and boiled with 30cm<sup>3</sup> of amyl alcohol, that amount being determined upon as convenient, until the normal boiling point of the alcohol was reached—128° to 130° C. During the boiling the beaker was placed upon a piece of asbestos board about 15cm<sup>2</sup> square to keep the inflammable fumes of the alcohol from the flame. When the temperature

\* This Journal, vol. xliii, p. 50.

of the alcohol reached its normal boiling point the beaker was removed and the barium nitrate filtered off upon an asbestos felt in a perforated platinum crucible, the crucible and felt having been previously dried and weighed. The filtration was carried on under gentle pressure, the filtrate being received in a beaker standing under a bell jar upon a ground glass plate. The last traces of barium nitrate were removed from the beaker by washing with small amounts of anhydrous amyl alcohol contained in a wash bottle, previously described, to the mouth piece of which a small chloride of calcium tube was connected. The crucible containing the barium nitrate was placed in an air bath and heated to 150° C. The process of heating and weighing was repeated until a constant weight was obtained. Series I shows the results of these experiments the barium being calculated as oxide.

SERIES I.

	BaO taken.	BaO found.	Error.
(1)	0·1040 grm.	0·1039 grm.	0·0001 grm. —
(2)	0·1043 “	0·1043 “	0·0000 “
(3)	0·0524 “	0·0522 “	0·0002 “ —
(4)	0·0519 “	0·0518 “	0·0001 “ —

These results show plainly enough the complete insolubility of the barium salt in the amyl alcohol; but to confirm them the filtrates of (3) and (4) were evaporated to dryness, ignited to burn off any organic matter from the amyl alcohol, treated with sulphuric acid, heated to low redness and weighed. The weights in both cases showed the absence of any residue.

SERIES II.

	BaO taken.	BaO found.	Error.	CaO taken.	CaO found.	Error.
	grams.	grams.	grams.	grams.	grams.	grams.
(5)	0·1410	0·1406	0·0004 —	0·0112	0·0114	0·0002 +
(6)	0·1300	0·1301	0·0001 +	0·0926	0·0926	0·0000
(7)	0·1043	0·1049	0·0006 +	0·0741	0·0736	0·0005 —
(8)	0·0781	0·0781	0·0000	0·0556	0·0554	0·0002 —
(9)	0·0525	0·0526	0·0001 +	0·0373	0·0372	0·0001 —

SERIES III.

	BaO taken.	BaO found.	Error.	CaO taken.	CaO found.	Error.
	grams.	grams.	grams.	grams.	grams.	grams.
(10)	0·1304	0·1308	0·0004 +	0·0927	0·0921	0·0006 —
(11)	0·1043	0·1046	0·0003 +	0·0371	0·0370	0·0001 —
(12)	0·1037	0·1036	0·0001 —	0·0743	0·0744	0·0001 +
(13)	0·0783	0·0776	0·0007 —	0·0427	0·0422	0·0005 —
(14)	0·0519	0·0521	0·0002 +	0·0369	0·0361	0·0008 —
(15)	0·0519	0·0512	0·0007 —	0·0570	0·0567	0·0003 —
(16)	0·0261	0·0259	0·0002 —	0·0925	0·0925	0·0000

The next experiments were directed toward a separation of barium and calcium nitrates. Definite amounts of a solution of barium nitrate were measured from burettes into counterpoised beakers and weighed, as already described, the calcium nitrate was then added in solution and the weight taken again. The water was evaporated and the dry salts dissolved again in the least possible amount of water, and boiled as before with 30cm<sup>3</sup> of amyl alcohol. The barium salt was filtered off into a perforated platinum crucible containing an asbestos felt, dried and weighed as previously described. The calcium was determined in the filtrate, in the form of the sulphate, by evaporation of the alcohol, treatment with an excess of sulphuric acid and ignition. Series II gives the results of this treatment.

In Series III the effect of a double treatment with the alcohol is recorded. In these experiments, after the first boiling, already described, the alcohol was decanted upon an asbestos felt, under the conditions previously mentioned, and collected in a beaker placed to receive it. The residue was then dried at a gentle heat over a radiator to remove amyl alcohol, dissolved in a few drops of water, and this solution was treated with a drop of dilute nitric acid to assure the condition of nitrate, and evaporated to dryness. After dissolving in a few drops of water, 30cm<sup>3</sup> of alcohol were added, and the boiling repeated. The residue was filtered off upon the felt through which the first portion had been decanted and washed with amyl alcohol, care being taken to remove all particles from the beaker by careful rubbing. The crucible and residue were heated to 150° C. as before and weighed. The results after one treatment are fully as satisfactory as those after the double treatment,—a point which simplifies the method considerably. In the separation of strontium from calcium the double treatment was necessary. The form in which the salts separate suggested a possible explanation. The strontium nitrate separates in plate-like masses, while the barium is much more granular and therefore less liable to include foreign matter.

Series IV contains the results of certain experiments directed toward the separation of barium and strontium together from calcium. Definite portions of the three nitrate solutions were measured into counterpoised beakers and the successive weights taken as previously described. The method of treatment was the same as that described in the double treatment of the barium and calcium salts. The correction for the solubility of the strontium salt was applied (0.001 grm. of strontium oxide to 30cm<sup>3</sup> of the alcohol used) in the manner defined in the paper upon the separation of strontium from calcium. The results are tabulated for the nitrates in the cases in which barium and strontium were treated together, but the errors are also aver-

aged on the oxides for the amounts of barium and strontium nitrates taken in order that they may be compared more conveniently with the results of the previous series.

## SERIES IV.

	Ba(NO <sub>3</sub> ) <sub>2</sub> and Sr(NO <sub>3</sub> ) <sub>2</sub> taken. grams.	Ba(NO <sub>3</sub> ) <sub>2</sub> and Sr(NO <sub>3</sub> ) <sub>2</sub> found and corrected. grams.	Error in nitrates. grams.	Error averaged and calculated as oxide. grams.	CaO taken. grams.	CaO found. grams.	Error. grams.
(17)	0.3941	0.3945	0.0004 +	0.0002 +	0.0283	0.0277	0.0006—
(18)	0.1436	0.1442	0.0006 +	0.0003 +	0.0568	0.0558	0.0010—
(19)	0.3163	0.3152	0.0011—	0.0006—	0.0284	0.0274	0.0010—
(20)	0.1978	0.1987	0.0009 +	0.0005 +	0.0285	0.0280	0.0005—
(21)	0.1948	0.1932	0.0016—	0.0008—	0.0833	0.0835	0.0002 +
(22)	0.1971	0.1971	0.0000	0.0000	0.0830	0.0817	0.0013—
(23)	0.1973	0.1960	0.0013—	0.0007—	0.0830	0.0824	0.0006—
(24)	0.1959	0.1970	0.0011 +	0.0005 +	0.0830	0.0819	0.0011—
(25)	0.1971	0.1963	0.0008 +	0.0004 +	0.0834	0.0831	0.0003—

In experiments (21), (25) 15cm<sup>3</sup> of the alcohol were used in each boiling instead of the 30cm<sup>3</sup> of the previous experiments, and thus the total amount of the corrections for the solubility of the strontium salt was reduced one-half. In experiments (21), (23) and (25) the calcium was determined by precipitation with sulphuric acid, the precipitate being filtered off, ignited at low redness and weighed.

The rapidity of execution and satisfactory character of the results of this method of separating barium from calcium seem to place it among good analytical methods.

ART. XXXVIII.—*On Plicated Cleavage-Foliation*; by  
T. NELSON DALE.

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THE schists and slates of the Taconic Range in Western Massachusetts and Vermont afford a good field for studying the various phases of cleavage: slaty-cleavage, slip-cleavage,\* close-joint-cleavage. Some of the results of such a study have been published in outline by the writer,† and others are in course of preparation.

De la Beche‡, and later Charles Darwin§ noticed that the upturned cleavage laminae of clay-slate were sometimes curved at the surface, and Dr. Hans Reusch of Christiania|| cites an

\* "Ausweichungs-clivage" of Heim; "strain-slip cleavage" of Bonney.

† The Greylock Synclinorium. American Geologist, July, 1891.

‡ Geological Manual, p. 42, 1831.

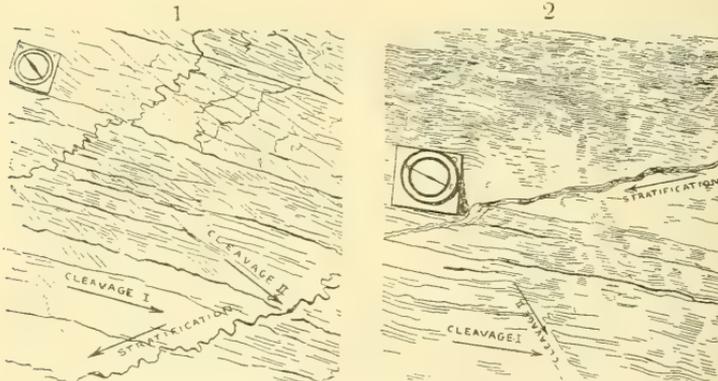
§ Geological Observations on Coral Reefs, Volcanic Islands and on South America, Part III, p. 160, London, 1851.

|| Bommeløen og Kommøen med omgivelser, p. 196, Kristiania, 1888.

interesting case on the Hardanger fiord in which the cleavage planes traversing a plicated layer have themselves been plicated along with the former by secondary pressure.

After examining many square miles of the Taconic schists, the writer found last summer a case of this kind at West Rutland, Vt. Although the structure is not as extreme as that described by Dr. Reusch it involves identical principles. Moreover the evidences of stratification at this locality are so conclusive as to separate distinctly the two foliations.

The exposure is on the south side of a vertical E.-W. joint face in a mass of sericite schist on the west side of the West Rutland valley. Traversing it with a very low westerly dip are several layers 1-3 inches thick and from 1-5 feet apart of calcareous schist which determine at once the direction of the stratification. Across this occurs the prevailing cleavage-foliation of the region, dipping about  $30^\circ$  east. Parallel with these small calcareous beds a highly plicated foliation is seen in places, and there are also indications of a second system of cleavage planes dipping at high angle east, about  $80^\circ$ . (See fig. 1).\* In the lower and eastern part of the ledge the prevailing cleavage-foliation (I) undulates in gentle folds which measure about one inch in width.

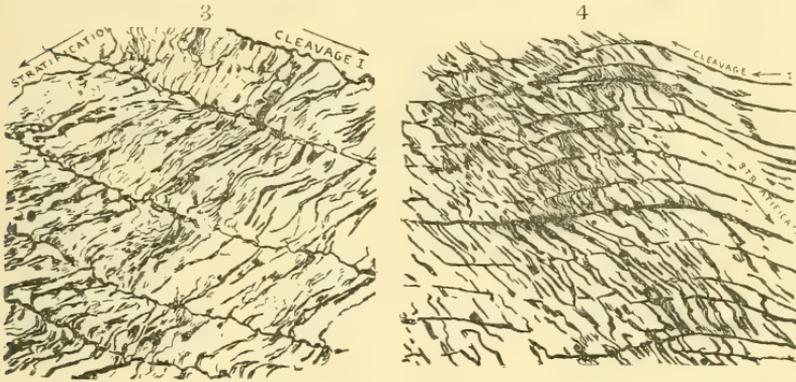


Figs. 1, 2, from photographs, the compass is 4 inches square.

See fig. 2 which shows also one of the smaller westerly dipping calcareous beds. A specimen taken here from between the calcareous beds would be utterly misleading for it would only show a gently undulating foliation dipping low east crossed by another dipping high east neither of which however is stratification-foliation.

\* In this and the other illustrations the exact relations of the foliation to the horizon are not preserved but only their mutual relations.

Fig. 3 shows the microscopic structure. The dominant cleavage is evidently slip-cleavage, and the cleavage-foliation itself shows in places extremely minute plications.



Figs. 3, 4, from photographs of thin sections ; 3, section 0.12 in. sq. ; 4, section 0.30 in. sq, the directions of the dip are here figured reversed.

Fig. 4, under less enlargement, shows the flexure of the cleavage-foliation which in this specimen is considerable. In both figs. 3 and 4 the prominence of the cleavage-foliation is due to the infiltration of ferruginous matter.

The steps in the formation of this structure appear to have been :

1. Plication of the beds and consequent cleavage-foliation (I), slip-cleavage.
2. Plication of cleavage-foliation (I) in consequence of secondary pressure operating in the direction of the cleavage dip.
3. Cleavage-foliation (II), slip-cleavage passing into close joint cleavage, produced by the plication of cleavage-foliation I.

This subject is not only of interest structurally but in some regions may be of economic importance.

Newport, R. I., Jan. 2, 1892.

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ART. XXXIX.—*Geological Age of the Saganaga Syenite* :  
by A. R. C. SELWYN.

I AM surprised to read in a paper by H. V. Winchell\* upon the age of the Saganaga syenite the statement that this Saganaga syenite was always supposed to be Laurentian. A glance at the Canadian Geological map, 1882, shows it as occurring with an extensive area of Huronian. That it should be

\* This Journal, vol. xli, May, 1891.

accompanied by Keewatin schists is therefore quite probable and that it is of Huronian not Laurentian age has always been supposed by Canadian geologists who have examined it. I am gratified to learn that this fact is now apparently recognized by Mr. H. V. Winchell.

A few remarks on the use of the names Huronian, Coutchiching and Keewatin are I think called for in view of the very erroneous ideas that have been promulgated, and of which the paper now referred to is an instance, respecting the Huronian system in Canada and the attempt to subordinate it to new and comparatively unknown names or to confound it and associate it with Paleozoic formations with which it has nothing in common. It is even indicated as Huronian on the map of 1866, though then the extent of it as also of many other similar areas had not been ascertained.

The name Keewatin as well as Coutchiching was originated on this Survey by Dr. Lawson. I sanctioned the use of these names in the Survey publications, but only as being useful to designate subdivisions, more or less local, of the great series of Archæan rocks, which is widely distributed in Canada, at intervals from Belle Isle Strait and Labrador to Lake Winnipeg, and thence perhaps to the Arctic Ocean and which has always been known and described wherever it has been recognized in Canada, as Huronian or Upper Archæan. The name Huronian is not, and never was used in Canada as equivalent to Taconic. The latter term, so far as I can make out, like Quebec Group, as depicted on the published maps, included parts of all the formations from Huronian up to Hudson River shales inclusive. Huronian, on the other hand, was always supposed to occupy in Canada one and the same interval in geological time, viz: that antedating the lowest Paleozoic. It was never supposed, like Taconic, to include Paleozoic formations though areas of it had in error been included in them. The Keewatin area of the Lake of the Woods had always been recognized as Huronian and the Keewatin schists are simply one lithological subdivision of that wide spread system. Perfectly similar schists occur in some portion of all the Huronian areas shown on the Geological map of Canada, 1882, and everywhere the system presents similar characters, mineral, lithological and physical, and, as I said of these rocks in 1879, they are largely of volcanic and igneous origin. Clastic, pyroclastic or aqueo-igneous and massive igneous rocks are intimately associated and interbedded and all have been subjected to such intense and long continued dynamic and thermochemic metamorphism as often to have obliterated their original characters. Microscopic investigation is now proving the correctness of this somewhat old strati-

graphic generalization. Large areas that will eventually be classed with the Huronian system have been colored on the geological maps of Canada as Laurentian. These areas however had never been and even yet are not examined. A comparison of the map of Canada of 1866 with that of 1882 indicates, though only partly, the extent of this error, and the advance of our knowledge of the distribution of Huronian in the interval. Thousands of square miles of territory in Northern Canada remain to be explored before all the areas occupied by the rocks of the Huronian system can be defined. Unfortunately the literature of the system has gone very far ahead of the knowledge of it derived from personal observation in the field. I have probably examined these rocks in the field over a wider geographical extent than any other geologist but have taken little part in the literature respecting them. I have however strongly deprecated the term "typical Huronian," and then using the very imperfect descriptions given in the early reports of the Canadian Survey of one small partially mapped area, viz: that on the shore of the north channel of Lake Huron, in arguments against the subsequent correlation with it of other areas. The chief arguments being based on the local greater development of some particular kind of rock as quartzite, etc., and low angles of dip—the latter being, however, if not indeed both, a wholly incorrect assumption. That it is so as regards the latter can be proved by the maps of the so-called "typical" area made by Mr. Murray and published in 1857 in atlas form.

Local development of any particular kind of rock is of no import in the correlation of systems, neither are high or low dips. The Archæan rocks in Canada, Laurentian and Huronian, are sometimes flat and locally dip at all angles, from that to vertical and yet low dips and local lithological characters have been the main reasons adduced by some of the writers on Huronian against the correlations made by the Canadian Survey, all of which are, however, based on careful observation in the field, and are as well founded as, in the absence of paleontological evidence, is possible. Every other kind of stratigraphic evidence is present and I hold it amply sufficient for the purpose of stratigraphic correlation.

In the present state of our knowledge of Archæan formations no new name is required in Canada, for this great system. As its subdivisions become worked out, local names, as Couthiching and Keewatin, can be used to designate them, and if, as is possible, though I think not probable, some part of it should eventually be proved, by the discovery of fossils, to belong to the Paleozoic era, it can be separated under some appropriate designation.

A still more glaring error is to correlate Animikie—plainly lower Cambrian, at least in Canada—with Huronian, with which it has scarcely any feature in common. The difference in degree of metamorphism exhibited under the microscope has no necessary relation to age, but is dependent on local circumstances and probably still more on original characters. There is no recognizable unconformity in this great Huronian series, and the rocks composing it undoubtedly all belong to the same rock-making era. The lapse of time represented may be less than, or it may exceed, that of all subsequent rock-making periods. On this point there is absolutely no evidence, neither is there that it represents other than an unbroken and very early, if not the earliest, series of events in the history of the evolution of the stratiform rocky crust.

An important area of very characteristic Huronian rocks has been recognized, during the past summer, on the east shore of Lake Winnipeg, greenstones, "slate conglomerates," Keewatin schists, etc.

I have recently visited the districts of Madoc and Marmora and I should now have no hesitation in, at least provisionally, correlating the Hastings series of the late Mr. Vennor with the Huronian, to which he himself surmised it was more nearly related than to Laurentian.

ART. XL.—*A Third Occurrence of Peridotite in Central New York*; by C. H. SMYTH, JR.

IN view of the interest attaching to the demonstration by Professor G. H. Williams, of the igneous nature\* of the so-called serpentine of Syracuse, N. Y., any further occurrence of similar rocks in this region seems worthy of note.

A recent paper† describes several dikes near Ithaca, N. Y., consisting of a rock closely related to the Syracuse peridotite. In both of these localities the dikes are associated with nearly horizontal, undisturbed strata, differing in this respect from the rock described in the present paper. This rock occurs in the form of a narrow dike in a fault plane at the village of Manheim or East Creek, seven miles east of Little Falls, N. Y. The dike is mentioned by Vanuxem in his description of the

\* G. H. Williams: The Serpentine (Peridotite) occurring in the Onondaga Salt Group at Syracuse, N. Y., this Journal, 1887, p. 144. Also Bull. Geol. Soc. Amer., vol. i, pp. 533, 534.

† J. F. Kemp: Peridotite Dikes in the Portage Sandstones near Ithaca, N. Y., this Journal, November, 1891, p. 410.

“Uplifts of the Mohawk,”\* and is spoken of in the papers above cited, though never visited by the authors.

The fault, which involves the strata from Archæan to Utica slate, is plainly shown at the highway bridge over the East Canada Creek, a short distance north of the railroad. Here the Utica slate forms a wall ten feet high on the east side of the creek, while the corresponding western wall, about eight hundred feet away, is Calciferous sand-rock. The strata on both sides are horizontal, but as the contact between the two formations is covered by stream deposits, there may be, and probably is, a flexure of the rocks near the fault. The strike of the fault is about N. 20 E., coinciding with the direction of the valley. One mile farther up stream the strike of the fault changes to N. 40 E. crossing the stream, and thus producing a considerable fall, the sand-rock here rising above the slate in a bluff over one hundred feet high. At this point, the contact between the sand-rock and the slate is shown, and there is a marked disturbance of the latter. Two hundred feet back from the fault the slate begins to bend slightly upward, and the inclination rapidly increases, till at the fault the dip approaches 90°. At the same time, the flexure brings to view the underlying strata of Trenton limestone. As would be expected, the thick bedded calciferous sand-rock on the upthrow side is much less affected, being bent downward very slightly.

It is at this point, near the foot of the falls and on the east side of the creek, that the dike occurs, filling a space ten inches wide in the plane of the fault between the sand-rock and the slate. In connection with the dike is a one inch vein of calcite carrying galenite and pyrite, and some fifty years ago, with a view of working this vein, a drift was run in about sixty feet, when the dike pinched out. In the opposite direction the dike passes under the creek and does not extend to the west bank. It is, therefore, not more than one hundred and fifty feet in length. However, it seems probable that the rock exists at other points along the fault, being covered by drift.

The rock is granular and of a dark green or gray color, with a mottled appearance due to the presence of a light green, to white, mineral. Scattered through it are abundant plates of dark brown mica, often 6–8<sup>mm</sup> in diameter. The appearance of the rock varies but slightly, excepting when it has been weathered. In the latter case the product is a light yellow, pulverulent clay, with scales of mica scattered through it. Microscopic study shows the rock to be made up largely of olivine, with less mica, in a ground mass chiefly crystalline. The porphyritic structure is distinct and constant, with but

\* *Geology of New York*, Part III, pp. 207, 208.

slight variations in the relative proportions of the constituents. The most abundant mineral is olivine, occurring both in irregular grains, and with sharp crystal outline. The diameter of individuals seldom exceeds  $1^{\text{mm}}$  though larger masses are occasionally seen. Twinning parallel to 011 is rare, having been noted in only two slides. Inclusions are not very abundant, and show no regularity of arrangement. The usual alteration to serpentine and carbonates is shown along the cracks, and in some cases the original substance is entirely changed, but this is not common, much of the olivine generally being present.

The large mica phenocrysts rarely show hexagonal outline. The color in thin sections is dark brown, with marked pleochroism. Cleavage plates of the mineral give, with convergent polarized light, a figure which differs but slightly from that of a uniaxial mineral. The mica is doubtless biotite. While some individuals are quite fresh, others show considerable alteration to carbonates. Occasional crystals of rhombic pyroxene are present, but hardly in sufficient quantity to be considered an essential constituent of the rock.

Though a large proportion of the ground-mass is distinctly crystalline, a glassy substance is present in small quantity, and numerous patches of nearly isotropic material probably represent a glass that has been slightly altered. Of the crystalline portion of the ground-mass, biotite is perhaps the most abundant member. It appears in irregular lath-shape particles, generally quite fresh and showing the usual pleochroism. The arrangement of the particles sometimes shows a decided flow structure. Next in order of abundance is the iron oxide, which occurs both irregular and with octahedral outline, and is evidently a primary constituent of the rock. As it is strongly attracted by the magnet and readily soluble in acids, it is undoubtedly magnetite. Indeed, the former property is so marked and the mineral so abundant, that pieces of the rock  $\frac{1}{2}$  inch in diameter may be lifted by a weak magnet. Mingled with the magnetite, both in the ground-mass and as inclusions, are numerous small octahedra never more than  $0.12^{\text{mm}}$  in diameter and usually less than half that size. The octahedral form as a rule is distinct, but irregular grains are also present. The color is deep yellow and the index of refraction high, giving strong marginal reflection. With crossed nicols the crystals are seen to be not perfectly isotropic. When the rock powder is treated with hydrochloric acid the crystals are left in the residue, but are completely dissolved by sulphuric acid. These facts show the mineral to be perovskite. The same conclusion is reached upon comparing the mineral with the perovskite of other American peridotites, their appearance and properties being precisely the same. Some sections of the rock show

still another constituent of the ground mass, of imperfect lath shape, and in color white, green or brown. There is a pronounced fibrous structure, perpendicular to the long axis, producing an appearance very similar to that resulting from the serpentinization of olivine along cracks. Both single and double refraction are high and extinction is parallel. The long axis is sometimes that of greatest, and sometimes of least elasticity in the section, showing the plane of the optic axes to be perpendicular to the long axis. This is also proven by the behavior of the mineral in convergent light. The mineral is decomposed by hydrochloric acid giving a jelly easily stained by fuchsine, and its color changed to red by ignition. All of these characteristics indicate that the mineral is olivine, in partially developed crystals. But in view of the rarity of a second generation of olivine in porphyritic rocks, it is possible that further study of better material may modify this conclusion.

The highly basic character of the rock indicated by its mineralogical composition, is clearly shown by a partial analysis given below. For comparison, the figures for the same constituents are reproduced from published analyses of other rocks of like nature.

	I (Smyth).	II (Morrison).	III (Peter and Kastile).	IV (Hunt).
Loss on ign. . . . .	15·20	12·67	16·55	12·77
SiO <sub>2</sub> . . . . .	33·80	37·44	29·43	40·67
Al <sub>2</sub> O <sub>3</sub> . . . . .	6·84	28·60	2·36	5·13
Fe <sub>2</sub> O <sub>3</sub> . . . . .	12·26	11·92	9·06(FeO)	8·12(FeO)
CaO . . . . .	9·50	5·45	6·94	----
MgO . . . . .	21·38	1·97	31·66	32·61
Sp. gr. . . . .	2·732	----	2·697	----

- I. Manheim Dike.
- II. Ithaca Peridotite.\*
- III. Elliot Co., Ky., Peridotite.†
- IV. Serpentine from Syracuse Peridotite.‡

The lack of closer agreement in composition of these four nearly related rocks, is readily explained by the strong tendency to decompose manifested in all members of this very basic group. But despite decided variations, they are all very low in silica and, with the exception of No. II, high in magnesia and iron. The altered condition of the Manheim rock is shown by the loss of 15·2 per cent on ignition, and by its ready effervescence with acids. Though the iron was determined as Fe<sub>2</sub>O<sub>3</sub>, it doubtless exists in the rock as FeO and Fe<sub>3</sub>O<sub>4</sub>. The

\* This Journal, vol. xlii, p. 412.

† Bulletin 38, U. S. G. S., p. 24.

‡ This Journal, vol. xxxiv, p. 138.

large percentage of lime is partly derived from the material of the adjacent vein, the dike having been broken by movements subsequent to its cooling, and re-cemented by infiltration. That there have been several such movements along the fault plane is shown by a series of slickensided vein surfaces, each slickenside having been covered by a layer of vein stuff, thus affording a smooth surface for the recording of the next movement.

The foregoing evidence, microscopic and chemical, is sufficient to class the rock of the Manheim dike as a member of the peridotite group, and of that division of the group to which Lewis\* has given the name kimberlite. It is a well known fact that the peridotites are, of all igneous rocks, the least prone to produce contact metamorphism, and when to this is added the fact of the extreme narrowness of the dike, it is not surprising that no clear evidence is given of any effect upon the enclosing rocks. Diligent search was made for fragments of these rocks included in the dike, but none were found.

Through the kindness of Professors G. H. Williams and J. F. Kemp, the writer has been enabled to compare sections of the Manheim rock with sections of the peridotites of Syracuse, Ithaca, Elliot Co., Ky.,† and Pike Co., Arkansas.‡ The Manheim rock differs from that of Syracuse in having magnetite instead of chromite and in the absence of pyroxene as an essential constituent. In the former respect it resembles the Arkansas rock, and in the latter, the Kentucky rock. In having olivine in the ground mass the Manheim rock differs from all the others. But in spite of these slight variations, the five rocks are closely related. It is interesting to note the unfailling presence of perovskite in the rocks of these widely separated localities.

As regards the age of the Manheim dike, it is certainly younger than the Utica slate, and its mode of occurrence is such as to indicate, with some degree of probability, the time of intrusion. The fault in which the dike occurs is one of a series of eight or more parallel faults, beginning near Amsterdam on the east and occurring at irregular intervals from there to Little Falls. These faults affect the rocks from the Archæan gneisses through the Utica slate. The throw is not large and varies a good deal, but the strike is always north, to northeast. The simplest explanation of these faults is that offered by Vanuxem fifty years ago, that they mark the western extension of the forces of the Appalachian uplift. If this be true, it fixes the intrusion at the close of the Carboniferous, unless it be assumed that the fissure was not filled when first formed, which seems highly improbable. Periods of oro-

\* H. C. Lewis: *The Genesis of the Diamond*, Science, viii, p. 345.

† J. S. Diller: *Peridotite of Elliot Co. Ky.*, Bulletin 38, U. S. G. S.

‡ J. C. Branner, R. N. Brackets: *The Peridotite of Pike Co., Ark.*, this Journal, July, 1889, p. 50.

graphic movement are periods of igneous activity, which fact of itself, suggests this as the time of intrusion. In view of this fact, as well as the similarity of the rocks, it is a natural conclusion that the dikes of Manheim, Syracuse and Ithaca are of the same age, dating from the close of the Carboniferous.

In this connection it is interesting to note that Mr. Diller\* suggests the close of the Carboniferous as perhaps being the time of extrusion of the Elliot Co., Ky., peridotite, which cuts Carboniferous strata, though the very slight disturbance in that locality leads him to think a later date more probable.

Geological Laboratory, Hamilton College, Clinton, N. Y.

ART. XLI.—*A Fulgurite from Waterville, Maine; by*  
W. S. BAYLEY.

THROUGH the kindness of Mr. G. K. Boutelle of Waterville, Me., the museum of Colby University has come into the possession of a fragment of fulgurite, which, when unearthed from the midst of a heterogeneous collection of unlabeled rock and mineral specimens, was found to be wrapped in a scrap of paper containing the following inscription:

“This sand tube was taken out of the garden of ——— Gilbert, some feet below the surface, after a thunder storm, during which a stroke of lightning was seen to fall on to his garden, where, after having torn up beans and other vegetables in an odd manner, it was tracked by a long tube descending through the soil and sand. I had one specimen which my children broke, into which I could put two fingers—this was from a part lower down. The garden is on the left hand side going to Crummett’s Mills bridge, a little more than half way from the Universalist church to the bridge.”

No date nor signature accompanies the inscription, nor can any one be found in Waterville who knows more of the incidents connected with the history of the tube than the paper itself reveals. The church mentioned is in the southern portion of the city, and the bridge spans the Messalonskee River, which crosses the main road running west from Waterville about half a mile west of the church.

The sand covering the surface in the region indicated by the above description is probably glacial. It consists of intermingled angular and rounded grains of quartz, feldspar and hornblende, and fragments of some green earthy material and slate.

The portion of the tube that has been preserved measures about three inches in length and has a rudely elliptical cross section with axes of an inch, and three quarters of an inch,

§ Bulletin 38, U. S. G. S., p. 29.

respectively. Its exterior surface is very rough and is thickly covered with sand grains, while its interior is glazed with a transparent coating of light yellowish green glass about a millimeter in thickness. This glass with its adhering sand grains compose the tube. A very close inspection of the glass discloses the presence in it of tiny whitish enamel-like portions, that probably mark the positions of some refractory particles that were not completely fused, and the existence of numerous small pores that may represent the original spaces between the grains.

The corrugations noted by Mr. Merrill\* in the fulgurites from Whitesides Co., Ill., are very noticeable in the Waterville specimen, but instead of running longitudinally, as in the first case, they possess a slightly spiral twist in opposite directions on opposite sides of the tube. These corrugations or "wings" are covered with little knobs, that are hollow spaces enclosed within walls of glass and sand. Only in these knobs, however, are the ridges hollow. Throughout their greater extent the "wings" are merely a single layer of glass to both sides of which sand grains adhere in large numbers. The continuity of the glass across the corrugations seems to lend credence to the view of Merrill, that these irregularities on the surfaces of sand-fulgurites are due, not to the collapsing of the walls of the tube, as suggested by Wichmann, but to the selective power of the electricity in directing its course through the sand. That the corrugations are original structures, due to the action of the electric current, rather than accidental ones, is also indicated by their spiral twist (see figure).



Unfortunately insufficient material forbade analyses of the various portions of the tube, and its fragility would not admit of thin sections being cut from it, so a small fragment was crumbled between the fingers, and the resulting particles were examined under the microscope. The glass could easily be distinguished from the grains of sand. Some of the glass fragments were perfectly colorless, others were greenish, and all were filled with little air bubbles. No microlites of any kind were seen in them, but occasionally a small unfused sand grain could be detected imbedded in a perfectly isotropic matrix.

\* Proc. U. S. Nat. Mus. for 1886, p. 85.

ART. XLII.—*Mineralogical Notes on Brookite, Octahedrite, Quartz and Ruby*; by GEORGE FREDERICK KUNZ.

AN interesting discovery of minerals was made at Placer-ville, Eldorado Co., California, by Mr. James Blackiston, in a quartz ledge running north and south and dipping eastward about  $45^{\circ}$  to  $50^{\circ}$ . The rock of the ledge is partly decomposed and partly compact, and is traversed for perhaps a hundred feet by a vein of crystallized quartz varying from six to fourteen inches in width. This vein is also decomposed and filled in with a reddish earth and sand, and can be dug into with a stick or board. It is full of quartz crystals, of all sizes from that of a man's finger up to remarkable dimensions, some of them weighing as much as 80 or 90 pounds. Several of these, over fifty pounds in weight, were pellucid and free from flaws: while others have peculiar interest from remarkable inclusions of chlorite, three to five millimeters in thickness, at several depths in the crystal—thus marking successive stages of crystal-growth, and making very striking "phantoms," generally of green chlorite, or white quartz layers. Of still greater interest, however, are other quartz crystals, two to four inches long and half that amount in diameter, containing at and near their centers inclusions resembling groups or clusters of dolomite or siderite crystals, cream-white to brown in color, and consisting of many curved rhombohedra from two to four millimeters in diameter. On breaking the specimens, however, the curious fact appears that these groups are hollow cavities in the quartz, the spaces being lined with a layer of chalcedony, or when brown, occupied only by a brown siliceous material. This would indicate that the original mineral must have been siderite or ankerite, afterward covered up by successive growths of the quartz, and in some manner decomposed during that process.

After receiving some of these specimens, the present writer detected a small crystal of octahedrite adhering to one of the small quartz crystals. Search was then instituted at the locality, which resulted in the discovery of a number of crystals of both octahedrite and brookite, some loose and some attached to the quartz. The octahedrite is in splendid crystals, from two to five millimeters in length, and varying in color from brown to almost a dark blue. Their form is that of the unit pyramid slightly distorted by horizontal striation.

The brookite is similarly implanted on the quartz, and partly or wholly overgrown by it, so as in some cases to be a true inclusion. The crystals are tabular, about two millimeters broad and one-fourth of a millimeter in thickness. Their color

is a rich reddish or yellowish brown, and they are free from inclusions. In form and association they closely resemble brookites from the Tyrol and from Maderananthal, Switzerland, lately described by P. Groth,\* von Zepharovich† and Zimányi‡. The following planes were kindly identified for me by Dr. S. L. Penfield of Yale University.

<i>a</i> , 100, $i\bar{i}$	<i>t</i> , 021, 2 $\bar{y}$	<i>n</i> , 121, 2 $\bar{y}$
<i>c</i> , 001, <i>O</i>	<i>x</i> , 102, $\frac{1}{2}i\bar{i}$	<i>ε</i> , 134, $\frac{3}{4}i\bar{i}$
<i>l</i> , 210, $i\bar{2}$	<i>y</i> , 104, $\frac{1}{4}i\bar{i}$	<i>Q</i> , 234, $\frac{3}{4}i\bar{i}$
<i>m</i> , 110, <i>I</i>	<i>e</i> , 122, 1 $\bar{2}$	

The faces were small but gave him sufficiently distinct reflections for the identification of the forms; the pinacoid *a* is vertically striated. A distinct pleochroism was observed for vibrations parallel to *a* pale yellow, and parallel to *c* reddish yellow. Small crystals of an asparagus-green epidote 2<sup>mm</sup> long and 2<sup>mm</sup> in diameter were also observed partly enclosed in the crystals of quartz.

Among a quantity of minerals brought to me for sale by peasants at Újakova, in the government of Perm, Ural Mountains, was a crystal weighing 25.4 grams, which was offered as garnet, but I at once recognized it as a monazite of remarkable size. This crystal measures 33 millimeters in breadth, 17 millimeters in length, and 11 millimeters in width, and presents a simple form, showing the planes *c* (001, *O*), *a* (100,  $i\bar{i}$ ) and *m* (110, *I*). I was told that one of the Romanovskys, Russian mineralogists,—but which one I cannot ascertain—had purchased two of these so-called “garnets” implanted on crystals of albite, and one had been found at the same locality some time before.

Owing to the exploration at the ruby mines of Burma during the last few years a number of very large ruby crystals have been found in the ruby mines on the Moguk near Mandalay, Burma. Some of these have weighed from 300 to 2,000 carats—61 to 410 grams each; but they have all been translucent, or only transparent in small spots, affording but little fine ruby for cutting. They have, however, been cut up into very interesting ruby asterias and poor colored ruby gems. One crystal examined by the writer was a perfect hexagonal prism measuring 29<sup>mm</sup> in height and 31 to 33<sup>mm</sup> across the basal plane, which was broader than the length of the crystal. It was doubly terminated, and had trihedral rhombohedral markings on each basal plane, visible also on the prismatic faces. This crystal weighed several ounces and was valued at some £200.

My thanks are due to Dr. S. L. Penfield for his crystallographical determinations.

\* Min. Samml. Strassburg, p. 110.

† Zeitschr. Kryst., vol. viii, p. 577.

‡ Földtany Közöny, xxi, p. 1.

## SCIENTIFIC INTELLIGENCE.

## I. CHEMISTRY AND PHYSICS.

1. *On the Existence of Suspended Matter in Flames.*—It has been observed by STOKES that when a beam of sunlight, condensed by a lens, is passed through a candle-flame, the area of intersection of the double cone of light with the luminous envelope is marked by two brighter patches of light of inappreciable thickness which exhibit the polarization of light scattered by fine particles—that is to say, when viewed in a direction perpendicular to the incident light it is polarized in a plane passing through the beam and the line of sight. These patches can be made more conspicuous by viewing the whole through a cell containing copper-ammonium sulphate solution, or through cobalt-glass. The same phenomenon is shown by a luminous gas or ether flame but not by the blue base of a candle flame or by a Bunsen flame, even when rendered luminous with sodium chloride, or by an alcohol flame or by an ether flame just expiring for want of air. The separation of carbon, or carbon associated with hydrogen, thus rendered evident by its polarizing effect on light, is due to the action on the volatile carbon compounds, in the absence of a sufficient supply of oxygen to effect complete combustion, of the heat evolved by the more complete combustion at the base of the flame. In the case of the dying ether flame, the heat is probably distributed over too large a mass of inert gases to effect the decomposition. The thinness of the stratum of glowing carbon is probably due to the combined attack of oxygen on the outside and carbon dioxide on the inside.—*Chem. News*, lxiv, 167; *J. Chem. Soc.*, lxii, 111, February, 1892. G. F. B.

2. *On the use of Surface Tension in Analysis.*—It is well known that any liquid may be made to roll upon itself in drops, these drops being separated from the main body of the liquid by a thin stratum of vapor. GOSSAERT has applied this fact to the detection and estimation of impurities in liquids, and finds it of special value in the case of spirituous liquors. For this purpose a drop is allowed to fall from the height of a millimeter upon the concave meniscus at the edge of the vessel containing the liquid. It is preferable to use a vessel having sloping sides so that the meniscus has a hyperbolic section. By the addition of such substances as citric acid or glycerin, the liquid is rendered viscous. If two pure liquids be used, the separating film of vapor is immediately absorbed and the drops of one liquid never roll upon the other. If however the supporting liquid contains an impurity, test drops of this same liquid will roll upon the supporting liquid, provided either that the two liquids contain the same percentage of the same impurity, or that this percentage varies only within fixed limits. With care these limits can be so far reduced that it becomes possible to find the amount of impurity present

within one five hundredth of the whole. Each impurity behaves as if it alone were present.—*C. R.*, cxiii, 537; *J. Chem. Soc.*, lxii, 286, February, 1892.

G. F. B.

3. *On certain Metallic Hydrosulphides.*—On critically examining certain metallic sulphides precipitated in the ordinary way, LINDER and PICTON found that they contained combined hydrogen sulphide, forming in some cases definite and stable compounds. Moreover, higher hydrosulphides were also obtained, of high molecular mass, which under the influence of acids undergo condensation with elimination of hydrogen sulphide and which form solutions of moderate strength. When neutral solutions of certain metallic salts are allowed to run into a solution of hydrogen sulphide in excess, a solution is obtained, clear by transmitted light, which in some cases can be freed from its uncombined hydrogen sulphide by a current of hydrogen without causing precipitation. Acids, however, and metallic salts of inorganic acids, caused precipitation. To eliminate the production of acids the metallic hydrates or sulphides suspended in water were treated with hydrogen sulphide and solutions were obtained which were clear by transmitted light although strongly fluorescent. The authors conclude (1) that almost all the metals precipitable by hydrogen sulphide are capable of forming hydrosulphides, (2) that in some cases they are definite compounds fairly stable though of high molecular mass, (3) that acids cause these hydrosulphides to lose a part of their hydrogen sulphide, thus producing compounds of progressively higher molecular mass, (4) that by dissolving the precipitated sulphides in hydrogen sulphide water solutions are obtained which show no tendency to deposit any precipitate even after months of standing, (5) that these experiments support the conclusion that sulphides themselves are in most cases polymerides of a very high molecular mass, (6) that hydrosulphides of copper  $(\text{CuS})_7 \cdot \text{H}_2\text{S}$ ,  $(\text{CuS})_9 \cdot \text{H}_2\text{S}$ ,  $(\text{CuS})_{22} \cdot \text{H}_2\text{S}$ , and hydrosulphides of mercury  $(\text{HgS})_{31} \cdot \text{H}_2\text{S}$  and  $(\text{HgS})_{62} \cdot \text{H}_2\text{S}$  have actually been obtained, and (7) that bismuth seems incapable of forming a hydrosulphide.—*J. Chem. Soc.*, lxi, 114, February, 1892.

G. F. B.

4. *On the Physical Constitutions of certain Sulphide Solutions.*—PICTON has submitted the hydrosulphide solutions, obtained as above, to a careful examination in order to test the question whether they are actual solutions or whether they contain the solid only in a very fine state of suspension. An arsenide acidified with hydrogen chloride and the liquid allowed to run into hydrogen sulphide water, readily gives a solution containing about five grams of sulphide in the liter; while in the case of mercuric sulphide thus treated, the solution contains ten grams to the liter. Examined with the microscope, under a power of 1000 diameters, the entire field is seen to be filled with exceedingly minute particles in very rapid Brownian movement. On filtration through a porous cell, the liquid came through colorless. Two solutions were obtained with arsenic; one ( $\alpha$ ) prepared by

running a solution of arsenous oxide in acid potassium tartrate into hydrogen sulphide water, the other ( $\beta$ ) by similarly treating a solution of arsenous oxide in caustic soda. Both these solutions have a clear yellow color by transmitted light and are strongly fluorescent. The  $\beta$  solution keeps rather better, depositing only a trifling precipitate in a year. On microscopic examination, solution  $\alpha$  was barely resolved with 1000 diameters, solution  $\beta$  not at all. By diffusion, it was observed that the tartrate in solution  $\alpha$  carried out the arsenic particles by its own diffusion. Using Graham's method for solution  $\beta$ , the solution, contained in a wide-mouthed bottle, being placed in a large beaker and covered with water, it was found that after 32 days there was no sign of diffusion; the water remaining colorless and containing no arsenic. Evidently the whole of the sulphide is in a state of suspension. Antimony hydrosulphide solution has a fine orange-red color, only slightly fluorescent. No particles could be detected by the microscope at first, but after dialyzing for ten days they appeared, the whole of the sulphide being precipitated when the dialysis became complete; showing a progressive condensation. No diffusion was observed into a tartrate solution, but when a calcium light beam was sent through the antimony solution, as in Tyndall's experiment, the track of the beam was marked by a beautiful soft red glow, the light of which was completely polarized. Hence the solution has no true fluorescence, but consists of exceedingly minute particles in suspension. No filtration of the solution took place through a porous cell, nor did its coagulation develop heat. A third arsenic solution  $\gamma$  was then prepared, from an aqueous solution of arsenous oxide. It resembles the other arsenic solutions, but is stronger containing 11 or 12 grams of sulphide in a liter. Only a mere trace of precipitate occurred in four months. Under the microscope no particles could be detected, but distinct diffusion was observed. The beam of light gave a soft yellow glow completely polarized. The author concludes that "there seems to be no satisfactory reason for imagining the existence of any sharp boundary between solution and pseudo-solution. It is quite possible that the one merges by imperceptible gradations into the others."—*J. Chem. Soc.*, lxi, 137, February, 1892.

G. F. B.

5. *On Solution and Pseudo-solution.*—Continuing the above researches, PICTON and LINDER have studied the character of a variety of colloidal solutions. The solutions of mercury, antimony and arsenic hydrosulphides already examined present a series passing from matter in a state of subdivision not too fine to allow of its observation under the microscope, to particles so fine as to diffuse after the manner of ordinary solutions. Indeed arsenic  $\alpha$  is made up of particles just visible under the microscope, arsenic  $\beta$  contains no visible particles, while arsenic  $\gamma$  consists of particles so minute as to be diffusible. Mercuric sulphide dissolves in hydrogen sulphide water, and the vibrating particles are readily seen under the microscope. This state of pseudo-solu-

tion may possibly merge gradually into that of true solution by carrying the subdivision farther and farther until finally perhaps we may have the substance dissociated into ions. Graham supposed the non-dialyzability of colloids to be due to the size of their molecules, which were too large to pass through the pores of the membrane. Of the colloidal solutions examined by the authors, ferric hydrate, dissolved in ferric chloride, yielded a fluorescent solution in which no particles could be detected under the microscope, but which showed a dense polarized glow when examined with a beam of light. After being dialyzed, it could not be filtered through a porous cell nor did it diffuse in water. In presence of hydrogen chloride, silicic acid showed no luminous beam and passed readily through a porous cell. A dialyzed portion gave a feebly luminous beam. Molybdic acid gave only a very faint track of light. Cellulose dissolved in Schweitzer's solution showed a well marked glow as did also soluble starch. The latter solution did not diffuse. Congo-red in neutral solution gave a well marked polarized luminous beam but did not diffuse nor filter through a porous cell. In alkaline solution it filtered through a porous cell, but showed no luminous beam. Oxyhæmoglobin in water gave a luminous beam perfectly polarized, but did not filter through a porous cell. Magdala-red gave a non-polarized beam and readily filtered through a porous cell. In these experiments we pass from obvious suspension to colloidal solution, from colloidal solution to non-electrolytic crystallizable solution and from these it is probably only one step farther to electrolytic solutions. This change may be regarded as continuous. The case however is not one of mere suspension. There must surely be some attraction chemical in its nature, between the molecules of water or of hydrogen sulphide on the one hand and those of mercuric sulphide on the other. So that in every case of so-called very fine suspension there is a certain degree of molecular attraction between the suspended solid and the solvent. The authors therefore consider that they have made out a good *primâ facie* case for the belief that there is a continuous series of grades of solution passing without break from suspension to crystallizable solution.—*J. Chem. Soc.*, lxi, 148, February, 1892.

G. F. B.

6. *Methods of Gas Analysis.* By Dr. WALTHER HEMPEL. Translated from the 2d German Edition by L. M. DENNIS. 12mo, pp. xvi, 384. London and New York, 1892 (Macmillan & Co.).—Those who have favorably known Dr. Hempel's book in the original will welcome its appearance in English; especially so since the translation has had the benefit of the author's personal revision. It is a standard book on the subject of gas analysis and in the new edition, the improved method of air analysis devised by Pettersson is given. There is also a valuable chapter on determining the calorimetrical power of fuel. The translator has presented the author's meaning clearly and accurately.

G. F. B.

7. *Leçons sur les Métaux.* Par ALFRED DITTE. Second Fascicule, 4to, pp. 64, 667. Paris, 1891. (Vve Ch. Dunod.)—We have already noticed the first part of this excellent and exhaustive work. The second part sustains fully the high standard of excellence previously attained. It begins with magnesium, zinc and cadmium, then treats of the iron group of metals, and of aluminum, then considers the rare elements of the cerium and yttrium groups, then antimony, tin, bismuth, tungsten, molybdenum, vanadium, silver, lead, mercury, copper, gold and the platinum group. As in the earlier part the thermochemical relations are given in each equation and the reactions of formation of compounds are well developed.

G. F. B.

8. *Solutions* by W. OSTWALD, Leipzig; being the Fourth Book with some additions of the second edition of Ostwald's *Lehrbuch der allgemeinen Chemie*. Translated by M. M. Pattison Muir, Cambridge. 316 pp. 8vo. London and New York, 1891 (Longmans, Green & Co.) The subject of solutions is at once one of the most interesting and difficult of those which belong in common to Physics and Chemistry. It is one, moreover, in which very rapid progress has been made of recent years largely as based upon the theory of solutions founded by van't Hoff. The presentation of the whole subject in its modern form is hence a great service to English-speaking students and this work must receive from them a warm welcome. As stated above, the volume is a translation of part of the last edition (1890) of Ostwald's great work on Chemistry, and has gained greater unity and completeness from the able work of the English editor as well as through the revision by the author.

## II. GEOLOGY AND NATURAL HISTORY.

1. *Ueber Tertiärpflanzen von Chile*; von H. ENGELHARDT. *Abhandlungen der Senckenbergischen naturforschenden Gesellschaft*, Band xvi, Frankfurt a. M., 1891, S. 629-692, pl. i-xiv.—This memoir, announced a year earlier in *Isis*, describes the fossil plants collected by Dr. Ochsenius chiefly at Coronel and Lota in the province of Concepcion on the bay of Arauco, west coast of Chili, a few from Punta Arenas in the Straits of Magellan. The deposits are of Tertiary age, believed by the author to be Lower Miocene (Oligocene) or possibly Upper Eocene. One hundred and one species are distinguished, only one of which, *Chondrites subsimplex* Lx., from the Laramie of Raton mountain, New Mexico, was previously known. There are four ferns, one cycad, two palms, one conifer (*Sequoia*), one unnamed species of *Ephedra*, and two fruits (*Carpolites*); the rest are all dicotyledons and consist of leaf impressions only, many of which, however, are well preserved. In determining these latter the author has been guided by the hypothesis that they ought to represent the ancestors of now living South American forms, and has referred the greater part of them to genera inhabiting that continent, chiefly

its tropical parts, arguing that they have migrated northward in later times with the gradual advance of the reduced temperatures in temperate latitudes. The deposits were laid down, according to him, anterior to the Andean uplift, and the genera represent mainly hydromegatherms of Candollean nomenclature, probably grown on low shores or islands in a warm moist climate. Whether he has carried this theory too far can only be decided by the subsequent discovery of more abundant material from these and other deposits. Certain it is that its adoption in this work furnishes a new basis for future investigations and can but lead to important results. For example, it must suggest to those engaged on the fossil floras of the Rocky Mountain region of North America the importance of comparisons with tropical American genera. Hitherto very little has been done in this direction and our investigations have followed too closely the lines of European authors. Many of the Chilian forms bear a close resemblance to some of the most problematical ones from the Fort Union and Laramie groups, as yet chiefly unpublished. Among these are some of those referred by Engelhardt to *Tetracera*, *Triumfetta*, *Ouratea* (*Gomphia*), *Casearia*, *Myristica*, *Phœbe*, *Omphalea*, and *Algernonia* (*Tetrapandra*), which have not hitherto figured in North American paleobotany. L. F. W.

2. *Miocene Plants from Northern Bohemia—Ueber fossile Pflanzen aus tertiären Tuffen Nordböhmens*; von H. ENGELHARDT. Ges. Isis in Dresden.—Abhandl. 3, 1891, pp. 20–42, pl. i.—*Ueber die Flora der über den Braunkohlen befindlichen Tertiärschichten von Dux*; von H. ENGELHARDT. Nova Acta der Ksl. Leop.-Carol. Deutschen Akad. d. Naturforscher, Bd. lvii, No. 3, 1891, pp. 131–219, pl. iv–xvii.—There is no one to whom the science of fossil plants is more indebted in these days than Prof. Engelhardt for making known the rich Tertiary floras of different parts of the world. His investigations are always painstaking and his illustrations are exceedingly clear and true to nature. In these two papers he gives another chapter of the interesting history of the ancient vegetation of northern Bohemia, already pretty thoroughly brought out by his previous labors and those of Ettingshausen and others. Seventy-nine species are treated in the first, four of which are new. They come from four different localities: Lieberwerd, Duppau, Holoikluk, and Salesl. The lignites of Dux, treated in the second and much larger memoir, yield him 177 species and form the subject of an exceedingly important contribution. He gives the history of the working of these coal or lignite mines, dating back as far as 1566, and of the accumulation of the paleontological material, chiefly fossil plants, which has now been placed in his hands for determination. A large number of the species are new to science, but the majority were previously known, and from these he concludes that the deposit represents the Middle Miocene or Helvetian stage. A remarkable fact is that he finds American types to predominate, thus confirming the current glacial theory of subsequent dispersion, by

which Europe, on account of the east and west trend of its mountain ranges was cut off from the reception of the polar types in their return from the more southern regions into which they had been crowded by the ice sheet. This renders these forms specially important to the student of American pre-glacial floras, and many of them exhibit close relationships to those of our western deposits.

L. F. W.

3. *Calcareous Algæ.—Fossile Kalkalgen aus den Familien der Codiaceen und der Corallineen*; von Herrn ROTHPLETZ in München. Zeitschr. d. Deutsch. geol. Ges., Bd. xliii, 1891, S. 295–322, pl. xv–xvii.—Dr. Rothpletz has here monographed, chiefly from the standpoint of their internal structure, the two families of fossil Algæ named in the title so far as his material would permit, confirming the views of Meunier-Chalmas and others, that many of the objects heretofore classed with the Foraminifera and other animal groups are really plants. The forms treated are referred to the three genera *Sphærocodium*, *Girvanella*, and *Lithothamnium*, of the last of which he describes fourteen species, and of the other two one each. They range from the Rhetic to the Pliocene, but the *Girvanella problematica* comes from the Ordovician of Ayrshire and was treated by Nicholson, Etheridge and Wethered as of doubtful affinities.

L. F. W.

4. *On the Fructification of Bennettites Gibsonianus*, Carr.; by H. GRAF ZU SOLMS-LAUBACH. Annals of Botany, vol. v, November, 1891, pp. 419–454, pl. xxv, xxvi.—A notice of this memoir as it appeared in the Botanische Zeitung in 1890 will be found in this Journal for April, 1891 (vol. xli, p. 331). As it is based entirely on English material the editors of the Annals have regarded it as worthy of reproduction in English for the benefit of its readers for whom it might be otherwise inaccessible. The translation was intrusted to Mr. H. E. Garnsey of Magdalen College, Oxford, who has recently translated the Count's *Einleitung in die Phytopaläontologie*. As was pointed out in a recent review of his translation of the latter work (Science, vol. xviii, Dec. 25, 1881, p. 361), this memoir contains important modifications of the views of the author therein expressed which should have been introduced into the English edition.

L. F. W.

5. *Le Nelumbium Provinciale des Lignites Crétacés de Faveau en Provence*; par le Marquis G. DE SAPORTA. Mémoires de la Soc. Géol. de France, tome i, Fasc. 3, Mém. No. 6, Paris, 1890, pp. 9, pl. xii–xiv.—These deposits have hitherto furnished very little paleontological evidence of their age which has been in considerable doubt. M. de Lapparent placed them in the Danian or extreme upper Cretaceous above the Maestricht beds, while the present author regards them as occupying the level of the Gosau chalk equivalent to the Campanian of the French geologists. The remarkable aquatic plant here described cannot be said to throw much light on this question although it bears the marks of a greater antiquity than any other of its kind thus far found in the fossil state. But besides the *Nelumbium*, the Marquis Saporta

figures in this paper from the same beds several other apparently aquatic plants, a palm, and three conifers. Two of these latter, *Brenelopsis Hoheneggeri* and *Geinitzia cretacea* are indicative of an even earlier period.

L. F. W.

6. *Recherches sur la Végétation du niveau Aquitainien de Manosque*; par le Marquis G. DE SAPORTA. Mémoires de la Soc. Géol. de France, tome ii; I, Nymphéinées, Fasc. i, Mém. No. 9, pp. 22, pl. iii-vi; II, Palmiers, Fasc. 2, Mém. No. 9, pp. 23-34, pl. ix-xi.—The first of these papers treats of some important recent discoveries of Nymphaeaceus plants in the beds of Manosque, Céreste, and Bois d'Asson, chiefly by local collectors, the principal of whom are M. Nalin and Mlle. Rostan. The flora of these deposits as previously published by the author is reviewed and the new species described and fully illustrated. These include five species of Nymphaea, one of Anæctomeria, and one of Nelumbium. Associated with these was found a Ceratophyllum (*C. aquitanicum*), and the view is expressed that this anomalous genus is really related to the Nymphaeaceæ. This view had already been suggested by Brongniart based on the similarity of the seeds, but most authors put this genus in an apetalous order by itself, though Baillon places it in the Piperaceæ. The second of those memoirs deals in like manner with the palms of these collections, of which there is one species each of the genera Flabellaria, Sabal, and Phœnicites. The author indulges in some important speculations upon the origin and development of these elements of the European Tertiary flora and its relations to that of the present day.

L. F. W.

7. *The Fauna of British India, including Ceylon and Burma*. Mammalia, Part II, by W. T. BLANFORD, F.R.S. Published under the authority of the Secretary of State for India in Council.—Part I. of Dr. Blanford's systematic work on the Mammals of India appeared in 1888, and is noticed in vol. xxxvi, of this Journal. This Second Part of this valuable treatise which concludes the work, making in all a volume of 618 pages, contains descriptions of the Cheiroptera, Rodentia, Ungulata (including the Pachydermata and Ruminantia of Cuvier), Cetacea and Edentata. Many figures illustrate the volume.

8. *Inheritance of Acquired Characters*.—Presidential address of D. G. ELLIOT, at the Annual Meeting of the American Ornithologists' Union, N. Y., Nov. 8, 1891, 28 pp. 8vo. From the January number, vol. ix, No. 1, of the Auk.—This address presents facts chiefly from ornithology in favor of the inheritance of acquired characters, making a successful argument against the views of Prof. A. Weissmann.

## OBITUARY.

SERENO WATSON, Curator of the Harvard University Herbarium, died on March 9th, in his sixty-sixth year. A biographical sketch will be given in a following number.

## A P P E N D I X.

### ART. XLIII.—*Recent Polydactyle Horses*; by O. C. MARSH.

IN this Journal for June, 1879, the writer made a brief summary of the facts then known to him in regard to existing horses with extra digits, especially in relation to the extinct species he had discovered in the Rocky Mountains, and also gave figures of typical examples of existing and fossil forms.\* Since then, he has collected much material bearing on the question, particularly of extinct horses, and an illustrated memoir on this subject has long been in preparation. Of recent forms, a number of polydactyle specimens have likewise been secured, some of which show new anatomical points of interest, and are discussed in the present communication.

In the article above cited, various recorded instances of extra digits in the horse are mentioned, some dating back to the beginning of the last century. A much earlier notice is the account of the famous steed of Julius Cæsar, given by Suetonius (*de vita Cæsaris*, LXVI), to which a classical friend has recently called the attention of the writer. According to the historian, Cæsar “used to ride a remarkable horse, which had feet that were almost human, the hoofs being cleft like toes. It was born in his own stables, and as the soothsayers declared that it showed its owner would be lord of the world, he reared it with great care, and was the first to mount it; it would allow no other rider.”

It is now known to every one familiar with the modern horse, that the main, functional toe of each foot is the third digit, corresponding to the middle finger of the human hand and foot. In addition to these, two “splint bones,” one on each side of the main cannon bone, are present beneath the skin. It is not so well known, however, that the latter are the remnants of two other toes possessed by ancestors of the horse.

\* Polydactyle Horses, recent and extinct, this Journal, III, vol. xvii, p. 497, June, 1879; see also by the writer, *New Equine Mammals from the Tertiary*, *Ibid.*, vol. vii, p. 247, March, 1874; *Fossil Horses in America*, *Am. Naturalist*, vol. viii, p. 288, May, 1874; and *Introduction and Succession of Vertebrate Life in America*, this Journal, vol. xiv, p. 338, November, 1877.

These slender metapodial bones still represent the second and fourth digits, and are shown in their usual position, in figures 1 and 2. One or more of these splint bones may become enlarged below, and support phalanges, forming another digit beside the main one, either beneath the skin, or, more commonly, developing into a small, external toe with hoof.

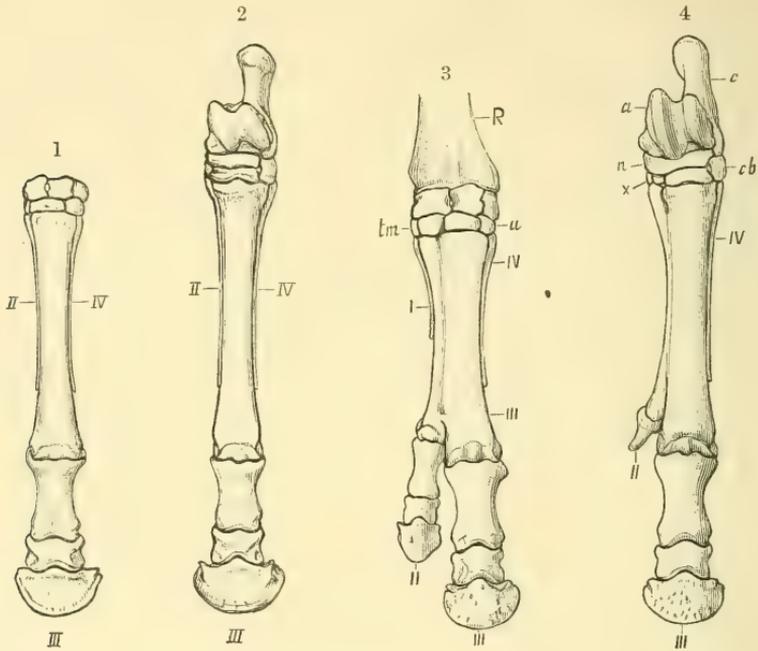


FIGURE 1.—Fore foot of modern horse (normal).

FIGURE 2.—Hind foot of same animal.

FIGURE 3.—Fore foot of "Clique, the horse with six feet" (polydactyle).

FIGURE 4.—Hind foot of same animal. All left feet, and one eighth natural size.

*a*, astragalus; *c*, calcaneum; *cb*, cuboid; *n*, navicular; *R*, radius; *tm*, trapezium; *u*, unciform; *x*, cuneiform; I, first digit; II, second digit; III, third digit; IV, fourth digit

The occurrence of such extra digits in the recent horse is much more frequent than is generally supposed. Since the attention of the writer was first called to the subject, he has seen and examined a large number of living animals with this peculiarity, and has had sent to him several interesting specimens of the same character. He has likewise received photographs, drawings, and detailed descriptions of various other examples, the authenticity of which cannot be questioned. This material, together with not a few published accounts, forms a fair basis on which to investigate the subject. This, however, would require much time in itself, especially if it led into the question whether polydactylism is atavism, and other

allied topics. In the present paper, it is intended merely to state the more important facts, and what they indicate, leaving the full discussion for another occasion.

The cases of supernumerary digits in the existing horse now known to the writer may be roughly classified, as follows:

(1) An extra digit on one foot. This is always much smaller than the main, or third, digit, the largest seen being about one half its size, and the smallest, very diminutive. This extra toe is almost invariably on the inner side of the main digit, and usually on the fore foot. Not infrequently it may be entirely beneath the skin, the only external evidence of it being a prominence, which, on close examination, will often be found to contain, below the splint bone, two or more movable phalanges, but sometimes only a single one, and very small.

(2) A corresponding extra toe may be present on the other fore foot, equally developed with the opposite one, but occasionally much smaller, or even concealed under the skin.

(3) A second extra digit may exist with those above described, but outside the main digit. This toe, as a rule, is smaller than the inner one, but may equal or exceed it.

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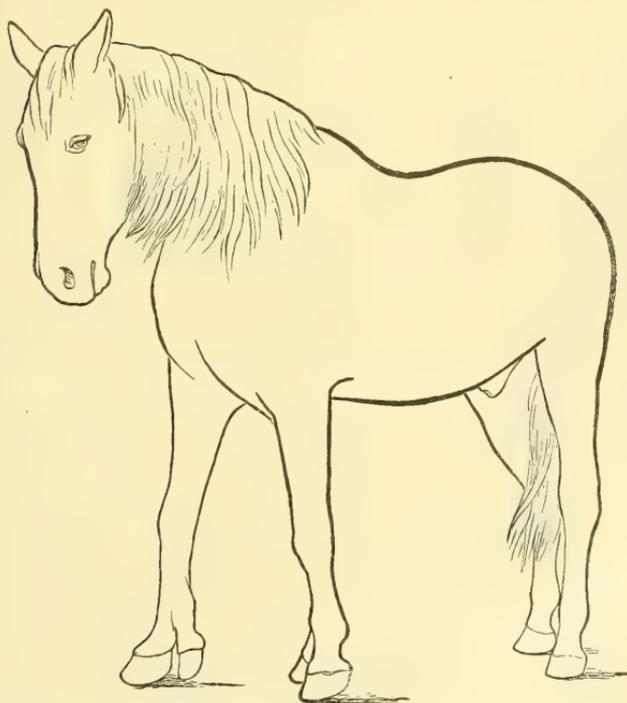


FIGURE 5.—“Clique, the horse with six feet,” showing two extra digits.

(4) With the extra inner toes of the fore feet, another of equal or smaller size may be present on one or both of the hind feet, almost always on the inside. Usually, however, these posterior toes are much smaller, and often beneath the skin, when the anterior extra digits are well developed. An example of the equal development of all the inner toes, fore and aft, is shown below in figure 6, which represents an animal examined during life, by the writer. Occasionally the hind feet may each have two extra digits, while the fore feet have only one, as in the horse shown in figure 7.

(5) In rare cases, both fore and hind feet may each have two extra digits fairly developed, and all of nearly equal size, thus corresponding to the feet of the extinct *Protohippus*, which are represented in the diagram on page 355.

(6) Sometimes, besides the extra toes above described (which appear to be always the second and fourth), the first digit, or pollex, may be represented by its metacarpal, supported by a distinct trapezium, all beneath the skin. In such cases, the fifth digit, corresponding to the little finger of the human hand, alone is wanting. Three examples of this four-toed polydactylism are preserved in the Yale Museum, and one of them is shown in figure 3. This type is of special importance, and is described more fully below.

The horse which best represents this type was examined casually by the writer when it was alive, and at its death was presented to him for the Yale Museum by the owner, Theodore F. Wood, of New Jersey. The animal was widely known to the general public as "Clique, the horse with six feet," having been exhibited for many years, in this country and in Europe. He was said to be from Texas, and at his death, in January, 1891, was very old. This horse, when alive, showed an extra digit of good size on the inside of each fore foot, and a corresponding prominence on each of the hind feet, but no free lateral toe. An outline of this horse is shown in figure 5.

The first digit of the fore foot, corresponding to the thumb of the human hand, was not apparent externally, but, by close examination, could be detected beneath the skin, where the upper part of the splint bone appeared as a ridge. The second digit was the free extra toe, which attracted especial attention from its large size, and pendent, elongated hoof. Its metatarsal is closely united to the main cannon bone, which thus seems much broader than usual. The fourth digit appears only as the usual splint bone, and of the fifth, there is no indication whatever. The hind feet showed no peculiarity except the inner prominence above the fetlock, formed by the lower end of the second metatarsal, with a single movable

phalanx and its sesamoid. In other respects, the limbs were well shaped, and in fair condition for so old a horse.

After the death of the animal, a careful dissection of the feet was made, and several points of interest became apparent. First of all, in the fore feet, the presence of the first digit was demonstrated by a robust, splint metacarpal about half the length of the main cannon bone. This splint was supported above by a large trapezium having the usual articulations of that bone in its full development. The first digit, as present in the left foot of this horse, is shown above in figure 3. In the opposite fore foot, this digit is also represented, and equally developed, as seen in figure 8.

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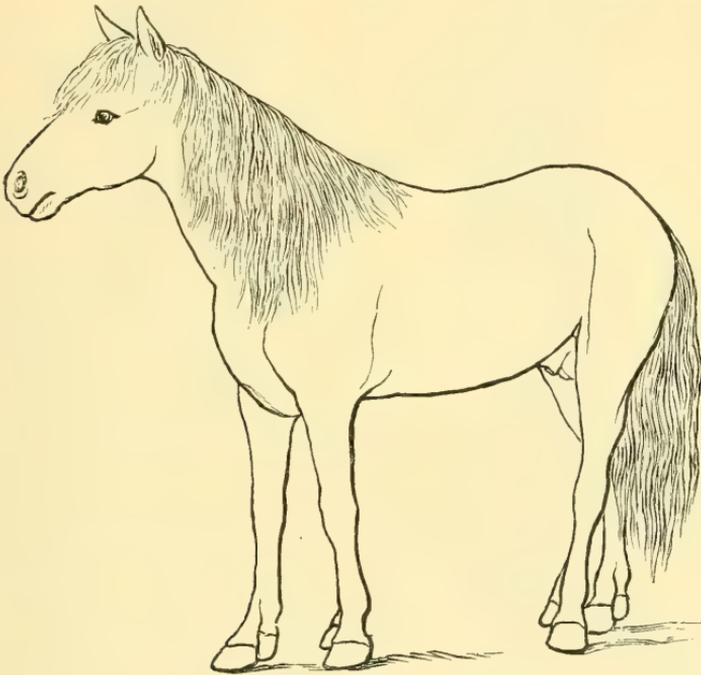


FIGURE 6.—“Eight-footed Cuban horse,” with extra digit on each foot.

The second metacarpal of the left fore foot is quite large, and fully developed above and below, but its shaft is coëssified with the main metacarpal. The line of the suture uniting the two is still strongly marked, as shown also in figure 3. The phalanges and sesamoids are all well developed, and had this toe been long enough to reach the ground, it would have afforded a strong lateral support to the main digit. The latter possesses no marked peculiarities except that the outer side is

more developed, especially in the coffin bone. The fourth digit is represented by a strong splint bone similar to that in the normal foot of the existing horse. The opposite fore foot appears to correspond in all respects with the one here described and figured.

The hind feet of this animal present some further points of importance. The first digit is wanting, but the first cuneiform bone is present, and well developed.\* The second digit is represented by a strong, complete metatarsal, coössified along its main shaft with the large cannon bone of the third digit, but with both extremities free. It was supported above by

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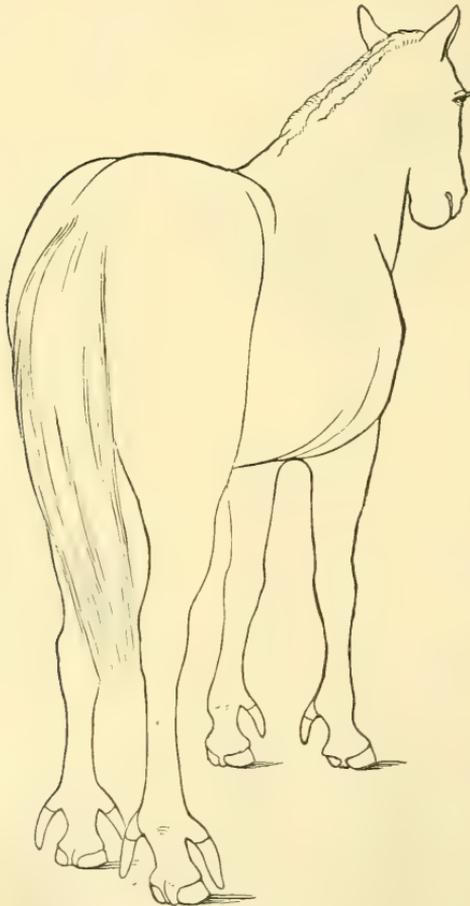


FIGURE 7.—“Horned horse from Texas,” showing six extra digits.

\* The name cuneiform as applied to the ulnare bone of the carpus is misleading, and should be discontinued, as the same word is used for two or more bones in the second row of the tarsus. The name pyramidal employed by many anatomists is not open to this objection, and its use for the ulnare is to be recommended.

two united cuneiform bones. The lower extremity of this metatarsal carried a single phalanx, with a posterior sesamoid evidently formed of two bones. The main cannon bone and its phalanges show no marked peculiarities except some obliquity. The fourth digit is represented by a large splint metatarsal, as shown in figure 4. The opposite hind foot appears to be similar in all respects, except that the three small cuneiform bones are separate, as shown in figure 9.

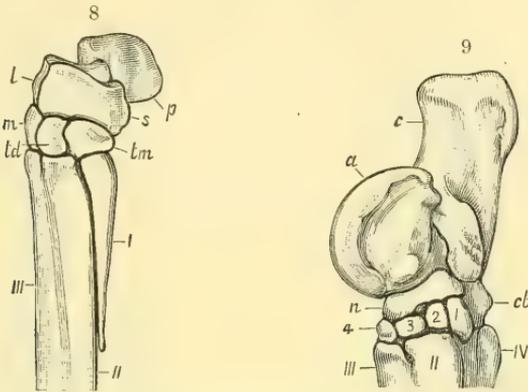


FIGURE 8.—Right carpal and metacarpals of "Clique."

FIGURE 9.—Right tarsals and metatarsals of same animal. One fourth natural size.

*a*, astragalus; *c*, calcaneum; *cb*, cuboid; 1, 2, 3, 4, cuneiform bones; *l*, lunar; *m*, magnum; *n*, navicular; *p*, pisiform; *s*, scaphoid; *td*, trapezoid; *tm*, trapezium.

In no case examined by the writer has there been conclusive evidence of any extra digit except one of a true pentadactyle foot, such as is now known in the ancestry of the horse. In every specimen examined, where the carpal or tarsal series of bones were preserved, and open to inspection, the extra digits were supported in the usual manner. No instances of true digital division were observed, although such cases might be expected. It is noteworthy that none of the extra toes examined represents the fifth digit, although the reappearance of this rather than the first might naturally be looked for. No digit has been noticed with more than three phalanges.

A large majority of the polydactyle horses known to the writer in this country, have been raised in the Southwest, or from ancestry bred there, so that their connection with the Mustangs or semi-wild stock of that region becomes more than probable. It is well known that the tendency to reversion is much stronger where animals run wild, and this fact must be taken into consideration in discussing the present question, for the late ancestors of the Mustang were certainly wild for at least several hundred years.

No example of extra digits has been observed by the writer in any wild species of existing equine mammals of the old world, or their immediate descendants, although it is evident that such cases are probable, and careful observation would doubtless bring them to light, especially if made in the native haunts of those animals.

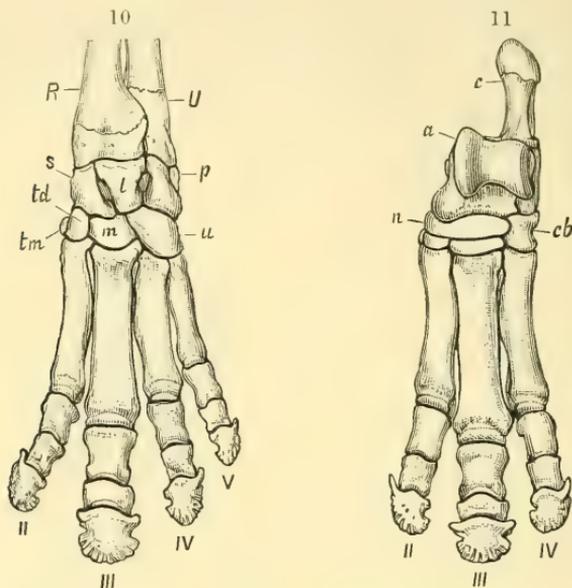


FIGURE 10.—Left fore foot of recent Tapir (*Tapirus indicus*, Cuvier).  
FIGURE 11.—Left hind foot of same animal. One fifth natural size.

Many examples of polydactyle feet in the recent horse, preserved in museums, have been cut off below the carpus or tarsus, and thus the real significance of the extra digits has been lost. The whole carpal and tarsal series, and the distal ends, at least, of the bones above them, may be important elements in the problem to be solved, if reversion or atavism is to be considered.

In reviewing what is now known of the extra digits in the existing horse, a few points are manifest, which could not have been anticipated from previous knowledge of the perissodactyle foot :

(1) The presence of a first digit in the fore foot, represented by a strong, styliform metacarpal supported by a well-developed trapezium, with its usual articulation, in the same foot in which the fifth digit is wanting.

(2) The frequent appearance of the second digit as a distinct, free toe in one or more feet, and the large size it attains, while the other digits, except the third, are aborted or wanting.

(3) The presence of five distinct bones in the second row of the tarsus. One of these is the cuboid fully developed; next, the external cuneiform bone supporting the great metatarsal; then three smaller bones on the tibial side. These five tarsals correspond either to those in the reptilian foot, or the first may be regarded as a sesamoid, and the cuboid, as double (including the fourth and fifth), as it is now usually considered by anatomists. Another explanation may be suggested; namely, that the inner, pendent bone is a remnant of the first metatarsal. Such a rudiment apparently exists in some fossil horses, and its appearance in the hind foot of a recent animal which had the first digit of the fore foot so well represented would not be strange. The bone usually regarded as the inner cuneiform in the existing tapir and rhinoceros may, perhaps, include the same remnant. In the modern horse, this bone is sometimes double, but the specimen represented in figure 9 shows that it may be composed of three elements.

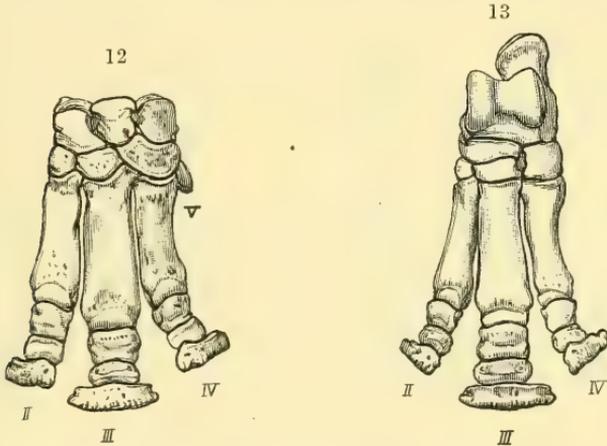


FIGURE 12.—Left fore foot of *Rhinoceros bicornis*, Linnaeus.

FIGURE 13.—Left hind foot of same animal. One eighth natural size.

The frequent reappearance of the second digit as an extra toe in the modern horse would seem to indicate that this feature was functional in a late ancestor, but no fossil equine with two toes has yet been found.\*

The presence of four toes in the fore feet, each supported by its true carpal bone, is a fact of much importance, and is clearly a case of reversion. The four distinct cuneiform bones

\* A small species of *Pliohippus* from the Pliocene of Oregon may be an exception. An incomplete hind foot in the Yale Museum shows the second metatarsal as a splint bone, the third very long and slender, and the fourth so well developed that it probably supported phalanges. This may also be a case of reversion. The species is new, and may be called *Pliohippus gracilis*.

in the hind foot of the same animal offer another point of interest, especially in connection with the corresponding carpal series.

The hoofs of the extra digits of the modern horse vary much in size and form at birth, and are subsequently affected by the surroundings of the animal, and the care it receives. If these hooflets are low enough to reach the ground, their growth is checked by wear, like the large hoof, although in less degree. As the main hoofs will become of abnormal length, and more or less twisted, if the animal is confined to soft, boggy ground, so the extra hoofs having no wear, and receiving no pruning, often become much elongated and curved, or by trimming may assume the form of a spur or horn. The "horned horse from Texas," shown in outline in figure 7, probably received some attention of this kind, as the hooflets are much more pointed than any examined personally by the writer.

The cleft seen in the last phalanges, or hoof bones, of *Orohippus* and other fossil equines, and occasionally present in the coffin bone of the modern horse, is interesting, but of no special significance. It certainly does not represent the union of two digits, as frequently supposed, and sometimes asserted by scientific writers.

The tapir has the most primitive feet of existing perissodactyles, and most like those of the early predecessors of the horse. The feet of the Middle Eocene *Orohippus* were, in fact, very similar in structure, as will be seen by comparing the manus and pes of each as shown in figures 10-11, and 16-17. The living rhinoceros has feet of the same general type, but less primitive (figures 12-13), while the modern horse, when normal, has the extreme specialization of the monodactyle foot. The frequent reversion to extra digits indicates a polydactyle ancestry, which is now demonstrated by actual discovery.

The terms *Perissodactyla* (odd-toed) and *Artiodactyla* (even-toed) proposed by Owen, and now in general use to distinguish two great groups of hoofed mammals, are misleading, and a stumbling block to the lay reader, as well as to many popular writers on science. The horse, tapir, and rhinoceros are the only recent examples of the so-called perissodactyles, or odd-toed ungulates, and the pig and peccary are certainly typical artiodactyles. The tapir, however, has four toes in the front foot, while the peccary has three only behind, and these exceptions do not prove the rule, for the number of toes alone has nothing to do with the profound distinctions separating the two groups, at least in all recent forms.

In the horse and its allies, recent and extinct, the axis of each foot passes through the middle of the main, or third, digit, while in all the so-called even-toed mammals, the axis is always along the side of this digit. This is the essential difference between the feet of the two groups.

The names *Mesaxonia* (middle axis) and *Paraxonia* (side axis) proposed by the writer in 1879,\* as substitutes for Owen's terms, are more exact definitions, but thus far have not met with general favor, for it seems almost impossible to dislodge an established error in science. The term "coral insect," for example, of the older writers, still maintains its place in popular science, and even in some modern text books.

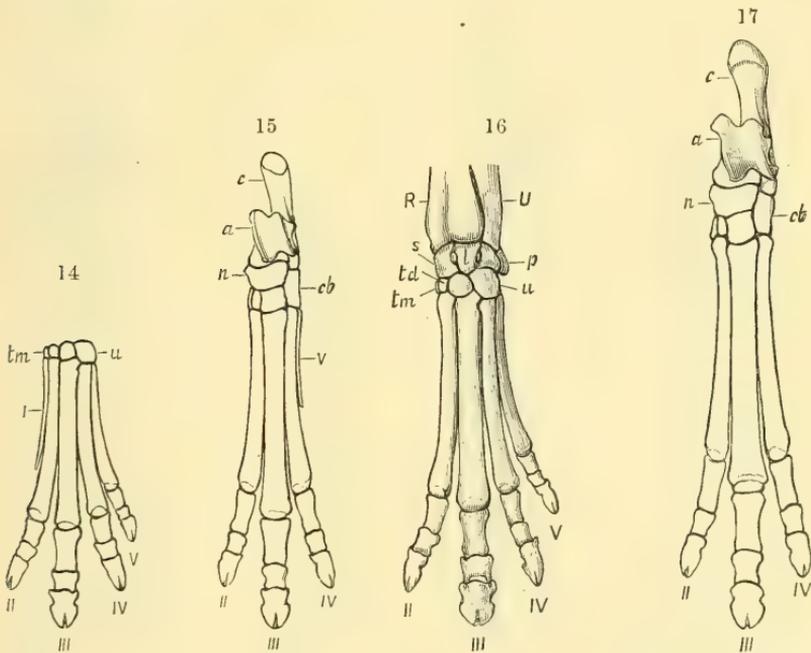


FIGURE 14.—Fore foot of oldest fossil horse, *Eohippus pernix*, Marsh.

FIGURE 15.—Hind foot of same. Lower Eocene.

FIGURE 16.—Fore foot of *Orohippus agilis*, Marsh (type).

FIGURE 17.—Hind foot of same.—Middle Eocene. All left feet, one half natural size.

In explanation of the extra digits of the recent horse, two views have been advanced: (1) that they are reduplications of the main digit, like the occasional sixth finger of the human hand, or result simply from a division of this toe; (2) that they are true cases of reversion to a polydactyle ancestor. The former view was long held by writers on the subject, and

\* This Journal, vol. xvii, p. 501, June, 1879.

is still maintained essentially by some eminent anatomists.\* The large number of cases, however, now investigated by the writer make it probable that, for most instances, at least, the second explanation is the true one.

In the case of horses, recent and extinct, the question of atavism is much simplified, as they start with a pentadactyle form, and each successive change in the modifications of the limbs, and of the feet, and likewise in the dentition, can be traced through a regular series from the early Tertiary down to the present time. Nearly every instance of polydactylism

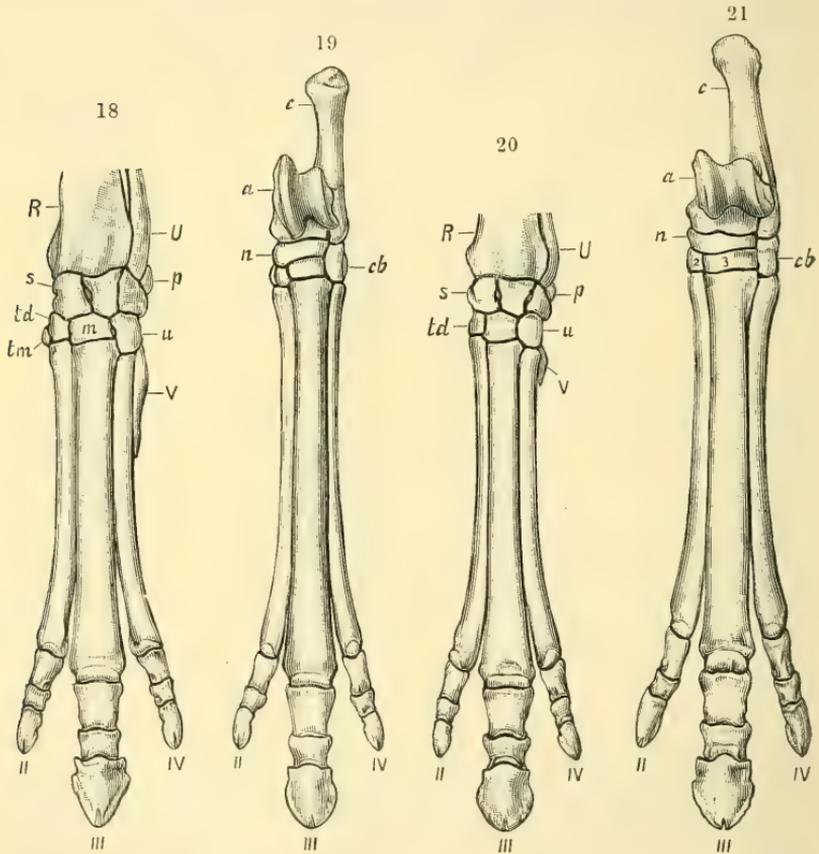


FIGURE 18.—Left fore foot of *Mesohippus celer*, Marsh.

FIGURE 19.—Left hind foot of same. One half natural size. Lower Miocene.

FIGURE 20.—Left fore foot of *Miohippus anceps*, Marsh.

FIGURE 21.—Left hind foot of same. One third natural size. Upper Miocene.

\* Flower, *Osteology of the Mammalia*, p. 296, 1885; and Gegenbaur, *Morphologisches Jahrbuch*, p. 584, 1880.

observed in the modern horse has its counterpart in some extinct species now known, and it is not at all improbable that future discoveries will bring to light examples corresponding to the present apparent exceptions.

All the examples of polydactylism in the horse which the writer has had opportunity to examine critically are best explained by atavism, and many of them admit no other solution. Taken together with the fact now known of their great frequency, they clearly indicate the descent of the horse from comparatively recent polydactyle ancestry.

The writer has traced back the genealogy of the horse through various stages, to a form, *Eohippus*, in which all five toes were represented, and has likewise given an explanation of the change which in succeeding forms has reduced the number to one functional digit, as in the existing horse. It is in these extinct species that the true solution of the problems relating to the extra digits of the modern horse is to be sought. In the various papers cited at the beginning of the present article will be found the main facts relating to the ancestry of the horse as made out by the writer from American forms.

The oldest ancestor of the horse, as yet undiscovered, undoubtedly had five toes on each foot, and probably was not larger than a rabbit, perhaps much smaller. This hypothetical predecessor of the horse can now be predicated with certainty from what is known of the early hoofed mammals. It may be called *Hippops*, and its remains will be found at the base of the Tertiary, or more likely in the latest Cretaceous. A still more primitive ancestral form, and next older in the series of Ungulates, will show the more generalized characters of the group called by the writer *Holodactyla* (Dinocerata, p. 172), from which both the Perissodactyles and the Artiodactyles branched off before the equine line became distinct.

It is impossible to say from what generalized form the horse line first separated, but at present the probabilities point to a genus allied to the Eocene *Hyracotherium*, Owen (1839), as the stem. In the latter genus, the molar teeth are of the bunodont type, the tubercles being conical and distinct. Similar teeth are characteristic of suilline mammals, and from the teeth alone, the two groups could not be distinguished, but it is now probable that the latter appeared as a distinct group later than the equine mammals, and that their oldest representatives were very diminutive in size.

The American representative of *Hyracotherium* was first described by the writer under the name *Helohyus*,\* and another form, nearly allied, as *Thinotherium*, all three being

\* This Journal, vol. iv, pp. 207, 208, September, 1872.

at first supposed to have close affinities with suilline mammals. Some of the latter may, in fact, be included in the species referred to these genera. Various perissodactyle forms, also from the Eocene of this country, have since been described by Cope under the generic name *Phenacodus* (1873), which is clearly identical with *Helohyus*, and some of these have been referred, under the former name, to the equine ancestral line.\* These mammals have been placed by the writer in a distinct family, the *Helohyidae*.†

#### *Helohyidae.*

The *Helohyidae* may with some probability be now regarded as the family from which equine mammals were derived. The members of this group were small perissodactyle mammals, with forty-four teeth without cement, the premolars unlike the molars, and both with short bunodont crowns. The ulna and fibula were complete and separate, and the feet had four or five functional digits. All the known forms are from the Eocene. During Tertiary time, this family apparently separated into various branches, some of which became specialized, and died out, while smaller forms became modified into the lines by which the horse, the tapir, and the rhinoceros gradually developed.

#### *Orohippidae.*

The successors along the first line form a well-marked family, which the writer has called the *Orohippidae*.‡ The representatives of this group were small equine mammals having forty-four teeth without cement, incisors without pit, canine teeth large, and the molar series with short crowns, and the cusps more or less flattened. The ulna and fibula were complete, and there were three or four functional digits in each foot. The members of this family appear to be all from the Eocene or Miocene.

#### *Equidae.*

Next in the succession came the *Equidae*, of which the horse is a typical member. All are large equine mammals, with less than forty-four functional teeth with cement, incisors with pit, canines small or wanting, the molars elongated, and the premolars essentially like the molars. The ulna and fibula are incomplete, and there is but one functional toe on each foot. These mammals lived in Pliocene time, continued on to the present, and are now represented by the horse, ass, zebra, and quagga.

\* W. H. Flower. *The Horse*, London, 1891; also, Madame Pavlow, *L'Histoire Pal. des Ongules*, I-V, Moscou, 1887-1890.

† *This Journal*, vol. xiv, p. 364, November, 1877.

‡ *Ibid.*, vol. vii, p. 249, 1874.

The dividing lines between these three families are not sharply defined, and cannot be, if evolution is true; in fact, the divisions in all classifications of extinct animals are, of necessity, like the book shelves in a library, merely convenient stages for the arrangement of present limited knowledge.

Among the extinct equines known in this country, the first genus of the series is *Eohippus*, described by the writer from the Coryphodon beds at the base of the Eocene (this Journal, vol. xii, p. 401, 1876). This is the oldest and most diminutive form, being about the size of a small fox. There is a diastema between the canine and first premolar, but none between the premolars, which are all unlike the molars. Three species are known. The feet of one species are shown in figures 14 and 15, and those of the others so far as known are similar.

In the next higher horizon of the Eocene, remains of another small equine mammal are found, which may be placed in a new genus, *Helohippus*. The type specimen was described by the writer in 1871, as *Lophiodon pumilus* (this Journal, vol. ii, p. 38), and others have since been found in the same horizon. This genus has a diastema between the first and second premolars, and the last premolar is like the molars. The known representatives of *Helohippus* are about as large as a fox.

The next genus in the series is *Orohippus*, described by the writer from the Dinoceras beds of the Middle Eocene (this Journal, vol. iv, p. 207, 1872). This form is the type of the family *Orohippidae*, and almost every part of the structure of several species is now known. The best preserved specimens show that there is no diastema between the upper premolars, and the third and fourth are similar to the molars. The skull is elongate, and has no antorbital fossa. The fore and hind feet of one species are shown in figures 16 and 17. Several other species are known, all about the size of a fox.

Another allied genus, *Epihippus*, occurs in the Diplacodon beds of the Upper Eocene. This genus, proposed by the writer in 1878 (Proc. Am. Assoc. Adv. Sci., page 236), also shows no diastema between the first and second premolars above or below, and the third and fourth are essentially like the molars. Two species are known, both somewhat larger than those of *Orohippus*, but having the same general structure, although the dentition and feet differ in several respects, being intermediate between that genus and the following.

At the base of the Miocene, in the Brontotherium beds, another equine mammal is comparatively abundant, and has been referred by the writer to a distinct genus, *Mesohippus* (this Journal, vol. ix, p. 248, 1875). The two species known are about as large as a sheep, and the feet of one are shown in

figures 18 and 19. The ulna is complete, but the fibula is not. There is no diastema between the premolars, and the third, fourth, and fifth are like the molars.

In the Upper Miocene of Oregon, the series is continued in *Miohippus*, a genus established by the writer in 1874 for several species found in this formation (this Journal, vol. vii, p. 249). All are much larger than *Mesohippus*, and more specialized in the skull and feet. The latter are shown in figures 20 and 21. The premolars form a continuous series, and three of them are of the molar type. This genus appears to be the American representative of *Anchitherium*, von Meyer (1844), but is somewhat less specialized.

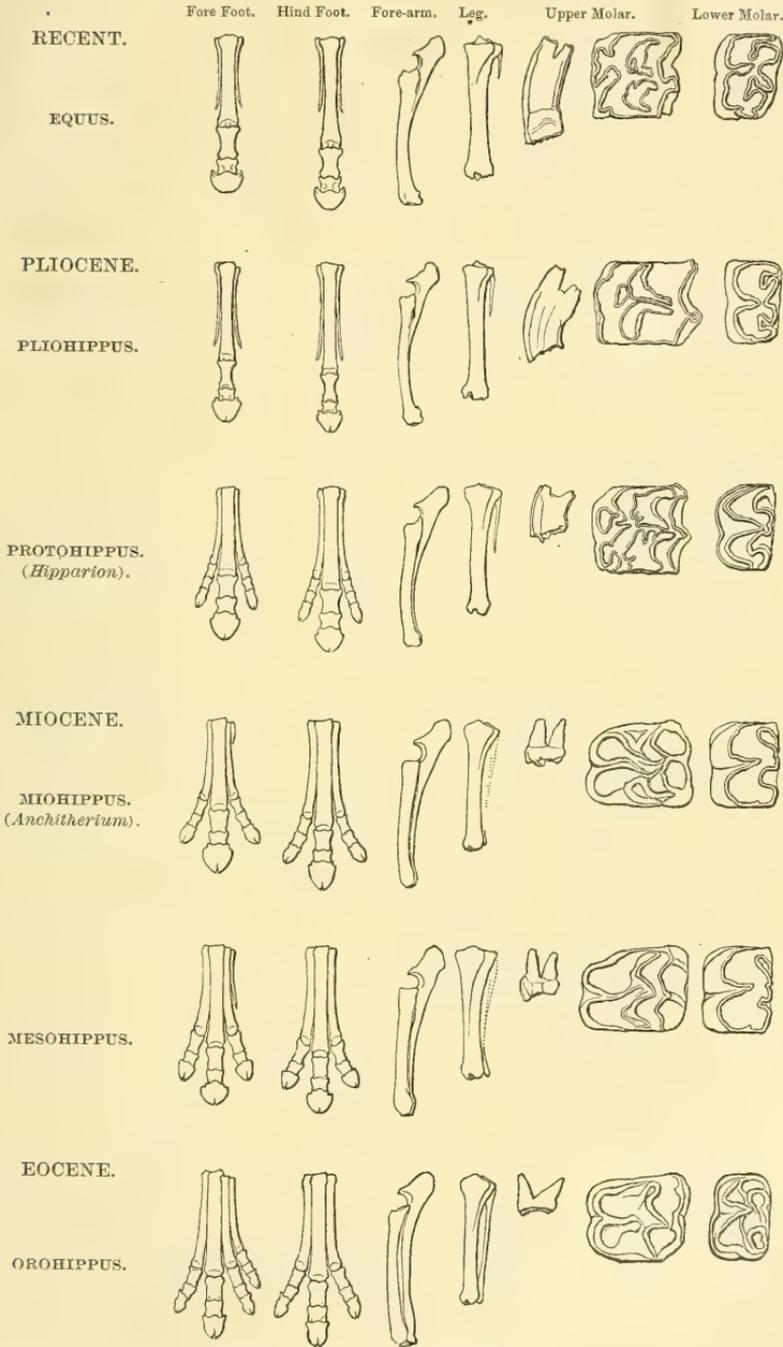
In the early Pliocene of this country, the genus *Protohippus* of Leidy (1858) is especially abundant, and several species about as large as a donkey are known. All have three functional toes on each foot, but these are more nearly of a size than the digits of the European *Hipparion* of Christol (1832). In the later deposits of this formation, three-toed horses are replaced by *Pliohippus*, named by the writer in 1874 (this Journal, vol. vii, p. 252). This genus has many species, all smaller than the horse, but with similar feet. A true *Equus* is entombed in a higher horizon, but apparently became extinct before America was discovered.

The type specimens of all the genera of fossil horses proposed by the writer up to 1876 were carefully studied by Prof. Huxley in that year, and made the basis of one of his New York lectures.\* The diagram shown on page 355 was prepared for that lecture under his direction, from specimens in the Yale Museum collected and described by the writer. It gives the main characters of the genera, and represents clearly the evolution of the horse as then determined from American specimens.

Since then, the writer has made large collections of remains of these and other genera and species, and the whole forms by far the largest series ever brought together. An examination of this collection makes still more evident the line of equine descent on this continent, and the genera since named, and described (*Eohippus*, *Helohippus*, and *Ephippus*), help to complete the series. Many details are yet wanting, but the writer hopes at an early day to bring all the facts together, and make out as far as possible the genealogy of the horse.

New Haven, Conn., March 24th, 1892.

\* American Addresses, p. 88, London, 1877.



GENEALOGY OF THE HORSE.



## ROWLANDITE, A NEW MINERAL!

We have secured the entire available supply of this new and wonderfully interesting mineral (see A. J. S., Nov. '91). Mr. Hidden informs us that it probably contains **twelve new elements** (!!) and that its spectrum embraces 10,000 lines!! An elaborate description by Prof. Rowland and Dr. Hillebrand is promised soon. All the type material not needed for the examination has been purchased by us, and as there is altogether less than five pounds the supply will doubtless prove inadequate to meet the demand. The mineral is found only massive and our specimens are all excellent though necessarily of but medium sizes. Prices, \$5.00 to \$20.00.

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# A. E. FOOTE, M.D.,

MINERALS, SCIENTIFIC AND MEDICAL BOOKS.

4116 Elm Avenue, Philadelphia, Pa.

## THE NEW RUBELLITE.

We have just received a second and larger lot of **Rubellite** from the newly opened locality in San Diego Co., California. In the latter part of March we received fifty pounds of this beautiful variety of Tourmaline and within ten days we sold all but three specimens. More than a week's hard work on the part of our collector is represented in the large consignment which has just arrived and we are informed that it embraces all the best specimens found. Two types predominate. Radial aggregates composed of columnar crystals, the radiations averaging 2 to 5 inches in diameter, often reaching 7 or 8 inches. The other form consists of single crystals thickly scattered through the matrix. In both cases the crystals are bright and well defined, often terminated and averaging one to three inches in length.

There are many variations of these types but all of them present the same exquisite shade of pink in a setting of pale lilac colored Lepidolite, making wonderfully showy specimens of a most attractive species.

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## ENGLISH MINERALS.

A shipment of twenty boxes of minerals collected and purchased by Prof. Foote during the last month in Cornwall and Derbyshire has just reached us. Space will only allow us to mention a few of the many rare and interesting specimens it contains. A fine lot of the rare **Phosgenite** and **Matlockite**; several large scalenohedrons of **Calcite**. Very fine large polished brown **Barites**; a great variety of handsome polished **Fluors** and variegated **Marbles**; Satin spar, crystallized **Fluors**; a fine set of **Hydrocarbons** and many others, all of which were taken from the mines years ago.

From Cornwall: rare forms of **Siderite**; **Chalcosiderite**; **Connellite**; **Uranochre**; **Stannite**; crystallized **Wolframite** and **Arsenopyrite**; a great variety of **Fluors**; **Bornite**; **Cassiterite**; beautiful **Cerussites**, etc., etc. We are able to sell many of the above at lower prices than they have ever been offered.

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THE

# AMERICAN JOURNAL OF SCIENCE

[THIRD SERIES.]

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ART. XLIV.—*Radiation of Atmospheric Air*; by C. C. HUTCHINS, Bowdoin College.

WE learn from the researches of Tyndall that the radiation from heated air streaming from about a copper ball heated to near redness was just detectable, but scarcely measurable with the most delicate apparatus then in existence.

He was also able to show that other gases, under like conditions radiated, some to a much greater extent than air, and he formed a table in which the different gases experimented upon stand in the order of their radiating powers. This at present comprises about the sum of our knowledge of this important matter. The recent invention of several forms of extremely delicate heat-measuring apparatus now enables us to deal successfully with quantities of heat so minute, that the ordinary thermopile gives no indication of their existence.

The apparatus used in the following investigation is something of an improvement upon that formerly here devised and described\* which improvement has been effected by the substitution of a junction of the bismuth, antimony and tin alloys in place of the iron-nickel couple formerly employed.

By a peculiar method of casting these alloys into thin leaves it is possible to give them a certain amount of temper by which their tenacity is considerably increased, so that by skill and patience they can be worked into bars as small as 0.002<sup>cm</sup> thick, and 0.03<sup>cm</sup> wide. More difficulty however being experienced with the alloy of bismuth and antimony. To avoid too

\* Proc. Am. Acad., vol. xxiv.

many accidents the bars in use are made a little stouter, about  $0.003^{\text{cm}}$  thick and  $0.05^{\text{cm}}$  wide, and are united to a very thin disc of copper foil  $0.1^{\text{cm}}$  to  $0.2^{\text{cm}}$  in diameter.

Such a junction has, when the component bars are each  $0.5^{\text{cm}}$  long, a resistance of four or five ohms, and consequently the galvanometer has been re-wound to about the same resistance. The result is an improvement in the sensitiveness and steadiness of the apparatus.

On account of the peculiar conditions under which we must work in determining the radiation of air we seem practically confined to Tyndall's method, using a moving mass of air, inasmuch as gases are nearly transparent to the rays from all solid bodies at ordinary temperatures. We can however improve the method in detail, making use of a moving column of air, hotter, but at the same pressure as the surrounding atmosphere, and moving at such a rate through it as to preserve definite and measurable dimensions. The following experiments deal entirely with air in the ordinary condition, neither purified nor dried. Little would probably be gained by using purified and dried air, for, as will be seen later, the radiation is mainly from the surface of contact between the hot and cold air, where more or less mixing must take place, so that the loss of heat from contact of hot and pure air, and cold and impure air, would in most respects be a less definite problem than that of the radiation from the ordinary air of homogeneous even if of somewhat variable and uncertain composition.

The variation in composition causes great and rapid alterations in atmospheric radiation, and as we cannot allow for the variations the only remedy seems to be to work rapidly when the conditions are favorable.

It has in fact been learned, at the cost of much time, that nothing can be gained by working under any but the most propitious circumstances. We must have nearly constant temperature and humidity, absence of wind, etc., if we are to expect consistency in observations made at even as short an interval as an hour. However, we have forcibly brought to mind the remarkable power that slight variations in the ordinary composition of the atmosphere have in altering its heat-radiating properties.

#### *Apparatus.*

A galvanized iron pipe three feet long, two and one-half inches in diameter is supported at an angle of about forty-five degrees and heated by one or more Bunsen lamps placed underneath. A large hole is made near the bottom of the pipe

for the entrance of air, and when the pipe is heated a strong current sets through the tube and is discharged at the top.

To cut off air currents from the outer surface of the pipe, tin screens are made to surround it and move with it. The upper opening of the pipe is furnished with a nozzle of lead, presenting an opening  $1^{\text{cm}}$  by  $3^{\text{cm}}$ . By burning touch paper at the bottom of the tube the lamps beneath being lighted, the shape of the column of air from the nozzle can be inspected at leisure by reason of the dense smoke that issues with it, and by filing the throat of the nozzle it can be given such a shape that the column of heated air will preserve uniform dimensions for a considerable distance from its exit. After the lamps have been lighted for twenty minutes the temperature of the air becomes constant, and changes but slightly for hours at a time.

The lower end of the tube is supported upon a pin, thrust across its diameter, so that while the bottom of the tube remains fixed, the remainder can be moved in a vertical plane by a pull upon a string, the tube falling back by its own weight when the tension upon the string is relaxed.

The thermopile points continuously to a large copper Leslie cube containing water at the temperature of the room, and furnished with a thermometer divided to  $0.1^{\circ}$ . When the observer at the galvanometer releases the pipe it falls to such a position that the hot air streams in front of the opening of the thermopile at a distance of  $3^{\text{cm}}$  causing a deflection of the galvanometer needle after which the tube is raised by the string attached, the heated air now being discharged high above the opening leaving the apparatus unaffected save by the radiation of the cube.

The breadth of the column of air is sufficient to fill the opening of the thermopile and leave a wide margin on either side. For finding the instrumental reduction factor, a long thin copper tank is provided which may contain water a few degrees above the temperature of the room. This tank is pushed between the stationary cube and the thermopile by an assistant and withdrawn again at a signal from the observer at the galvanometer. It is furnished with a delicate thermometer which can be read to  $0.01^{\circ}$ .

#### *Reading Galvanometer.*

Both the forward and backward swings of the needle are observed, and the mean of these constitutes a single observation, the mean of five or ten observations comprising a set. The sensitiveness of the galvanometer has been frequently

changed to suit the conditions of experiment by changing the position of the controlling magnet. The period of the needle has always been kept less than ten seconds.

#### *Reduction Factor.*

The instrumental reduction factor is the amount of heat in small calories per second from a surface that fills the aperture of the thermopile, necessary to give a deflection of one division of the galvanometer scale.

The reduction factor is always obtained one or more times each day, and is considered as applying to that day's observation only. It is found by observing the deflection produced by the warm copper tank, coated with lampblack. The amount of heat radiated per degree of difference per sq. c. m. per second for the difference of temperature between the tank and cube is found from the equation  $x = 0.000238 + 3.06 \times 10^{-6}t - 2.6 \times 10^{-8}t^2$ .\* The instrumental constant  $c = \frac{x}{a}$  where  $a$  is the galvanometer deflection per degree of difference in temperature between the cube and tank.

#### *Radiation of Air.*

Measures for finding the absolute radiating power of a column of air one centimeter thick at a temperature near  $100^\circ$  were made upon eight days. The results of each day's work were fairly satisfactory, but there was no sort of agreement between those of separate days.

A preliminary experiment upon the effect of humidity, made by measuring the radiation of the air in its ordinary state and then again after letting steam into the room from the heating pipes, showed that the radiation increases with the amount of moisture in the air, confirming the result reached by Tyndall.

The readings of the barometer, and of the wet and dry bulb thermometers were thereafter recorded. But even after making a very sensitive wet and dry bulb apparatus using two thermometers reading to  $0.01^\circ$  and swinging the whole from the ceiling, like a long pendulum, to the same level as the air entrance to the heated tube, I was unable to make out the exact connection between the heat radiated and the amount of moisture contained in the atmosphere. The utmost care was used and every precaution suggested by experience observed, but after more than a month no result beyond what was given in the preliminary experiments was reached. Notwithstand-

\* Proc. Roy. Soc., 1872, p. 93.

ing the failure to establish a connection between the absolute amount of moisture and the radiation, the tabulated results show a striking connection between the relative humidity and the radiation, as is exhibited in the following table.

TABLE I.

<i>a</i>	<i>b</i>	<i>m</i>	<i>n</i>	<i>t-t'</i>	<i>f'</i>	<i>h</i>
Oct. 20	76.16	14.7	15.6	88.2	90.	0.000002562
Nov. 7	76.41	16.1	23.9	89.0	40.	1189
Nov. 9	76.76	16.7	22.8	88.7	50.	1273
Nov. 10	76.76	10.0	13.9	84.0	57.5	1559
Nov. 11	76.19	14.4	17.3	84.5	71.	1812
Nov. 11	75.80	18.9	20.4	87.7	85.5	1986
Nov. 12	75.99	14.0	17.9	88.3	62.5	1597
Nov. 13	76.38	13.6	19.4	82.6	47.	1513

*a* is the date.

*b* " barometer reading.

*m* " wet bulb.

*n* " dry bulb.

*t-t'* " difference of temp. between hot air and cube.

*f'* " relative humidity.

*h* " absolute radiation.

It will be seen that *h* increases quite regularly with *f'*, though the plotted observations do not lie well enough upon any smooth curve to enable us to assert the law of connection, which law it would be difficult to deduce without the means of controlling the presence of other accidental constituents of the atmosphere; such as carbonic acid and gases resulting from the decomposition of dust, coming in contact with the heated tube. That these accidental impurities have a very great influence, is shown by the following experiment. On Dec. 7, the mean deflection produced by the air column at 120° was 64 scale divisions. A small amount of pure dry carbonic acid gas was allowed to mix, a bubble at a time with the air at the entrance of the heated tube. The deflection rose to 140 or more than doubled. When a very small amount of illuminating gas was mixed with the air, the deflection was too great to be recorded on the scale. As it is impossible at present to allow for the presence of these impurities or even for the aqueous vapor in assigning a value to the absolute radiating power of atmospheric air we are obliged to employ an average result obtained from several days' observations.

The following table presents the measures made on six days after considerable practice had been had with the apparatus.

The observations were made at four or more different temperatures of the air column, with a view to learning the law connecting the heat radiated and the temperature.

TABLE II.

<i>a</i>	<i>b</i>	<i>f</i>	<i>c</i>	<i>t-t'</i>	<i>g</i>	<i>h</i>	
Nov. 23	---	---	4.741067	53.7	18.42	0.000001889	
				77.6	29.9	2123	
				89.3	36.4	2246	
				119.0	59.7	2763	
				167.5	93.8	3085	
Nov. 26	76.3	7.89	4.714927	53.0	14.2	0.000001390	
				80.0	27.0	1751	
				86.0	29.2	1761	
				96.5	35.5	1908	
				138.0	64.0	2453	
				167.0	92.5	1908	
Dec. 4	76.0	6.50	3.014392	53.0	10.37	0.000002022	
				67.5	14.9	2282	
				100.0	24.3	2511	
				145.0	39.9	2845	
				188.0	62.5	3437	
Dec. 6	75.5	4.76	4.440807	64.3	32.8	0.000001407	
				83.5	40.4	1305	
				3.166587	84.0	9.0	1572
				4.440807	115.0	57.5	1380
					152.0	87.0	1574
					3.166587	185.0	21.6
Dec. 7	75.3	6.16	4.339524	47.0	28.3	0.000001393	
				87.5	58.6	1464	
				113.0	74.2	1435	
				153.5	103.5	1473	
				205.0	147.6	1573	
Dec. 8	76.6	5.08	4.393008	46.0	20.5	0.000001102	
				82.0	43.0	1299	
				104.0	51.9	1234	

*a* is the date.

*b* " barometer reading.

*f* " absolute humidity.

*c* " log reduction factor.

*t-t'* " difference in temperature between air and cube.

*g* " mean galvanometer deflection.

*h* " absolute radiation of air.—The amount of heat lost each second from each square centimeter of surface for each degree of difference between the temperature of the air and of the surroundings, the sheet of air being one centimeter thick.

Upon plotting each day's observations separately using the value  $t-t'$  as ordinates, and the corresponding values of  $h$  as abscissas we find that in every case the observations are represented by a straight line. Whence we deduce that in the case of air within the limits of temperature here employed the increase of radiation is proportional to the increase of temperature. This relation will doubtless be found true of other gases, and to apply to a wider range of temperatures. The mean equation of the six sets of observations given in the table is,

$$h = 0.000001133 + 0.0000000711(t-t')$$

which may be taken as fairly representing the radiation of air in an ordinary room under average conditions, the sheet of air being 1<sup>cm</sup> thick.

*Effect of thickness of radiating column.*

It was noted at the outset that the galvanometer deflection was not proportional to the thickness of the heated column of air.

A flat sheet iron pipe was made 100<sup>cm</sup> long, 10<sup>cm</sup> wide and 2.5<sup>cm</sup> thick. This pipe was substituted for the one previously used. The air exit was from a pair of jaws, one fixed, one movable, so that the thickness of the air column at its escape could be regulated at pleasure. Measures with this apparatus were made on eight days. The results were recorded as the amount of galvanometer deflection per degree of  $t-t'$ .

With openings less than 1<sup>cm</sup>, no difference in the amount of radiation can be detected. With larger openings a small increase is observed. The results of six determinations distributed over four days are here given.

Opening,	0.5 <sup>cm</sup>	1 <sup>cm</sup>	2 <sup>cm</sup>	3 <sup>cm</sup>
Deflection per degree,	0.193	0.195	0.245	0.259

We observe that radiation is very largely from the surface of contact between the hot and cold air, which seems to indicate that a heated gas absorbs all or nearly all those rays that it itself emits and that radiation takes place only when there is a fall of temperature within the limits of molecular action.

*Wave length of rays.*

It would probably be hopeless to undertake a prismatic analysis of the rays from heated air. We can however get a suggestion as to the length of these waves from their behavior towards an absorbing medium. A very pure plate of quartz 0.5<sup>cm</sup> thick was placed over the opening to the thermopile. With the air at 100° no deflection could be obtained, and even when the temperature was raised to 200° it was decided after many trials, that there was no measurable effect. Without the quartz plate the deflection was 151. The quartz plate allows 93 per cent of the sun's rays to pass it, 31 per cent of rays from red hot platinum and 3.0 per cent of rays from lamp-black surface at 100°, being in a manner progressively opaque to waves of increasing length. The waves from heated air must therefore be of great length since they seem incapable of penetrating the quartz in any considerable degree.

ART. XLV.—*Atmospheric radiation of Heat and its Importance in Meteorology*; by CLEVELAND ABBE.

(1.) IT is evident that our planet, considered as a whole and on the average of many years, loses all the heat that it receives from the sun; but all the details of this process have not yet been completely worked out. Fourier, Poisson and their disciples have treated of this radiation in the most general manner; Melloni, Tyndall, Langley and their followers have gone into some of the details as to character and quantity. These physicists have served to awaken meteorologists to the necessity of carefully distinguishing the influence of the absorption and radiation by the soil, the vegetation, the snow and the ocean respectively; even as to the atmosphere itself we have to distinguish the absorbing and radiating powers of the dry air, of the clouds or haze and of the dust respectively.

(2.) Heat is thrown into the atmosphere not only by conduction and convection from the immediate surface of continents or oceans, but the radiant heat from these surfaces is in part directly absorbed (just as is solar radiation) by the atmosphere and in part transmitted to outer space. All of the immense quantity of heat thus communicated to the whole atmosphere (viz. 50 per cent of the direct solar radiation, plus about 50 per cent of the specular reflection from the earth and water, plus all of the convection from the surface of the earth and ocean, plus a large per cent of the radiation from the earth's surface) must be lost through a process of radiation from the atmosphere as distinguished from radiation through the atmosphere; judging from the known values of these items one would *a priori* conclude that this radiating power of the whole atmosphere must average about 0.5 calories per minute per square centimeter of its outer surface.

(3.) At first thought one would say that, according to Kirchhoff's law any radiation from a mass of air must be of such a quality as to be immediately absorbed by the adjacent air in the attempt to pass through it and therefore cannot escape into space except when radiated by the very outermost layer of the atmosphere. But in reply to this we note that the processes of radiation from and absorption by layers of air within the atmosphere depend (like those of conduction) upon differences of temperature and possibly on differences in density consequently it is quite possible that heat radiated from the warmer and denser, moister and dustier layers below may in part escape directly through the upper layers into ethereal space; that portion of this heat which is absorbed by the upper layers will in turn, by a similar process, escape from them.

(4.) The fact that some such process is going on in the atmosphere has, I presume, been recognized by many although the published expressions in regard to it are generally very indefinite. It is almost invariably the case that the cooling of the air at night is attributed to the radiation of heat from the earth and the fact that the surface of the soil becomes cold is quoted as an evidence of this action. But it can easily be shown numerically that the nocturnal conduction of heat between the surface of the earth and the air above it can only affect a very thin layer of air during the twelve hours of nighttime (3 meters according to Maurer) and that there must be an appreciable radiation from the air itself.

(5.) On this whole subject the writings of Dr. Julius Maurer offer us some valuable formulæ and data; especially has he been the first (see Schweiz, Met. Beob., 1885, vol. xxii, Append. v, Zürich, 1887,) to give us an approximate value of the coefficient of radiation of a cubic centimeter of air. This coefficient he deduces from the ordinary meteorological observations of the temperature of the air at nighttime as given by the ordinary screened thermometers. Maurer finds that the cooling of the free air during night in the lower layers of the atmosphere and on the average of the whole year, namely without distinguishing between cloudy and clear weather, or calms and winds, proceeds as though a cubic centimeter of air gives up to an enclosure,  $1^{\circ}$  C. cooler than itself, 0.0000007 gram-calories per minute. Now the specific heat of air under constant pressure is 0.2377 and the density of the air to which Maurer's coefficient pertains is about 0.00129 or  $\frac{1}{773}$  of water. We may therefore convert his coefficient of radiation in absolute calories into a coefficient of cooling in Centigrade degrees whence it results that the cubic centimeter of air within such an enclosure cools by radiation at the rate of  $0.0000007 \times 773 \div 0.2377 = 0.0023$  degrees C. per minute or 0.138 C. per hour.

Maurer finds indications that this coefficient is larger in summer and smaller in winter. The above average value results from observations of temperature for many years at St. Petersburg, Prague, Berne, Toronto and Barnaul and may be considered as belonging to air that has an average pressure of  $750^{\text{mm}}$ , a temperature of  $5^{\circ}$  C., is nearly saturated with moisture, and contains the average amount of dust and aqueous particles that belong to the air of those stations. Maurer especially notes that the coefficient thus found is larger than belongs to pure, dry air on account of the solid and liquid particles contained in the ordinary atmosphere and participating in the radiation. He further states that similar computations based on observations made at the high stations, St.

Bernard and Säntis, give a coefficient about 15 per cent smaller.

(6.) It is evident from Tyndall's observations and those of Ångström and others that this coefficient must vary with the chemical nature of the gases contained in ordinary air and, although it is therefore of a very indefinite nature, yet we need to know its probable limiting values in order to understand the extent of the influence of atmospheric radiation upon meteorological phenomena. On this account I have applied Maurer's formulæ to other meteorological observations and during the past three years have mentioned to several physicists the desirability of the direct determination of this coefficient by ordinary laboratory methods. I am therefore much pleased that Prof. Hutchins has been able to make a direct experimental response. The values deduced by him are considerably larger than those given by Maurer, as was to be expected, because Maurer's computation considers only the average radiation during cloudy as well as during clear nights and also because it assumes that the convection during windy nights has not obscured the simple effect of radiation. Furthermore there is a possibility that the heated metallic tube of Prof. Hutchins may have given off an extra quantity of dust or of gaseous compounds all of which would increase the apparent radiation. But although neither of these determinations represents pure, clean, dry air and although both must at present be considered only as first steps in our knowledge, yet they give us invaluable indications of the possible dimensions of an important fundamental constant in meteorology.

(7.) The importance of this subject in the study of the mechanics of the atmosphere may be enforced by the following consideration of the progress of our knowledge.

(a.) Espy, having reasoned his way up to the conclusion that rising air cools by virtue of the work done by it in its expansion against the surrounding pressure, also clearly stated that descending air is warmed by compression (i. e. by the work done upon it) whence it is able to dissipate any fog or cloud that it contains and becomes perfectly clear; inversely, cloudless skies, whether in small patches or large regions, demonstrate in general the prevalence of descending air. The further development of Espy's principle gave rise to what is called his latent heat or condensation theory of storms, the items of which are briefly as follows; ascent is due to buoyancy; cooling is due to the work of expansion incident to the ascent; when cooling has brought the air to the dew point and to precipitation then latent heat is liberated and the cooling is checked but the relative buoyancy of the ascending air is increased, the indraft and updraft increase and the storm

grows; when the inflow is prevented, or when it brings dry air instead of moist air, then the condensation of moisture stops and the storm subsides.

(*b.*) Ferrel worked out, from the point of view of hydro-mechanics, the theory of the circulation of air in cyclones and in the surrounding pericyclonic region; he also developed the mechanics of cyclones with cold centers; he then showed how ordinary areas of high pressure and cold air (which Galton in 1863 first called anti-cyclones) may result from the interaction of two or more pericyclones; he mentions without further development the radiation of heat from the air but gives greater weight to the conduction to the ground and thus explains the inversion of temperature in the clear still air of winter. Much of this was done before the publication of the weather maps of the Signal Service or indeed of any European weather bureau. Ferrel subsequently developed the thermodynamics of the condensation theory of Espy and showed its excellent agreement with all the known facts of local storms, hence it was assumed to also apply to the large storms or areas of low pressure.

(*c.*) Hann, having shown that the föhn wind is a rapidly descending mass of air whose warmth is due to an initial rain or snowfall with the evolution of latent heat and to the subsequent rapid compression of the air, follows this up by the study of the slowly descending movements as exemplified in the European area of high pressure of 1889, Nov. 11–23. He finds, as Ferrel had done before him, that in the high areas the temperature at a few thousand feet altitude is higher than that at the surface of the ground; he concludes that the average temperature for a depth of 3000 meters is somewhat higher in an anti-cyclone than in a cyclone. Hence Hann throws doubt upon the idea that an area of high pressure with cold air near the surface of the ground only, is really a mass of descending cold air; like most others he also explains that the coldness of the lowest stratum of air under a clear sky is due to radiation from the surface of the ground. Hann's array of data requires that we now consider more closely the mechanical theories of atmospheric motion; these have usually assumed an incompressible atmosphere of about 8000 meters in depth.

(8.) Some features of recent researches in the mechanics of the atmosphere may be presented as follows: A comprehensive study of fluid motions shows that air and water alike may be forced to ascend without being warmer and lighter or to descend without being colder and denser than the surrounding fluid. The currents and whirls behind any obstacle in streams of air or water are almost wholly independent of differences

of density and are caused by differences of pressure as modified by simple kinetic laws. The uprush of water at one place and its downrush, as a whirlpool, at another place in a swift stream is a vortex phenomenon in which temperature and density have no part. The rise of the surface of a river at any bend in the channel or at the junction with a tributary stream is a kinetic phenomenon; so also is the resulting surface overflow to the right and left of the channel; so also the slow spiral circulation that goes on, in consequence of which the surface water flows from the center out to the banks of the river then down to the bottom of the channel and thence up to the swift surface and back to the banks again.

We must expect to find similar phenomena in the atmosphere where, corresponding to the general current of a river, we have a general circulation of air due to the greater warmth of equatorial air and to the swift diurnal rotation of the whole atmosphere about the polar axis.

(a.) Ferrel was the first to show that the tropical belts of high pressure are due—not to local cool air or to local density—but to the interaction of pressures and that they would exist if the atmosphere were a mass of incompressible fluid; they may be affected to some degree by various forms of resistance, they may also be affected by temperatures due to local radiation and convection, and also by thermodynamic relations, but all these are minor incidents subordinate to the action of the hydro-dynamic laws that bring them into existence.

(b.) Ferrel maintains that areas of high pressure with cold anti-cyclonic winds give evidence of originating with upper currents of air such as those that are conceived to flow out from great cyclonic areas and be whirled toward each other; Ferrel's reasoning would justify his conclusion that there is only sufficient energy in those whirls that are due to the general circulation between the equator and the pole, to generate very moderate high and low pressures but not the great barometric depressions and elevations that characterize the low and high areas. He therefore looks to the latent heat of the precipitated vapor as not only maintaining the lows but furnishing the energy that enables these to overflow as pericyclones which by interference among themselves give rise to the high areas.

(c.) It has been shown by Prof. Finger of Vienna that westerly winds have a tendency to rise above the earth's surface due to their excess of centrifugal force, while easterly winds having a deficiency tend to press down upon the earth's surface; but these effects are inappreciable in our barometric measurements and cannot be quoted as efficient mechanical causes for the production of high or low pressure.

(*d.*) Besides the horizontal movements and whirls, Helmholtz has studied what may be called the vertical whirls or the general vortex motion of which the ideal case is an atmospheric vortex ring surrounding the earth at the equator and moving, as a whole, poleward. If such a ring of incompressible air is to retain its energy as it moves northward and is to contract as the circles of latitude diminish, it must exhibit far greater velocities than are observed, therefore some way must exist by which it loses its energy. If, however, by reason of the irregularities of the earth's surface such rings become broken up each part will revolve as an independent ring having an inclination to the earth's surface and by the interferences and mixtures of these rings the motions may become reduced so as to agree with the observed winds. From this point of view all movements from the equator carry rapidly revolving air into regions where the rotation is less rapid and such air must rise above the earth's surface, whereas for motions toward the equator the air must descend and hug the earth's surface thereby acquiring the greater speed of rotation that belongs to low latitudes and forming local high pressure areas.

(*e.*) We see therefore that whether we study horizontal or inclined or even vertical whirls in the atmosphere, we are alike brought into the presence of ascending and descending motions which the air is forced to take for purely kinetic reasons. So long as we, with the above-mentioned authors, consider only the ideal case of a homogeneous, incompressible, dry atmosphere having an average depth of about 8000 meters and whose temperature at any point depends upon its absorption of solar radiation and upon its warming up by conduction, we have perhaps no need of a special study of the thermodynamics that is so important in the real atmosphere of compressible air. For such a problem it may therefore be sufficient to assume, as seems to be implied by Ferrel, Hann and Helmholtz, that the air loses heat by the simpler process of conduction to the cold earth. But when we investigate the real atmosphere on the basis of actual observation we find that the thermodynamics of the compressible air adds a most important feature.

(*f.*) We have thus far concluded only that local areas having a slight excess or deficiency of pressure would be maintained if the atmosphere were perfectly dry and were an incompressible fluid; but if the air is moist and is compressible then the regions of diminished pressure give rise, by Espy's thermodynamic process, to the formation of clouds and rain which form temporary and local episodes in the general motion. Such condensation of moisture especially tends to form in the rising part of the circulating air, and thus coöperates with the general mechanism to produce spiral, ascending currents that intensify

and prolong the meiobars and therefore the overlapping pericyclones of Ferrel or vortices of Helmholtz, thus eventually intensifying the pleiobars.

(*g.*) According to these views the primary factors in the origin and maintenance of local rains, water-spouts, thunderstorms and tornadoes are local buoyancy, expansion, thermodynamic cooling, condensation and latent heat. On the other hand in extensive storms of the temperate and arctic zones it is the slight depression, due to a whirl in the general circulation, that determines where a storm or low area will originate. Finally in tropical hurricanes the general circulation must decide whether an initial local disturbance shall die away or shall be fed and developed into an extensive hurricane.

(*h.*) So mobile is the air that two conflicting currents cannot produce any considerable excess or deficiency of pressure and such a mechanical heaping up, or compression, as would produce a barometric gradient of  $0.1^{\text{mm}}$  per degree is immediately followed by a movement in the air that will relieve the excess. Therefore, as Ferrel distinctly shows, we must not expect that any obstruction to the moderate currents of the general circulation can explain such great barometric elevations as occur in the high areas of the United States or Europe. A slight mechanical excess of pressure may possibly initiate a high just as a deficiency does a low, but the further development of the pressures must depend upon other considerations. Among these latter Ferrel so long ago as 1856 showed that just as the low pressure depends upon the centrifugal forces due to a cyclonic whirl so the high pressure depends, at least in part, upon a centripetal force due to an anti-cyclonic whirl.

Again Ferrel has stated that if the cold of the lowest layer in the high area extends upward then the weight of this dense air would help to explain the high pressure. This suggestion needs careful consideration in view of the observed presence of warm air in the upper layer where cold air was supposed to exist. Although Ferrel maintained that the air in the high areas must on the average be colder and therefore be descending by virtue of its own gravity yet he has not made clear the details of the process by which descending air can become cooler and denser.

(*i.*) The existence of warm air above the cold layer near the ground has long been recognized for moderate elevations during clear nights; its influence upon the atmospheric refraction is apparently often very notable in astronomical observations. The fact of its existence has also been brought out, even for the daytime, by many balloon observations notably those of Glaisher in England and of Mr. Hammon in the United States (see the *Am. Met. Jour.*, Feb., 1891.) To the

early observations of the Signal Service at Cheyenne and subsequently at Pike's Peak, as displayed on the daily weather maps, we owe the knowledge, that has these twenty years been public property in the United States, that warm air exists above the western side of our great cold waves. Ferrel in his "Recent Advances" explains this upper warm layer as due to the compression of the descending air which latter eventually flows horizontally above the lowest layer which latter is composed of air that has cooled by conduction to the cold ground near which it lies quietly resting; he states furthermore that an additional cooling is due to the evaporation of moisture from the soil and also to the "radiation of the air" but no special importance is attached to the latter factor nor to the fact that often during daylight sufficient solar heat does not penetrate into the lowest stratum to dissipate the haze and fog that is often formed during the night. Hann has presented the details of the continued existence of such a warm layer for many days over the midst of the European area of high pressure of Nov., 1889; his suggested explanations, so far as they go, agree with Ferrel's.

(j.) But the slow horizontal flow, the evaporation of moisture from the ground and the conduction of heat to the ground by the air within a few meters distance, explain only a portion of the observed phenomena. We need a thermal process that shall do for the high area that which the condensation of vapor, and its precipitation as rain or snow, do for the low area. I have been accustomed to explain this abstraction of heat in a general way as due to the warming of the air by compression and the loss of this evolved specific heat by direct radiation, but the numerical application of this idea was hindered at first by our ignorance of the coefficient of radiation and eventually by the very small coefficient deduced by Maurer. The larger coefficient of Hutchins and a conviction that Maurer's value is too small, lead me with some confidence to ask the attention of meteorologists to the present study from which we find that we need not hesitate to accept Espy's conclusion that a cloudless blue sky demonstrates that descending movements are present and are more efficacious than any minor ascending movements that may be present. The existence and qualitative influence of radiation from the air was discussed by me with Ferrel before the publication of his "Recent Advances" and admitted by him as a possibility, but in the absence of any knowledge as to the coefficient of radiation Ferrel seems to have decided to mention the subject only in a general way.

(9.) If the air itself radiates its own heat then the temperature of an ascending or descending mass, or the general law of the diminution of temperature with altitude must depend upon

the time during which radiation has been progressing and this duration will enter as an exponent in the analytic formula. Again the enclosure to which this heat is radiated, as imagined in connection with Maurer's coefficient, is on the average  $1^{\circ}$  C. cooler than the radiating mass, therefore its dimensions may be calculated and it appears that, near the earth's surface, the lower portion of such a sphere is cut off and is replaced by the cold ground which is equivalent to diminishing the size of the sphere or increasing the rate of radiation; a similar consideration obtains at the outer limit of the atmosphere; in general the radiation of a descending mass causes it to cool least rapidly when at a medium altitude above the ground or in the midst of the atmosphere.

As for conduction between the earth and the air it is easily recognized, as Maurer has shown, that this has an inappreciable influence during twelve hours at three meters above the soil or during 48 hours at six meters; it can only become moderately important for calm air during long arctic nights. As concerns convection of heat by currents rising from the earth this will directly affect the dry, cold, clear, calm air in the midst of high pressures only up to a moderate altitude, say 1000 meters, and that only in the warmer part of the day because the rising currents are rapidly cooled by mixture and cease rising at an altitude whose limit in such weather is usually defined by a thin layer of dust and haze. Up to this altitude therefore atmospheric radiation of heat, during 24 hours of day and night, may be partially compensated by convection during sunshine but this limit is much lower for still air lying over ice, snow or water. As concerns the cooling due to evaporation this can be computed from the known amount of evaporation and is a very small quantity for the cold air over the land north of latitude  $50^{\circ}$  where our high areas form.

Therefore the factors that principally affect temperature in extensive areas of high pressure are: 1. The direct absorption by the air of the solar radiation. 2. The direct radiation by the air of its own heat. 3. The thermal changes due to changes of barometric pressure in the radiating mass which are themselves due principally to its descent in the atmosphere.

(10.) With regard to the direct absorption of solar radiation, the bolometric researches of Langley show that the general coefficient of transmission of solar radiation through the atmosphere varies from about 0.8 in the red and 0.6 in the yellow to 0.4 in the violet and averages approximately 0.6 for the whole spectrum. These figures relate to the general absorption of a zenithal ray passing through the whole atmosphere down to the layer whose elastic pressure is  $760^{\text{mm}}$  and give no idea of the special absorption of specific wave-lengths that may

radiate from the sun or the earth. The corresponding transmissions for the same rays, when they have penetrated only down to the layer at 10,000 meters altitude or down to a pressure of 217.4<sup>mm</sup>, are 0.939 in the red, 0.864 in the yellow and 0.769 in the violet; hence 0.14 and 0.26 and 0.37 are the respective fractions of the original heat absorbed from the ray in its passage through the lowest 10,000 meters of the atmosphere. Now the relative thermal intensities of these radiations are respectively 68, 108 and 52 and for the present approximation we may consider that about 20 per cent of the original incident solar heat (3 gram-calories per sq. centimeter per minute) is distributed by absorption along the 10,000 meters of this lower path. Therefore during the slow descent of air in the midst of a high area the principal external source of heat is the direct absorption of solar heat and this, at its maximum for zenithal rays, can in the lower atmosphere only amount to an absorption of  $0.20 \times 3 \div 10,000 \times 100 = 0.000,0006$  calories per minute per cubic centimeter of air; in northern latitudes and on the average of the ordinary 6 to 12 hours of sunshine the absorption becomes much less; for Central Europe in November the average for the whole duration of sunshine would be less than 0.000,0002 calories per minute.

(11.) As opposed to this gain of heat we have only the loss by direct radiation which is, according to Maurer, expressed by 0.000,0007 gram-calories per minute per cubic centimeter or 0.0006 calories per kilogram mass of air when the surrounding enclosure has an average temperature 1° C. less than that of the radiating mass.

Without discussing the nature of the diffusion of heat by radiation or conduction within a gas, we remark that Maurer's coefficient of radiation relates strictly speaking to a mass not to a volume; we may plausibly assume that the unit mass of air has the same coefficient whatever the density of the air, at least within a pretty wide range, therefore it will follow that the rate of linear descent within our atmosphere that produces a rate of compression and dynamic warming sufficient to compensate for the cooling by radiation must be greater at high altitudes than at low ones.

Dusty, hazy or moist air, as also the ammonia and the hydrocarbons or the carbonic acid ordinarily present in the air, have somewhat larger specific heats than those for clear dry air, but they also all have larger coefficients of radiation so that their cooling by radiation is more rapid than that of pure, dry air.\*

\* A parallel process must take place in the solar atmosphere if we suppose the gases that ascend from the immediate surface of the sun to be at such a high temperature that all the chemical combinations ordinarily known to us are dissociated; when a mixture of such elementary gases in this highly heated condition ascends until by expansion it is cooled to the temperature at which chemical com-

This atmospheric radiation, moreover, continues day and night and is much more effective in direct cooling than the solar radiation is in direct warming. Since the loss by radiation may according to Prof. Hutchins, be far greater even than this and since Maurer's figures represent only an average for all kinds of weather we are fully entitled to at least the general statement that the cooling by radiation is to only a very slight extent offset by the direct absorption of solar heat and that its coefficient may vary from the minimum value of  $0.1^{\circ}$  C. per hour, as previously computed, up to an unknown and much higher limit.

The actual rate of cooling varies approximately as the difference of temperature of the radiating mass and its enclosure and this is probably least in the mid-atmosphere as before stated and must increase as the mass sinks to the region where the colder terrestrial surface becomes an integral part of its enclosure and especially when the effect of conduction to that surface is superadded.

(12.) The thermodynamic warming by compression takes place at the rate of about  $1^{\circ}$  C. for each 100 meters of descent. As the coefficients of absorption and radiation are uniform for equal masses or for equal changes in barometric pressure as we descend in the atmosphere, the thermal effects therefore vary more rapidly for a given change of altitude at low levels than at high levels; therefore in the early stages of any descending motion the downward movement may be accelerated but there will be a tendency towards a steady rate of descent such that the loss of temperature by radiation exactly counterbalances the gain by compression. If we accept Maurer's coefficient and diminish this by a unit in the seventh decimal place in order to allow for the absorption of solar heat, as just calculated above, we have a resultant 0 000,0006 gram-calories as the loss of heat on the average of twenty-four hours; this corresponds to a diminution of temperature of  $2.88^{\circ}$  C. per day and if this is to be compensated by compression it will require a descent at the rate of 288 meters per day; a more rapid cooling by radiation, such as is required by Hutchins' coefficient, would require a proportionately rapid rate of descent. Such a thermodynamic compensation would bring

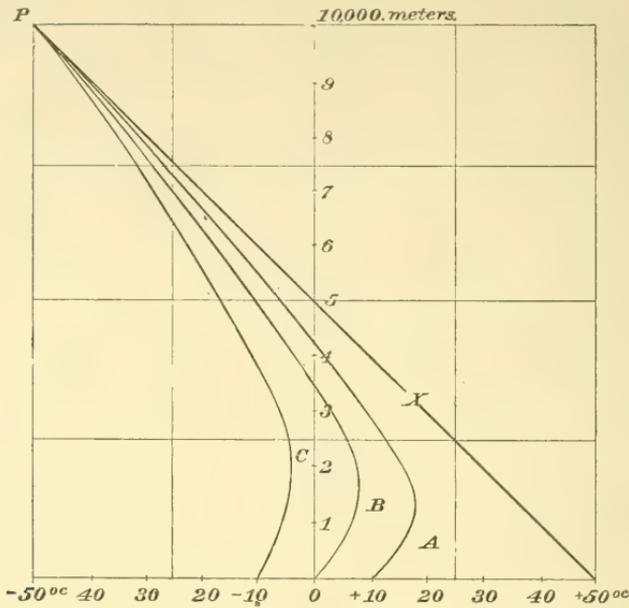
binations are possible then these take place and generally with an evolution of heat (the latent heat of combination). The continued evolution of this heat compensates for further cooling by expansion just as the latent heat of vapor operates in Espy's theory of storms; when however the combined gases have further cooled by expansion and radiation as they ascend until the molecules of the new complex gases can form clouds of vapor there forms an outer layer of radiating cloud matter such as we call the surface of the sun. If the colder vapors, at this surface, are by any process drawn down or if by condensation they sink at a steady rate, they are again warmed up by compression, the descending gas becomes clear and may pass through the dissociation stages by absorbing a new quantity of heat radiated from the solar nucleus which heat is in turn to be lost by radiation in the subsequent ascension.

about an uniform temperature at all altitudes in the descending air. The fact that in high areas air is warmer as we descend down to a certain altitude must therefore be held to prove that the air is descending faster than this compensating rate, just as it does in the case of the föhn.

The resulting rate of warming expressed in degrees Centigrade per 100 meters of descent is given by the formula: one less the quotient of 288 divided by the rate of descent expressed in meters per day. Thus if the descent is 144 meters per day, the air will cool at the rate of  $1^{\circ}\text{C}$ . per 100 meters of descent; if the rate be 432 meters per day the air will be warmed up at the rate of  $0.33^{\circ}\text{C}$ . per 100 meters. In the upper layers of the maximum area of 1889, as investigated by Hann, the air grew warmer at the rate of  $0.38^{\circ}\text{C}$ . per 100 meters, corresponding to a rate of descent of 457 meters per day; on the other hand in the lower layer, namely between 500 and 1000 meters the air grew colder as the altitude diminished at the rate of  $1.8^{\circ}\text{C}$ . per 100 meters, corresponding to a rate of descent for the air itself of 103 meters per day.

(13) These figures must for the present be considered merely as illustrations of the quality of the influence that atmospheric radiation must exert on the temperature and motions of the air. If the coefficient of radiation of the upper air is less than Maurer's figure or if the coefficient for the lowest strata is as large as Hutchins' figures owing to the abundance of dust and haze, or if, as is generally the case the enclosure is more than  $1^{\circ}$  cooler, then the numerical rates just given will need to be modified. In either case the general principle remains that on the average throughout the whole atmosphere the cooling by atmospheric radiation largely compensates for the warming by compression and that in this way we must reconcile the hydrodynamic theories with the facts of observation so clearly set forth by Hann.

The compensating process here discussed is illustrated by the curves in the accompanying diagram which express the fact that if air starts at a height of 10,000 meters at P at a temperature of  $-50^{\circ}\text{C}$ . and descend to the earth's surface adiabatically its temperature will be expressed by the straight line X and will be  $+50^{\circ}\text{C}$ . on reaching the earth's surface. But if it cool by radiation its temperature at any altitude will be represented by such curves as A, B, or C, whose curvature will depend upon the rates of radiation and descent. The apices of these curves, or the regions where the increase of temperature with descent ceases and becomes a decrease, will be nearer the surface of the ground in proportion as the coefficient of radiation is smaller or the rate of descent is smaller and especially if the rate of descent diminishes with the time.



*Temperature and Altitude.*

These curves agree with the general tenor of all observations on the temperature of the air, namely that under a cloudy sky the diminution of temperature with ascent is very slight and uniform; within a cloud the diminution is given by the laws of evolution of latent heat; above all clouds and in all clear air as in areas of high pressure the temperature depends upon the radiation of heat and on the thermodynamic changes of a compressible atmosphere.

(14.) In addition to the cases recently under discussion between Ferrel and Hann there are other important problems in the mechanics of the atmosphere that are elucidated by the study of radiation.

(a.) The general circulation of the atmosphere from the equator to the pole can only take place by virtue of the fact that the air which overflows from the equator and from the tropical highs actually loses its heat (not merely diminishes in temperature) and contracts as it cools. Radiation is the only efficient process capable of accounting for the great loss of heat that the atmosphere experiences. Although we are not yet able to state the average amount and law of radiation as dependent on temperature and pressure yet it is easy to see that this must be known and must enter into our equations of condition before we can fully account for the phenomena observed in the general circulation of the atmosphere.

(b.) The passage of a steady atmospheric current over a mountain range depositing rain and snow on the windward side but descending as dry air on the leeward side gives rise to a standing wave such as may be seen above any obstacle in a rapid river. Thus kinetic energy is converted into static pressure and therefore on the leeward side under the summit of the wave down to the earth's surface there is a somewhat higher pressure than there would be in case no such current existed. The clear descending air by its dryness has also a slightly greater density than before at the same temperature and pressure which adds somewhat to the barometric excess. The cooling by radiation annuls approximately the warming by compression and again gives increased density. These three factors therefore conspire to increase the pressure at the earth's surface and this is again further increased largely by the influences of the earth's rotation and the southward flow as explained by Ferrel and Helmholtz. This is the best explanation that I have yet been able to frame of the formation of the high areas and cold waves that move southeastward over Canada and the United States. I believe that I first stated my conclusion as to this mechanism when, in 1876, I had occasion to urge the importance of maintaining meteorological stations in Alaska. The reports from these stations as subsequently established, as well as the international maps of the Signal Service, served to confirm that view. The original current on the Pacific side of the Rocky Mountains may be due either to a special cyclone or to the general circulation of the atmosphere resulting in a standing wave whose summit is over the Mackenzie River; when the current temporarily ceases, the summit and the high area die away; and when it is strongest, the high pressure is the greatest; generally the original current may be considered as a temporary overflow from northern Siberia along the arctic circle to Alaska.

Washington, March, 1892.

[P. S. As I finish this paper I perceive from the last number of the *Meteorologische Zeitschrift* that Dr. William Trabert of Vienna has repeated and confirmed Maurer's calculation of the coefficient of radiation. But the values (respectively 0.036 and 0.032 calories per hour per kilogram of air) thus deduced from meteorological observations cannot be preferable, as I have above stated, to the direct experimental determination. Trabert gives the values of the annual average temperature of the enclosure toward which radiation is supposed to have taken place during the night, which values are between 1 and 8 degrees Centigrade below the temperature of the radiating mass.]

ART. XLVI.—*Experiments upon the Constitution of certain Micas and Chlorites*; by F. W. CLARKE and E. A. SCHNEIDER.

SHORTLY after the publication of our first joint paper upon the constitution of the natural silicates,\* we received from Mr. A. Lösch, curator of minerals in the Imperial School of Mines at St. Petersburg, some highly important material bearing upon our researches. Our work upon leuchtenbergite, it will be remembered, was defective, on account of impurity in the specimens at our disposal; and Mr. Lösch therefore sent us a supply of the perfectly pure mineral, selected with extreme care, and in the very best condition for study. To this gift he added four other minerals which he thought would be of interest to us, and upon these five specimens our present communication is founded.

The minerals, and the analyses are as follows:

- A. Xanthophyllite, var. Waluewite, from the Nikolai-Maximilian mine, District of Slatoust, Ural.  
 B. Clinochlore from the same locality. Green, broadly foliated, closely resembling the mineral from West Chester, Pennsylvania.  
 C. Leuchtenbergite from Slatoust.  
 D. "Diallage serpentine" from the River Poldnewaja, District of Sysstert, Ural.  
 E. White mica from Miask, Ural.

	A.	B.	C.	D.	E.
SiO <sub>2</sub>	16·85	30·84	30·00	42·55	44·17
TiO <sub>2</sub>	trace	----	----	----	----
Al <sub>2</sub> O <sub>3</sub>	42·33	18·31	20·43	1·25	37·35
Fe <sub>2</sub> O <sub>3</sub>	2·35	1·94	1·68	1·56	1·29
FeO	0·20	1·08	0·14	1·52	0·20
MnO	----	----	----	----	0·10
CaO	13·30	----	0·21	none	----
MgO	20·77	34·38	34·26	40·05	----
K <sub>2</sub> O	----	----	----	----	10·00
Na <sub>2</sub> O	----	----	----	----	1·14
Chromite	----	----	----	0·37	----
F	----	----	----	----	0·90
H <sub>2</sub> O, 105°	0·04	0·55	0·55	0·21	1·06
" 250°-300°	0·12	0·49	0·35	0·11	0·53
" ignition	4·44	12·84	12·85	12·15	4·14
	<hr/>	<hr/>	<hr/>	<hr/>	<hr/>
	100·40	100·43	100·47	99·77	100·88
Less O=F	----	----	----	----	·37
					<hr/>
					100·51

\* This Journal, Oct., Nov., and Dec., 1890.

The molecular ratios deducible from these analyses, rejecting water given off below 300°, and the chromite contained in the serpentine, are as follows :

	A.	B.	C.	D.	E.
SiO <sub>2</sub>	·281	·516	·500	·709	·736
R <sub>2</sub> O <sub>3</sub>	·430	·192	·211	·022	·374
RO	·759	·874	·861	1·022	·004
R <sub>2</sub> O	-----	-----	-----	-----	·124
H <sub>2</sub> O	·247	·713	·714	·675	·230
F	-----	-----	-----	-----	·050

Hence we get the following empirical formulæ, in which all R''' = Al, all R'' = Mg, etc.

Waluwite,	$\text{Al}_{86}\text{Mg}_{76}\text{H}_{50}(\text{SiO}_4)_{38}\text{O}_{174}$
Clinochlore,	$\text{Al}_{38}\text{Mg}_{87}\text{H}_{143}(\text{SiO}_4)_{52}\text{O}_{118}$
Leuchtenbergite,	$\text{Al}_{45}\text{Mg}_{86}\text{H}_{43}(\text{SiO}_4)_{50}\text{O}_{121}$
Serpentine,	$\text{Al}_4\text{Mg}_{102}\text{H}_{135}(\text{SiO}_4)_{71}\text{O}_{35}$
Mica,	$\text{Al}_{75}\text{K}_{25}\text{H}_{46}(\text{SiO}_4)_{74}\text{O}_9\text{F}_5$

The last of these minerals is evidently an ordinary muscovite, possibly a little altered, and will receive no further consideration in this paper. The other minerals were examined more in detail, with very interesting results. As in our previous work, all experiments upon each mineral were made upon a uniform sample of the powdered material, so that direct comparisons with the analyses might be possible. The analyses themselves agree closely with the published analyses made by others, and are noteworthy only in the fractional determinations of the water.

Towards dry, gaseous hydrochloric acid, at the temperature interval 383°–412°, the minerals under investigation were somewhat refractory. From the waluwite, after nine hours heating in the gas, only 0·22 per cent of lime and 0·10 per cent of magnesia were extractable by water. Hence we may fairly infer that the species contains practically no -Mg-OH groups, a result which is in accordance with theory, as will be seen later. The chlorites and the serpentine, however, gave anomalous results, as follows; there being two experiments on each.

	Clinochlore.	Leuchtenbergite.	Serpentine.
Hours heated,	8½      13	16½      18½	28½      7
MgO extracted,	7·34      5·48	7·33      5·62	3·66      2·66

In each case the heating was continued to constant weight, but the amount of action was much less than in the American clinochlore and serpentines which we formerly investigated. The leuchtenbergite behaves much like the impure material

discussed in our earlier paper, from which 6.29 per cent of magnesia was removable; but more than double that amount is required to represent the MgOH which must be present under any recognized theory.

These results were so unsatisfactory that further work seemed to be desirable, but the tediousness of the process was discouraging. As a possible abbreviation of the method a new device was tried, which, although as yet unconvincing in its outcome, is nevertheless interesting. Ammonium chloride, as is well known, dissociates upon vaporization into ammonia and hydrochloric acid. Will it then, dissociating in presence of a silicate, act in any way by virtue of the acid so liberated? This question is still under investigation; but some preliminary data may here be given. In each experiment the mineral was intimately mixed with ten times its weight of sal ammoniac, and then heated in a platinum crucible, well below redness, until all the ammonium salt had been vaporized and driven off. The residue was then leached out with water, and the soluble magnesia determined. Upon olivine and waluwite there was very little action, as in the case of the treatment with gaseous hydrochloric acid; but upon the chlorites and serpentine there was a vigorous attack. The magnesia thus rendered soluble was as follows:

	Clinocl.ore.	Leuchtenbergite.	Serpentine.
Percent MgO,	2.12	3.98	4.93

In a second series of experiments the minerals were heated as before with ammonium chloride until the latter was driven off. Then a fresh charge of chloride was added to the contents of the crucible and expelled like the first. Finally a third charge was added and likewise expelled. By this means more magnesia was converted into chloride than in the first experiments, as the subjoined figures show:

	Clinocl.ore.	Serpentine.	
	3 heatings.	2 heatings.	3 heatings.
Soluble MgO,	3.80	14.30	10.63

The irregularities in all these data remain to be explained. So far the results have only qualitative value. In those minerals which must contain the group MgOH, some action takes place, but in variable amount. But the magnesium silicates which cannot contain MgOH are practically unattacked, and so far all the evidence is harmonious and clear. Contrary to our earlier expectations, however, we cannot trust the dry hydrochloric acid reaction quantitatively, at least until its conditions and its nature are more fully understood. We can determine when the group MgOH is present as an essential

part of a silicate, but not its actual amount. Probably the hydroxyl is first replaced by chlorine, converting the group  $-MgOH$  into the chlorhydrin-like group  $-MgCl$ . The latter, by continued action of the gaseous acid is then possibly split off as  $MgCl_2$ , but with secondary reactions to which the anomalous and irregular results may be due. The question is still open, and we hope by further experiments to get at something more conclusive. The problem is, to measure basic hydroxyl by its replacement with chlorine; and there seems to be no good reason why it should not be solvable.

By strong aqueous hydrochloric acid the chlorites and the serpentine were easily decomposed; but by previous ignition they were split up into soluble and insoluble portions. This splitting up is, in the case of serpentine, already well understood; the products being as Daubreé has shown, olivine and enstatite. For the waluewite and the chlorites, however, the existing data were scanty, and accordingly new experiments were undertaken. In each case the powdered mineral was ignited over a blast for several hours. It was then digested with strong hydrochloric acid, and after evaporation to dryness and re-solution, the residue was filtered off. Then, after drying and ignition, it was boiled with aqueous sodium carbonate to remove the silica which had been released from the soluble silicates, and the final residue was weighed and analyzed. As this process was followed in our first investigation with the Pennsylvania ripidolite, the results are included here for comparison with the Siberian material. The percentages of insoluble residue were as follows:

	Waluewite.	Clinochlore.	Leuchtenbergite.	Ripidolite.
Found,	45.01	17.56	19.24	19.74
Corrected,	43.96	16.63	18.05	18.49

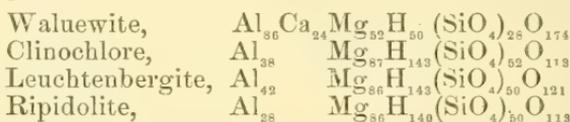
In the second line the silica found in the residues, being presumably extraneous, is deducted. The composition of the residues is given below.

	Waluewite.	Clinochlore.	Leuchtenbergite.	Ripidolite.
$SiO_2$	2.34	5.25	6.16	6.32
$R_2O_3$	71.12	67.20	68.52	67.81
$MgO$	26.75	27.89	25.12	25.67
$CaO$	trace	----	----	----
	100.21	100.34	99.80	99.80

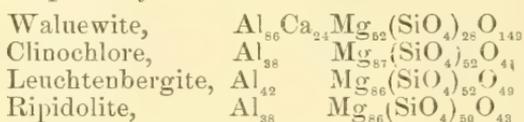
In these analyses the silica ranges from 0.93 to 1.25 per cent of the original mineral, and the remainder has quite sharply the composition of spinel. This point was noticed in our former paper, in the case of the West Chester ripidolite; but

since then it has acquired new significance, and it is emphasized by the new analyses. Leaving the waluwite for separate consideration, it is to be noted that the three chlorites studied by us are all typical members of Tschermak's orthochlorite series; which, according to him, are mixtures of two end compounds, serpentine and amesite. How amesite may behave upon ignition, we do not know; but serpentine splits up, as is well known, into olivine and enstatite; the latter being insoluble in hydrochloric acid. Under Tschermak's theory of the chlorites, a clinochlore of the composition  $\text{SpAt}$ , should upon ignition yield about 18 per cent of enstatite; or in other words, the insoluble residue should contain *at least* one third of all the silica in the mineral. Since no enstatite is actually formed, or practically none, it is plain that the three chlorites here considered contain no serpentine molecules; and hence, so far at least as these minerals are concerned, Tschermak's theory falls to the ground.

Approximately, but not exactly, the formation of spinel from the waluwite and the chlorites, seems to follow a single quantitative law. To illustrate this the empirical formulæ may be reproduced here.



Upon ignition, of course, water is expelled, and the ignited residue is empirically as follows:



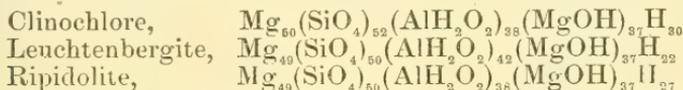
Here we have in each mineral an excess of oxygen over  $\text{SiO}_2$ , and to that excess the amount of spinel residue is approximately proportional, thus:

	Found corrected.	Calculated.
Waluwite,	43.96	43.15
Clinochlore,	16.63	14.80
Leuchtenbergite,	18.05	17.62
Ripidolite,	18.49	15.83

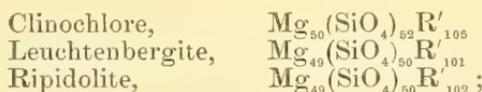
Considering the impurities in the original materials, and the unavoidable inaccuracies of manipulation, the agreement here is as close as could be expected. The calculation assumes that the excesses of oxygen represent quantitatively the amount of spinel formed, and all the errors of analysis are accumulated in

the final result. If we deduct the spinel from the composition of each mineral, the soluble portion is expressible as a mixture of olivine and magnesian garnet; two species which are among the commonest progenitors of the chlorite group. That olivine and garnet are actually formed is certainly not proved; but it seems highly probable that the chlorites studied do split up in the manner indicated, yielding water, spinel, garnet and olivine as the final products of decomposition. Other chlorites may behave differently; and it is quite likely that the species or varieties rich in iron may diverge widely from the types considered here. Speculation upon this theme would be premature.

As to the chemical structure of the leuchtenbergite and clinochlore, the evidence now available is quite in harmony with the general theory of the chlorite group recently advanced by one of us.\* Again including the Pennsylvania ripidolite, the three chlorites reduce to compositions as follows:



Condensing, by union of the univalent factors, these become—



or, in general, all three examples have nearly identical composition, and conform to the typical expression—



in accordance with the theory which represents them as substitution derivatives of the normal salt  $Mg_4(SiO_4)_2$ . We may interpret the minerals in detail as was done in the case of our earlier discussion of the West Chester ripidolite, or we may regard them as mixtures of the two salts—



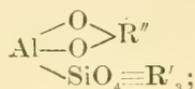
In either case the juxtaposition of the groups  $AlH_2O_2$  and  $MgOH$  renders the formation of spinel intelligible.

In the waluwite, or more properly xanthophyllite, we have the first example of a true brittle mica met with in the course of our investigations. Being the most basic known member of the clintonite series, it has peculiar interest; and it deserves a somewhat detailed discussion. In the empirical formula deduced from our analysis,

\* This Journal, March, 1892.



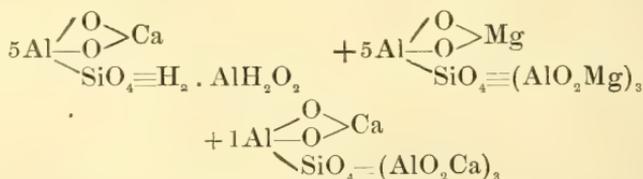
the most noticeable feature is the great excess of oxygen compared with the possible hydroxyl and the small amount of  $\text{SiO}_4$ . This excess is accounted for in part by the general formula which we have heretofore assigned to the clintonite group,



which formula, however, needs some extension along a new line. In that formula the group of atoms  $-\text{AlO}_2\text{R}''$  appears, an equivalent obviously of the group  $\text{AlO}_2\text{H}_2$ ; and this group may fairly be repeated among the components of  $\text{R}'_3$ . With such a group, the extreme member of the clintonite series should have the composition  $(\text{AlO}_2\text{R}'')_4\text{SiO}_4$ ; and a molecule of that type is theoretically capable of splitting up into olivine and spinel in the ratio of 1:2, when each mineral is given its lowest possible formula:



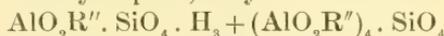
In the case of xanthophyllite, if such a molecule is contained in it, the olivine formed should be partly monticellite. At Monzoni, monticellite is found associated with spinel; and brandisite, a member of the clintonite series, occurs in the same region. In fact, all three of the true clintonite micas are commonly associated with spinel, a fact of much interest when considered in its relations to our experiments. In the light of the foregoing argument the composition of waluwite and its manner of decomposition by heat, may be represented as follows:



These three molecules are all of the general type heretofore assigned to the clintonite series, and two of them are presumably capable of yielding spinel. Reducing the original analysis to 100 per cent with consolidation of like bases as usual, we get the following comparison between experiment and theory; the calculated composition being in accordance with the structural formula above cited.

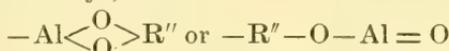
	Found, reduced.	Calculated.
SiO <sub>2</sub>	16·97	17·02
Al <sub>2</sub> O <sub>3</sub>	44·14	44·71
CaO	13·50	13·00
MgO	20·92	20·63
H <sub>2</sub> O	4·47	4·64
	<hr/>	<hr/>
	100·00	100·00
Spinel formed,	43·96	43·94

Reckoned on a similar basis, clintonite, according to the analysis published by Sipöcz, may be written—

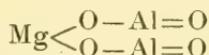


and brandisite is of the same general character, with a small admixture of the first of the three xanthophyllite molecules given in our structural expression. Whether chloritoid is a true member of this group, seems to be uncertain; but if it is, its composition may be written  $\text{AlO}_2\text{Fe} \cdot \text{SiO}_4 \cdot \text{H} \cdot \text{AlOH}$ ; the last factor being a bivalent group related to the univalent  $\text{AlO}_2\text{H}_2$ .

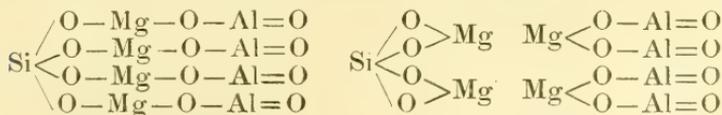
As for the ultimate structure of the group  $\text{AlO}_2\text{R}''$ , it may be written in two ways, thus:



The first form corresponds to the group  $-\text{Al}(\text{OH})_2$ , the second to the formula commonly assigned to spinel,



In either case two of the groups  $\text{AlO}_2\text{R}''$  coalesce to form one molecule of spinel, with removal of a single magnesium atom. Such a coalescence is easiest comprehended when the second form of the radical is chosen; but the first form is more harmonious with the constitution of the mica series in general. If the xanthophyllite compound  $(\text{AlO}_2\text{R}'')_4\text{SiO}_4$  be regarded independently of the micæ, it is most simply written as follows, with its splitting up into olivine and spinel as indicated:



If, however, for the sake of preserving harmony with the mica formulæ we adopt the first expression for  $-\text{AlO}_2\text{R}''$ , then spinel would seem to have the constitution



Although the last formula is somewhat novel, it is not altogether improbable; but between it and its alternative we cannot yet certainly decide. Another open question is furnished by the chlorites, in which the formation of spinel may possibly be due to the presence of  $\text{AlO}_2\text{Mg}$  groups. Upon this supposition, however, the chlorites do not reduce to simple formulae, and therefore the suggestion has slight value. Apart from all theoretical considerations, the spinel reaction, as it may fairly be called, is one of an entirely new order in mineral chemistry, and it opens up a noteworthy line of attack upon the difficult problems before us.

Laboratory U. S. Geological Survey, Washington, Jan. 14, 1892.

ART. XLVII.—*On the Qualitative Separation and Detection of Strontium and Calcium by the Action of Amyl Alcohol on the Nitrates*; by P. E. BROWNING.

[Contributions from the Kent Chemical Laboratory of Yale College, XIII.]

IN a recent paper\* I have shown that strontium and calcium may be separated quantitatively by boiling the nitrates of these elements with amyl alcohol and applying the corrections determined for the solubility of the strontium salt. The qualitative separation, however, is somewhat vitiated by the deposition of a slight residue upon the bottom of the test tube or beaker when calcium nitrate is boiled with amyl alcohol. While this deposit weighs but a few tenths of a milligram and is insignificant in its effect upon the interpretation of the quantitative results, it may easily be mistaken for strontium in the qualitative test unless tested spectroscopically. This residue when dried, dissolved in water and nitric acid, and again treated with amyl alcohol is not dissolved completely but again separates out wholly or partially. The possibility of the formation of the calcium salt of an organic acid by the action of the nitric acid on the amyl alcohol (a point to which reference was made in the paper before mentioned), suggested the idea that ignition might so change the residue that it would not re-appear upon a second boiling with the amyl alcohol. Experiment proved the truth of this presumption; for it was found that after getting the ignited residue into solution with water and a drop of dilute nitric acid, subsequent boiling with amyl alcohol effected complete solution, as shown by experiments (1), (2), (3), (4) of Series I below. In applying the method qualitatively, small amounts of the amyl alcohol may be conveniently used and the boiling carried on in a test tube, care being taken

\* This Journal, vol. xliii, p. 50.

to keep the inflammable fumes of the alcohol from the flame. Five cubic centimeters of the alcohol is a convenient amount to use in each boiling and the error introduced by the solubility of the strontium salt is thus reduced to a minimum, the solubility in 30cm<sup>3</sup> having been determined to be 0.001 gram. of the oxide. Experiments made to test the delicacy of the method as regards the detection of strontium alone are recorded in Series I (5), (6), (7), (8), (9); and (10), (11), (12), (13), give the results of the treatment in the presence of both strontium and calcium. Into a test tube is put the mixture of the nitrates of strontium and calcium not exceeding 0.2 gram., that being the limit of the solubility of calcium nitrate in 5cm<sup>3</sup> of amyl alcohol. After dissolving in a few drops of water 5cm<sup>3</sup> of amyl alcohol are added and the boiling is carried on until the normal boiling point of the alcohol, 128–130° C., is reached. If strontium is present to the amount of 0.001 gram. of the oxide or more a very decided separation takes place. If the amount is smaller it cannot be readily distinguished from the residual spots deposited on the bottom of the tube by the calcium salt. The alcohol containing the calcium salt dissolved is decanted upon a dry filter paper in a dry funnel and the residue washed in the tube with about 5cm<sup>3</sup> of absolute ethyl alcohol, this also being filtered into the tube containing the amyl alcohol. The filtrate is reserved to be tested for calcium, while the residue, if so small that it may be a calcium deposit, is dried gently and finally ignited by agitating the tube over a flame. After cooling the tube a few drops of water and a drop of nitric acid are added and the boiling repeated. As the results of Series I show, any amount of strontium above 0.0005 gram. of the oxide separates out distinctly, while the slight calcium residue does not reappear. My experience has been that amounts of calcium nitrate equal to 0.2 gram. give a deposit on the first boiling about equal to 0.0003 gram. of strontium oxide on the first boiling. The residues from the second treatment in Series I (5) to (13) were all dissolved in a few drops of water treated with a drop of hydrochloric acid and tested before the spectroscope, all giving distinct strontium lines but no trace of calcium. The calcium residues from the first boiling gave distinct calcium lines but no trace of strontium.

The delicacy of the process in the detection of calcium is shown by the experiments of Series II. The method of treatment was the same as described above excepting that the filtrates and washings after the first boiling were used for these tests. To these clear filtrates about 2cm<sup>3</sup> of dilute sulphuric acid were added, and in five minutes or less the results recorded were apparent. When strontium alone was taken either in

large or small amounts, the result was uniformly a faint cloudiness gathering after standing sometime to a minute precipitate of a granular character. In the case of the calcium the detection could be carried easily to 0.0005 gm. of the oxide, and satisfactory results were obtained with 0.0002 gm. The character of the precipitate in the case of calcium was moreover, distinctive, it being in every case light and flocky, and collecting in floating masses. With the precautions noted very satisfactory results can be obtained by this method, not the least advantage being the rapidity with which a determination can be made. It will be noticed that in some cases calcium and strontium are recorded as the nitrates and in others tabulated as oxides. When either strontium or calcium were used in large quantities the pure nitrate was weighed out directly; when very small amounts were used these were taken from the standardized solutions of the nitrates used in the quantitative work, the standards of which had been recorded in terms of the oxide. The strontium and calcium salts used in this work were specially purified by the methods detailed in my previous paper.

#### SERIES I.

	SrO taken.	Ca(NO <sub>3</sub> ) <sub>2</sub> taken.	Deposit after 1st boiling.	Deposit after 2nd boiling.
( 1 )		0.1 gm.	Trace.	None.
( 2 )		0.2 "	Slight.	None.
( 3 )		0.2 "	Slight.	None.
( 4 )		0.2 "	Distinct.	Faintest trace.
( 5 )	0.0003 gm.		Faint trace.	Faint trace.
( 6 )	0.0003 "		Faint trace.	Faintest trace.
( 7 )	0.0005 "		Distinct.	Distinct.
( 8 )	0.0005 "		Distinct.	Distinct.
( 9 )	0.0010 "		Distinct.	Distinct.
(10)	0.0010 "	0.2 "	Distinct.	Distinct.
(11)	0.0005 "	0.1 "	Distinct.	Faintest trace.
(12)	0.0007 "	0.1 "	Distinct.	Faint trace.
(13)	0.0008 "	0.05 "	Distinct.	Distinct.

#### SERIES II.

	Sr(NO <sub>3</sub> ) <sub>2</sub> taken.	CaO taken.	Result.			
( 1 )	0.001 gm.		Faint granular cloudiness.			
( 2 )	0.1 "		"	"	"	"
( 3 )	0.2 "		"	"	"	"
( 4 )		0.001 gm.	Decided	flocky	floating	masses.
( 5 )		0.0005 "	"	"	"	"
( 6 )		0.0002 "	"	"	"	"
( 7 )		0.0001 "	Plain	"	"	"
( 8 )		0.00005 "	Faint	"	"	"
( 9 )	0.1 "	0.0005 "	Decided	"	"	"
(10)	0.1 "	0.0002 "	"	"	"	"
(11)	0.1 "	0.0001 "	Plain	"	"	"
(12)	0.2 "	0.0002 "	Decided	"	"	"

ART. XLVIII.—*The Age and Origin of the Lafayette Formation*; by EUGENE W. HILGARD.

THE interest so widely felt in the Lafayette formation since its great extension northward has been definitely established and its details in that region studied by Mr. W. J. McGee, and described in other special communications on the subject which have reached me, suggests the timeliness of a summary presentation of my views, as shaped under the light of a fuller view of the whole formation and a review of the matter in the Mississippi Embayment during the past summer, by a party of geologists. This party included, besides Mr. McGee and myself, Professors Safford of Tennessee, Smith of Alabama, Holmes of North Carolina, and Lester F. Ward and R. T. Hill of the U. S. Geol. Survey.

As the publications containing the record and discussion of my former observations (in which the formation carries the name of "Orange Sand," now dropped by agreement) are difficult of access after the lapse of from twenty to over thirty years, it may be necessary to recapitulate, summarily, the main points as then presented, in order to render the later discussion intelligible to all interested.

The eastern outline of what I have called the "Orange Sand Delta" extends from a point near Cairo, through western Kentucky and Tennessee, nearly through the northeast corner of Mississippi into Alabama; whence, as I then ascertained from the descriptions of Tuomey, and by correspondence with Dr. Joseph LeConte, it passes eastward around the Appalachian highlands into the Carolinas and thence north to Virginia and Maryland. On the west, I traced the formation by D. D. Owen's descriptions through Arkansas, and personally through Louisiana and across the Sabine into Texas.

Within the limits given, say between the Warrior river on the east and the Sabine on the west, and excepting the areas occupied by the Cretaceous prairies, the (Tertiary) "Flatwoods," the Loess, and the Mississippi bottom, the formation as a rule lies at or near the surface of the country, most frequently covered by a few (three to ten) feet of brown or yellow loam of much later date, since it also overlies the Loess. The characteristic concretionary ferruginous sandstone of the formation (replaced occasionally by a white siliceous sandstone or chert) caps nearly all the higher ridges, the crests of which it has protected from degradation, and usually forms the upper portion, or sometimes the entire body of such ridges; showing, by their alternation with others bearing only a thin cap of the

“Orange Sand,” that the latter has been deposited on a deeply denuded surface. The latter fact is also shown in numerous profiles, and is the rule in the interior uplands; while near the larger river troughs, and notably in a north-and-south direction, the unconformity is less conspicuous and the lower limit of the formation is less uneven. In the southern portions of Mississippi and Louisiana, the rolling plateaus that bear the great long-leaf pine forest, are underlaid by the formation sometimes to the depth of over 200 feet. It reaches the Gulf shore at only a few points; in Mississippi near Shieldsboro', where prominent ridges abut on the coast plain on Pearl river about 20 miles above its mouth. In Louisiana the shore is reached at the Island of Petite Anse, where it immediately overlies the (doubtless Cretaceous) rock-salt deposit. Within the last few years it has been proved to reach the shore of Mobile Bay, by Lawrence Johnson.

The material of the formation, away from large channels and from contact with underlying beds, is predominantly a ferruginous (sometimes more or less clayey), hence usually orange or rust-colored, but sometimes purplish, white or variegated sand, consisting almost entirely of quartz grains much rounded and smoothly polished, and very commonly incrustated with the rusty pigment. This external character of the sand is popularly so well understood that building contracts expressly provide for “river or creek” sand, prohibiting the use of that formed of the smooth, round grains for mortar. Near the surface of the formation this sand is commonly more or less commingled with the surface loam or its washings; while where it overlies clayey formations of whatever age, it is commonly more or less commingled with similar clays (more or less altered), whether by inter-bedding, intermixture, or very commonly by the inclusion of rounded clay fragments, ranging in size from mere grains to boulders of a foot or more diameter. Where in contact with sandy formations, the lower portions of the “Orange Sand” (identified as such by the peculiar bedding, and unconformity with the underlying older beds), commonly consists of the materials of such beds, re-stratified in the manner of the later formation.

Near the great river channels, notably that of the Mississippi on either side, on the Tombigbee and Tennessee, as well as on the Sabine, there is a steady increase of gravel; shown conspicuously on the landward margin of the Loess belt of the Mississippi, as well as, at numerous points, close to the river itself; and (near the line between the states of Mississippi and Louisiana) eastward to Pearl river and Lake Pontchartrain. Conspicuous gravel deposits lie along the lower course of the Tennessee river, in Mississippi and Tennessee.

The *substance* of this gravel is by far predominantly chert of Subcarboniferous age, less frequently siliceous sandstone and quartzite; but the corals and crinoids, as well as occasionally the trilobites of the older Paleozoic rocks are always more or less represented. No calcareous rocks have been found anywhere; but in and near the main channel of the Mississippi, pebbles of crystalline rocks—granite, syenite, gneiss, mica-schist, as well as dioritic greenstone and eruptives—are not uncommon, though always much rounded, usually small but occasionally of several pounds weight, and usually also much decayed. A similar assortment of crystalline rocks was observed by me at Petite Anse island, on the Gulf shore, in the direct line of the axis of the Mississippi valley.

While the *size* of the pebbles commonly ranges from that of a walnut to that of a fist, there occur occasionally boulders of considerable weight, up to several hundreds of pounds, of the same rock material as the smaller gravel.

The *structure* of the formation is extremely irregular. It may broadly be said to be approximately horizontally bedded or stratified, without having any well-defined general dip, save in that it conforms to that of the general surface of the country to southward. In its upper portions it is sometimes wholly structureless in profiles of as much as twenty feet, when the material is usually somewhat clayey and constitutes a sandy loam. Most commonly however the bedding-lines are conspicuous and very complex, showing the flow-and-plunge structure of sand-bars, often alternating with that of beaches, and then again, particularly on the more consistently continuous stratification lines, the peculiar wavy structure which belongs to the flood-deposits of valleys. The bedding and stratification lines are commonly conspicuously marked by the ferruginous coloring which pervades more or less the whole formation and doubtless forms an important landmark in its history.

In this irregularity of stratification and bedding the formation differs pointedly from the bulk of the Tertiary formations that have preceded it on the same areas; although locally, cross-bedding occurs in these as in all formations of sandy materials. But in the Lafayette beds the structure resulting from deposition in flowing and violently agitated waters is all but universal.

In its *stratigraphic relations* to other formations the "Orange Sand" of the Mississippi embayment shows a prevalent unconformity with both the older and later beds with which it is in contact. It has been deposited on a deeply eroded or sculptured surface, and has itself suffered deep erosion before the deposition of the succeeding deposits. Yet inasmuch as in its formation it has largely drawn upon the materials of the subjacent beds, apparent conformity frequently exists where these

are sandy; while complete and unquestionable unconformity may be exhibited in the next ridge, where the subjacent beds are indurated or clayey. Similarly, apparent conformity exists very commonly along the Mississippi river, between the upper member of the Lafayette and the Loess and Port Hudson—the “Columbia” of McGee. But inland the most striking unconformities may be seen in abundance, proving the reverse condition to be accidental.

As regards its *geological age*, since it overlies the latest recognized Tertiary (the Grand Gulf beds) and is in turn overlain by the earliest recognized Quaternary of the region (the Port Hudson), the Lafayette may, *a priori*, be claimed for either of the two subdivisions; being (in the “Orange Sand” facies at least) entirely devoid of fossils that can with certainty be claimed as its own, although containing abundance of borrowed ones.

Considering the conspicuously detrital nature of the materials, the predominantly “fluvial” structure, and the total absence of any traces of contemporary marine fossils, even close to the shores of the Gulf and in materials perfectly adapted to their preservation: it has seemed to me most probable that the formation as a whole is the outcome of the action of “fresh water in the state of violent flow.” At the geological level we must attribute to the “Orange Sand” at least—the latest Tertiary or the earliest Quaternary—the melting of the continental glacier naturally suggested itself to my mind as well as to that of Tuomey, with whom I discussed the subject in 1856. This suggestion acquired especial force by the fact that crystalline boulders, apparently identical with those occurring in the moraines of Illinois and Missouri, occur in the main axis of the embayment down to the Gulf shore, where the current-velocity would presumably be greatest; while outside of that great axis only the local rocks, or those not derived from any great distance at least, form the bulk of the gravel deposits. I was thus led to consider the “Orange Sand” as the direct representative and continuation southward of the “stratified drift” of the Northwest, and have alternatively so designated it in my later publications.

Such was, summarily, the condition and aspect of the subject when, nearly twenty years ago, the stoppage of the Mississippi Geological Survey, and my removal from the Southwest, put an end to my personal researches in the premises. The matter has passed into several text-books in that form; and the only important change made until McGee, a few years ago, approached the subject from the eastward, was the recognition by Dr. Eugene Smith of Alabama of the lower portion of the Warrior gravel beds as belonging to old Cretaceous or

even pre-Cretaceous time, while with me he still considers the upper portion of the "Tuscaloosa" as being the same materials re-arranged by aqueous agencies during the "Orange Sand" or Lafayette epoch. This discovery changes the general aspect of the latter formation in so far as I had attributed the heavy gravel deposits of the Tennessee and Warrior river borders to strong currents coming from the northward—as indicating the course of the easternmost delta-bayou of the glacial flood; while from the point of view that these gravels are merely debris torn from the ancient sub-Cretaceous beach formed almost on the site of the parent rock-formation (the Subcarboniferous chert), the assumption of any such large current flowing to southward in that region becomes unnecessary. In fact, it becomes possible that even the older border gravels of the Tennessee river may have traveled in the reverse direction, down the present Tennessee valley; and we gain an insight into the origin of the enormous gravel masses of that region without resorting to any violent hypotheses concerning events in Quaternary time.

Another point involving a former error of interpretation on my part is the recognition of the Cretaceous age of the lower portion of the profile at the "Big Hill" near Pocahontas, Tenn., that in my report of 1860 (p. 16) is figured and described as a conspicuous "Orange Sand" locality. Now that the rains of thirty-five years have sculptured the smooth sides of the original cut, it is easily seen that the lower portion is not of the Lafayette character, and that the clay basin then supposed by me to contain here, at least, vestiges of the Lafayette flora, is therefore referable to a time anterior even to the Tertiary; probably the Ripley Cretaceous.

It would seem natural and logical to seek for the record of changes of level concerning the Mississippi valley—the great central drainage basin of the continent—in the border lands of the Gulf into which this drainage passes; but for years I have sought in vain to impress this point of view upon those in whose hands lay the power for initiating such researches. It thus happens that prior to the time when McGee's researches carried him into the field where I had previously worked, the discussion of the continental changes of level was carried on by geologists working at the head of the great valley, largely irrespective of what is recorded near the only datum-plane to which such oscillations can legitimately be referred; since the Archæan highlands of the northeast form a pivotal area from beyond which no reasonable conjectures can be translated, the Mississippi axis being known to be a line of weakness and unstable equilibrium, whose movements have been largely independent of those of the Atlantic coast. Witness the peculiar develop-

ment of the Cretaceous and Tertiary formations in the Mississippi embayment.

I think that many if not most of the differences which have arisen between McGee and myself in the interpretation of the phenomena of the Lafayette formation have been due to the different starting points. McGee, coming from the Atlantic coast, naturally carried the views acquired there into the territory where, I am inclined to think, a materially different mode of development has occurred; as would naturally be expected in so critical a region. The joint reconnoissance made last summer has, I think, materially diminished these differences of views; and the extension of this reconnoissance around the Gulf shore into Mexico by himself and party will, I hope, prove the fruitful first step toward the final unraveling of the complex questions which, alone, I was powerless to solve.

Broadly speaking, the difference of views referred to may be summarized in this, that while McGee regards the whole of the Lafayette formation as having been formed under a condition of continental depression and marine submergence, I have on the contrary, referred the origin of the "Orange Sand" of the Embayment to a period of elevation, and the deposition of its materials essentially to fresh water in the form of broad and shallow floods coming in from the northward and practically devoid of organic life of which the remains would be likely to be preserved. All are, however, agreed that the deposition, by whatever agency, was succeeded by a relatively long period of elevation or at least emergence, during which subaërial exposure brought about both the surface sculpture and the condition of complete peroxidation, and leaching of all water-soluble ingredients, that is so prominent and essential a feature of the "Orange Sand" phase of the formation. For within its beds, nothing that is capable of further oxidation or water-solution remains, so that agriculturally the formation, alone, is about as barren as can well be.

That the paludal nature of the overlying Port Hudson beds, as well as the fluvial and calcareous nature of the Loess, necessitates the assumption of a subsequent re-depression, need hardly be more than mentioned. The extent of this oscillation I will presently consider.

It would seem from the character of the formation as observed on the Atlantic coast, that the evidence of long emersion and subaërial exposure is not so cogent there. Certainly the leaching process, as well as that of ferrugination, has not been carried so far as is the case in the Embayment, since according to McGee, the gravels still contain rare calcareous pebbles; of which, as before stated, not a trace remains in the "Orange Sand," although limestone formations are plentiful

both in and around its area of occurrence. I am not however, prepared to discuss the eastern phase of the formation, of which I know merely generalities. From statements made by McGee I infer that there are wide and material differences in the maximum elevation at which the formation is found at various points around the Appalachian highlands; the data thus far published by him are not sufficient for an outside discussion of this point.

In the Embayment itself, some questions arise in regard to the identity of the formation as a whole, since McGee inclines to consider as belonging to it a lower phase of "plant beds" which I have always regarded, and do still regard, as belonging to the subjacent formations of various ages. Nothing that I have seen during the late joint reconnoissance seems to me to justify a change of opinion on my part in this respect; I have now as formerly seen the lignitiferous beds of the several stages of the Tertiary, from the lowest Eo-lignitic to the Grand Gulf, underlying the characteristic transition beds of the "Orange Sand;" but I hope to be able to set this question at rest by a microscopic examination of the specimens collected. If there is any true "Lafayette" plant bed, it should be possible to identify it at the various points of occurrence; which to my mind, however, exhibit simply contact phenomena. Prof. Ward's paleobotanic researches, also, will I hope be brought to bear on this question. I understand, however, that McGee does not claim such a plant bed as an integral part of the Eastern phase of the formation. Its existence would not necessarily conflict with either his or my views of the origin of the Lafayette sands.

One of the most vital points to be settled by closer investigation than has yet been made is the exact correlation of the gravel deposits. From their apparent continuity I have referred to the Lafayette age most of the larger gravel beds of the interior and river border, distinguishing only those manifestly belonging to the surface loam, and certain limited deposits within the Port Hudson beds. McGee has shown that small gravel beds do occasionally occur at the base of the Loess itself; and a late detailed examination of the instructive profile at Natchez proved, to the satisfaction of all of the exploring party, that even considerable gravel beds do occur within what, from all characters, must be presumed to be Port Hudson beds. Within these I found several small crystalline (gneissic and mica-schist) pebbles; but it was in a bed of ferruginous gravel conglomerate of some 25 feet thickness, underlying the typical Port Hudson and reaching below water level, that an abundance of crystalline pebbles, and cobbles up to three and four pounds weight, were found. It was proba-

bly from the same locality, as well as from the gravel beds at Proffit's island, below, that the collection of such gravels, formerly at the capitol at Jackson, Miss., that was destroyed during the war, were obtained. The ledge of ferruginous gravel conglomerate is underlain (as seen at the landing a mile above) by a bluish clay of the peculiar aspect and texture of the typical Grand Gulf Tertiary, which is everywhere else overlain by the Lafayette. We thus appear to have in the Natchez profile the usual regular sequence, in full, of Grand Gulf, Lafayette, Port Hudson beds with calcareous nodules, "Sand Loess," calcareous (typical) Loess, and brown surface loam.

It has seemed to me, from the outset, but natural that the larger crystalline gravel, coming from beyond the barrier of Carboniferous rocks above Cairo, should remain within a short distance of, or entirely within, the deep central channel which has always coincided closely with the Mississippi trough of today; while the flood waters carrying the lighter gravel and sand would spread over the uplands, laterally, where afterwards, by long subaërial exposure, the small crystalline gravel would disappear completely by weathering, as indicated by the very "rotten" condition of the same class of gravels at Natchez and Proffit's island. To my mind it would be rather surprising if such pebbles had survived up to this time in the upland or lateral portions of the Lafayette deposits; it greatly surprised me to find them as far south as Petite Anse, for although small and much decayed, there still were some of several ounces weight. I do not therefore see that the absence of crystalline moraine gravels from the lateral portions of the Lafayette in Tennessee, Mississippi and Louisiana, even if as complete as has been thus far supposed, has the weight assigned to it by Chamberlin and Salisbury (this Journal, xli, 359, who contend that on that ground alone the formation must be referred to a period preceding the glacial epoch—inferentially, the Tertiary; the same observers having found the loess to contain essentially the materials of the Illinois moraines, while the gravels which they consider as contemporaneous with the "Orange Sand" and which they find to reach as far up as Keokuk, are free from such material and are evidently pre-glacial. On the other hand, Call, in his discussion of the formations of Crowley's ridge in Arkansas, refers certain gravels found there to Quaternary time and identifies "Hilgard's Orange Sand" with underlying deposits in which he finds unquestionable evidence of Eocene age. He is clearly mistaken as to the nature and identity of the much-discussed formation so designated by me; which as he should have

known, overlies the latest Tertiary of the Southwest, the Grand Gulf.

The concrete question whether the Natchez gravel, bearing crystallines, is continuous with, and equivalent to the abundant gravel beds of the adjacent uplands, should be solvable without any serious difficulty by direct tracing along the deep ravines and valleys that run at right angles to the river at and below Natchez; and the same can, doubtless, be done at most other points on the Mississippi River. But it must be done by those who can be relied upon not to confound accidental continuity with that which is essential. It is clear that here as in the case of the Warrior or Tuscaloosa beds, a very critical judgment must be exercised; since one and the same gravel may have been "worked over" several times during successive geological epochs, and it must often be extremely difficult to discriminate between that which is essential to the origin and composition of the deposit, and that which is a local accident.

Pending the determination of this point in the field, and possibly with the aid of further microscopic research on the samples already collected, I call attention to the fact that intrinsically, the discussion of the "Tertiary" or "Quaternary" age of the Lafayette may easily be more a war of words than of essentials. If preglacial, as is maintained by McGee and Chamberlin, it certainly stands at the very top of the Tertiary series, if the beginning of the Glacial period be made the criterion of the lower limit of the Quaternary. But this is a purely arbitrary limit. It is quite certain that the conditions under which, from any point of view, the Lafayette was deposited, differed widely from those which presided over the formation of all the other Tertiary stages in the Southwest. During early Eocene times there prevailed in the upper portion of the Embayment, estuarian, marsh and paludal conditions, as is evidenced by the lignitiferous beds of that region. Later we find steadily increasing marine conditions, represented by the Claiborne, Jackson and Vicksburg terranes: at the end of the latter epoch the Embayment had already lost so much of its northward extension that the Gulf shore was only slightly more convex than at present. Then comes the somewhat enigmatical Grand Gulf terrane, clearly a brackish water deposit, consisting largely of remarkably solid clays and (usually) very soft and more or less clayey sandstones. Of recognizable fossils this formation contains only plants, so far as has been definitely ascertained; but certain calcareous beds within it seem to contain the macerated, concretionary remnants of a molluscan fauna, such as are now found over the greater portion of the Port Hudson terrane, but which at some points differentiate, into well defined fluvio-marine shells.

While the Grand Gulf beds thus indicate a predominance of fresh-water conditions for which the end of the preceding (Vicksburg) epoch has not prepared us, yet it follows the older Tertiaries in that it offers no evidence of any other than quiet modes of shore and marsh sedimentation, undisturbed, so far as we have seen, by any invasion of fluvial conditions. Cross-bedding even is unusual, and what there is clearly of the kind induced by wave action; gravel is almost foreign to the formation, although sometimes seen near the axis of the Embayment. At the end of the Grand Gulf epoch the Embayment had practically ceased to exist; the northern Gulf-shore line was almost exactly parallel to the present one, and all this had been done in a quiet, systematic, orderly way, during a slow upward movement of the land.

With the next succeeding formation, the Lafayette, there is a total change both in the material and its mode of deposition, preceded by deep erosion of the surface of the older formations. So far from continuing the advance of the shore-line into the waters of the Gulf of Mexico, we suddenly have (according to McGee's views) the latter advancing at least to the head of the Mississippi Embayment, and according to Chamberlin, clear up to Keokuk, by a general depression. But this general depression does not carry marine features backward over the land; on the contrary, while not a marine fossil, even in the most "demoralized" condition, can be found in the entire enormous area covered by the formation, we have a marked increase in all features that we habitually look for in a fresh-water, fluvial formation; including the evidences of violent currents, with a total absence of beach lines to show either the advance or recession of the supposed submergence. The only evidence that might be thus construed are the gravel beds; but as these run in the main *parallel* to the axis of the Embayment, while according to the Tertiary régime they should run *crosswise*; and since in the very axis of the Embayment the material of these gravels gives evidence of transportation from north to south, on a slope materially greater even than exists at the present time: it seems to me very difficult to construe the gravel beds into beach shingle.

It seems to me, further, that such an extraordinary continental oscillation as that which brought about the change from the quiet Grand Gulf epoch to the stormy one of the Lafayette, would in most cases in itself constitute good cause for drawing a taxonomic line, as such lines are usually drawn. It can hardly be doubted that the change from the Grand Gulf to the Lafayette régime must have resulted in a material change in the character of the aqueous fauna, if any there was. We may therefore well question whether such events may not

as truly constitute the beginning of a new era—the Quaternary—as the incipient glaciation of the continent.

I have heretofore suggested that the extraordinary change of character from the Vicksburg to the Grand Gulf epoch—the substitution of brackish and fresh-water features for the exclusively marine—may have been caused by a diversion of the Gulf Stream to the outside of the Antilles, leaving the present Gulf as a receptacle for the continental waters, by the continued influx of which at least the north-shore deposits must have been sensibly freshened. However that may be, it is indisputable that from some cause there was a great increase of fresh-water influx during the Grand Gulf epoch; and a still greater one during that of the Lafayette, completely excluding marine features from that formation, even where its beds actually project into the waters of the Gulf.

I, with Tuomey and others of the older geologists, have sought the origin of this increase of fresh-water influx in the melting of the continental glacier; and on the evidence before me of the actual translation of moraine material to low latitudes by such influx, and manifestly on a much steeper slope than now exists, or could exist during a period of submergence, I have attributed the Lafayette formation to a period of high elevation rather than one of depression; conceiving such elevation, greater in the northern latitudes, as a possible cause of glaciation.

As to the *extent* of such elevation, I have in former papers shown that, adding to the present maximum altitude of the loess summits in Louisiana (450 feet) the greatest depth at which gravel had then been found below sea level (in the bored wells of Calcasieu), viz: 450 feet, we obtain 900 feet as the minimum amount of the oscillation which has occurred since the gravel reached the Gulf shore. I am now enabled to increase this figure to 1200 feet, the gravel bed having been reached at the depth of 760 feet in the latest borings made at New Orleans. In this estimate no allowance is made for the degradation of the land surface that has occurred since the deposition of the loess.

But if the Lafayette gravels are found at the depth of 760 feet below sea level at New Orleans, it follows that at the time it was deposited, the land was *not* submerged, but stood higher at least to the extent of that same depth. The only escape from this conclusion is to prove that this gravel, together with that of the Calcasieu wells, and inferentially that of the Natchez profile, is not a part of the Lafayette at all but belongs to the Port Hudson epoch.

Admitting this for the sake of argument, where do we stand? We are then forced to conclude that at the beginning

of the Port Hudson epoch there existed the elevation of the continent which I have conjecturally assigned to the Lafayette time. According to Chamberlin and Salisbury, the loess, indissolubly connected with the Port Hudson, derives its materials from the continental moraine; and the Natchez profile, showing the moraine gravel lying at the base of the Port Hudson, conclusively settles this point. If then, as McGee contends, the Lafayette was formed during a period of submergence, it would be necessary to assume a reëlevation of the land prior to the beginning of the Port Hudson period, which, with the loess and overlying loams, manifestly represents a subsequent period of depression, coincident with the melting of the glaciers. The variations of materials within this Port-Hudson-Loess-Loam ("Columbia") series should, then, in some measure indicate the advances and recessions of the continental ice sheet.

The question is whether the "Orange Sand" of the Embayment does not represent the first period of recession and ice-melting, and the Port Hudson (or Columbia) series the second and final one. Under this point of view, instead of the double oscillation postulated by McGee, the land would simply have risen at the end of the Tertiary (Grand Gulf) period, assuming at the north a considerably greater altitude than at the south, as is postulated by the transportation of such large gravel to the margin of the Gulf. I gravely question that any such extreme elevation as has been suggested as necessary by Chamberlin (8,000 to 10,000 feet) would even now be required to re-glaciate the northern United States. Half of these figures would come nearer my estimate of the probable requirements, provided the rise extended into the arctic region, as is the case in Greenland.

It seems to me that, had the Tertiary climatic conditions (which in the Grand Gulf beds are made manifest by the extended prevalence of tree palms) continued during the Lafayette period, we could not help finding in its deposits the same evidences of a subtropic forest growth at some points. But no such evidences exist; all the fossil woods thus far identified and found within the Lafayette beds are derived from the underlying Tertiary, even though the process of silicification has probably occurred during Lafayette time, concurrently with the formation of the curious local masses of siliceous sandstone, which show plain intrinsic evidence of the intrusion of siliceous solutions into beds of loose white sand. In these at least, remnants of the peculiar plants of the period might be sought; but a few indistinct indications of what might be construed into roots or grass leaves are the only vestiges observed by any one. In the superficial paludal beds to which McGee

has called special attention and which in part at least undoubtedly fall within the Lafayette proper, such grass and sedge vegetation is all that is indicated. It argues, during the sub-aërial exposure admitted on all hands, a more rigorous climate than is consistent with our knowledge of even late Tertiary times; we are reminded of subarctic bogs, not of subtropic forests. It is in connection with such bog vegetation too, I think, that the process of ferrugination that is so conspicuous within the Lafayette, and has even given rise to iron ore deposits, is to be explained. It is obvious that the solutions which subsequently oxidized into limonite incrustations and ferruginous sandstone ledges, must have been of the same character as those now forming similar deposits in our northern latitudes; e. g. in Oregon and Washington, where under the influence of a cool, moist climate, limonite deposits and ferruginous sandstones are forming under our very eyes, from the seepage and drippings of the dense and ever moist covering of moss and grasses, percolating through more or less ferruginous surface beds and impregnating all pervious formations underlying, with what ultimately becomes a limonite cement for sands and sandy clays. A similar vegetative covering, with its concomitant reduction of the ferric hydrate resulting from the decomposition of hornblende and other iron-bearing materials of the moraine sands, would naturally have covered the Lafayette surface when left free from overflow; and would explain the prominent ferrugination, as well as the fact that the minute grains of clay which we so frequently find intermixed with the quartz sand are so commonly, in contrast to the latter, decidedly angular, and have manifestly not undergone any sensible attrition. I conceive these clay-particles to be the result of kaolinization *in place*, under the influence of the carbonic acid solutions which evidently have been so very active within the entire formation as to leave little or nothing behind that is still subject to weathering, or carbonate solution.

I have in the foregoing discussion designedly confined myself to the ground with which I am familiar—The “Orange-Sand Delta” in and contiguous to the Mississippi Embayment; both because its phenomena *are* most familiar to me, and because I believe that, as previously stated, its development may have been largely independent of the events that happened beyond the Appalachian axis of upheaval and the Archæan highlands. How far such assumption may be compatible with the evidence in the possession of McGee, as regards the intervening ground in Georgia and farther east, the publications thus far made by him are insufficient to determine. But so far as they have been published, I cannot reconcile the lithological, stratigraphical and (negative) paleontological charac-

ters of his Appomattox with the idea of oceanic submergence, unless under conditions for which, in the actual state of our knowledge or conjecture regarding the climatic and surface conditions of the pre glacial epoch, we have there no adequate explanation. I therefore do not venture to suggest any for the Atlantic region, but do suggest for the critical region which has formed the subject of my special studies, such explanation as seems to me warranted by the regional facts, applicable to a very wide stretch of country distinctly correlated with the great axis of the Mississippi valley. The one prominent and indisputable fact, that after the Vicksburg period there has been a steady increase of fresh-water (or decrease of marine) conditions within the Gulf region, does not, so far as I am aware, apply to the Atlantic coast; and this distinctive and important feature requires special consideration and explanation. The latter may be found in the glacial phenomena, or as McGee has suggested to me, in the discharge of the great lakes of the continental interior toward the Mississippi valley, or in both combined. In either case these conditions have no analogue on the Atlantic slope south of the Hudson at least; and it would be precarious to attempt to gauge the two regions according to the same preconceived ideas. No one recognizes more than I do, the relative scantiness of our present information in the premises, particularly in view of the wide extent of country involved in any and every change in or near that common reference plane, the Gulf of Mexico. I feel confident that the practical recognition of the fundamental importance of this plane for the interpretation of the interior continental movements, and the consequent active investigation of its border-lands as starting points, will quickly lead to the solution of many problems that have heretofore puzzled geological investigators at the heads of its drainage system.

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ART. XLIX. — *On the Influence of Swamp Waters in the Formation of the Phosphate Nodules of South Carolina*; by CHAS. L. REESE, PH.D.

IN the introduction to Bulletin, No. 46, of the U. S. Geological Survey on "The Nature and Origin of Deposits of Phosphate of Lime," by R. A. F. Penrose, Jr., Prof. Shaler suggests that the South Carolina phosphates may have been formed by the action of swamp waters lying on beds of marl, and it was with this idea in view that I determined to look into the chemistry of the subject.

The South Carolina phosphates are nodular in form and found varying in size from that of a pea to nodular aggregates weighing ten pounds and more. They all have smooth and rounded surfaces as if water-worn and vary greatly in shape. The rock is found in beds varying from a few inches to one to two feet in thickness, underlying from three to ten and more feet of siliceous clay and overlying the calcareous marl of the region. It contains from 50 to 65 per cent of normal calcium phosphate; and the marl lying directly under it contains from 20 to 30 per cent of the same salt, which amount rapidly decreases at a depth of a few inches to 10 to 20 per cent and finally reaches the usual amount found in the marls—2 to 9 per cent.\*

This concentration of phosphate in the marl directly underlying the rock clearly indicates a gradual segregation from the rock above.

The rock on examination with the eye, with and without the aid of the glass, is found to contain fossil shell forms and casts similar to those found in the underlying marl, but in a much better state of preservation and much harder in the former than the latter.

I have found, in many instances, in the cavities which have been left by shells between the outer and inner casting, a brownish white, very finely divided powder, which gave on analysis 84.65 per cent calcium phosphate [ $\text{Ca}_3(\text{PO}_4)_2$ ], a small quantity of silica, of fluorine, organic matter and the rest calcium carbonate. This clearly shows the direct replacement of the carbonate of the shell by phosphate.

From the similarity in structure of the phosphates and the marls, and their occurrence, it is clearly seen that the former are the phosphatized product of the latter; and the object of my work has been to see how far swamp water could have aided in bringing about this result.

There has been considerable work done on the action of the so-called humus acids (humus, crenic and apocrenic acid, etc.) on the soil† and also on phosphates‡ in the soil, and it was my intention to study the action of these acids on the normal phosphate of calcium both alone and in the presence of calcium carbonate; but owing to their uncertainty of composition, the extreme difficulty of obtaining them in a pure condition, and particularly their liability to undergo change in attempts to isolate them, I decided to study their action in their native condition, and under circumstances as nearly as possible like those under which they act in nature.

\* C. U. Shepard.

† A. A. Julien. Am. Association for Advancement of Science, Proceedings, 1889.

‡ J. M. Bemmelen, Landwirtschaftliche Versuch-Station, 35, 36.

I obtained a series of specimens of water from both fresh and salt water swamps, as well as of the deposits from the bottom of the same, from the neighborhood of Georgetown, South Carolina, but after a preliminary and unsuccessful test for phosphate with ammonium molybdate with both of them, I decided for a number of reasons, only to use the specimens from the fresh water swamp. The salt waters contain very little organic matter, and are constantly changing, and could consequently have little effect; whereas the fresh swamp waters are dark in color, and contain a large quantity of organic matter, and are at the same time more or less stagnant, not being affected by the tides at all. The material from the bottom of salt swamps consists mainly of the roots of marsh grass, whereas that from fresh swamps is composed of an accumulation of decaying leaves, roots, etc. Finally I have been led to believe that fresh swamps have been influential in the formation of phosphate nodules from the fact that cypress stumps are frequently found in the phosphate beds, and occasionally an amber-like substance.\*

On getting no appreciable test for phosphoric acid in the swamp waters, I allowed specimens of fresh swamp waters to stand for two weeks mixed with precipitated and carefully purified calcium phosphate, filtered, evaporated to dryness, ignited, and tested for phosphoric acid with negative results in each case.

I next mixed the material taken from the bottom of fresh water swamps (composed of cypress and black gum leaves and roots, sand, etc.), with swamp water and normal calcium phosphate, and allowed the mixture to stand one day, filtered, and filtrate gave slight test for phosphoric acid. On evaporating to dryness, igniting, and redissolving in nitric acid, it gave a heavy yellow precipitate with ammonium molybdate, showing that some of the phosphate had gone into solution.

In subsequent experiments, by allowing the mixture to stand for a longer time, I got heavy precipitates of phosphomolybdate without evaporating.

Further experiments, in which the floats of the natural phosphate rock were used instead of the precipitated phosphate, gave similar results although not so marked, as should be expected, owing to the presence of some calcium carbonate which would have a tendency to cause the phosphate to be reprecipitated, particularly after the action of the humus materials should be completed, as is shown in the results of later experiments. The floats are also less finely divided, and hence we could not expect the phosphate in them to be so rapidly dissolved.

\* This substance will be described in another paper.

These experiments having demonstrated the solubility of the normal phosphate in water in the presence of decaying vegetable matter, such conditions as are found in the bottom of swamps and at the same time in soils containing vegetable mould, the question presents itself as to how the solution is brought about, that is whether it is owing to the conversion of the tri- into the mono-calcium phosphate by the acid action of the mixture (humus acids) or to the formation of certain absorption compounds with the so-called humus acids as described by Bemmellen,\* or to both. I think it likely that both processes enter into the reaction, and it is intended to carry out further investigation in the direction of solving this problem.

On neutralizing the solution with ammonia, the phosphate was partially precipitated, while neutralization with calcium hydroxide caused a complete precipitation.

To determine whether water then charged with phosphate would give it up in coming in contact with marl, I allowed specimen to stand in vessels over pure calcium carbonate in some instances, and marl in others; and in each case all trace of phosphoric acid was removed in the course of twenty-four to forty-eight hours.

It is highly probable that carbonic acid plays an important part in the formation of the phosphate nodules, so that it is important to consider its action in this connection.

Carbon dioxide passed into water containing normal calcium phosphate dissolves it under the formation of mono-calcium phosphate and acid calcium carbonate, so that the solution contains both of these substances.

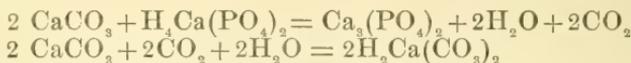
This solution remains unaltered on standing, but if it be boiled or allowed to stand over normal calcium carbonate or marl, all of the phosphate will be precipitated, as was demonstrated by a number of experiments, just as in the case of solution of phosphate by means of swamp water mixture. This experiment shows that phosphates may be transported in hard waters, but on standing on calcareous beds would tend to be given up.

From these experiments it certainly seems probable that both carbonic acid and the humus substances in fresh water swamps play an important part both in the accumulation and the concentration of calcium phosphate, and the formation of nodules in this way. The marls in the first place contain a small percentage of phosphate, which percentage would be gradually increased as the carbonate is gradually removed.

Calcium phosphate, held in solution from whatever source as the diacid salt, or in combination with the so-called humus

\* *Landwirtschaftliche Versuchs-Stationen*, xxxv, p. 130.

acids as absorption compounds, on coming in contact with the carbonate of the marl, which forms the bottom of the swamps, is deposited either as the mon-acid or normal salt (if the former it changes into the latter in the course of time) and carbon dioxide is liberated. This carbon monoxide in its turn dissolves some of the carbonate, thus bringing about a concentration and consequent tendency toward nodulation as will be seen from the reaction; one molecule of the phosphate would remain and four molecules of the carbonate would be removed.



The humus substances also give off carbon dioxide on decomposition and consequently we have a further cause for concentration from this source.

There can be no doubt, from the similarity in structure, that the phosphatic nodules are phosphatized marls. And from their occurrence in beds in a country that has in recent geological history been covered from time to time with swamps, some of which at present underlie a bed of argillaceous sand covered by salt marsh, taken together with the above observations and experiments, it certainly seems probable that swamp waters have brought about this change through the agency of carbonic acid and the humus substances contained in them.

The question as to the source of these large deposits of phosphates is of course a very difficult one to answer. There are many fossil remains of animals found associated with the rock but their numbers do not seem to be sufficient to account for the large quantity of the phosphate found. Again these fossils (mainly sharks' teeth and bones) seem to be of a later date than the nodules, as was suggested by Mr. Penrose, owing to the fact that they are not embedded in the nodules but are simply found loosely mixed in with them. Some of the phosphate is that which was originally in the marls, and I might suggest as other sources, that brought down in solution by drainage, and a small quantity contributed by the potassium phosphate from the decomposition of vegetable remains, particularly such accumulation in swamps.

"The Citadel," Charleston, S. C., Jan. 20th, 1892.

ART. L.—*Plattnerite, and its Occurrence near Mullan, Idaho*; by WILLIAM S. YEATES, with *Crystallographic Notes*; by EDWARD F. AYRES.

[Read before the Chemical section of the American Association for the Advancement of Science at the meeting in August, 1891, at Washington, D. C., and published by permission of the Assistant Secretary of the Smithsonian Institution.]

UNDER the name, *Schwerbleierz*, in the year 1837, lead dioxide as a mineral species was described by Breithaupt.\* A quantitative determination of the lead by Plattner was given. As to its occurrence, Breithaupt† says, that the only piece of the mineral obtained by him was a large botryoidal mass formed of concentric layers, almost entirely covered by cerussite, pyromorphite and leadhillite. Also, that he did not know the place of its occurrence; but, as the last-named mineral was then known to occur only at Leadhills, Scotland, he concluded, that the “*Schwerbleierz*” was probably found at that locality. The mineral is described as having a metallic-adamantine luster, becoming dull by tarnish; in color, iron-black, with brown streak; opaque; crystallized and massive, the crystals, rhombohedral, in hexagonal prisms with the combination,  $P, \alpha P, OP$ ; indistinctly cleavable; fracture, uneven; brittle; specific gravity, 9.392 and 9.448, the result of two determinations. Some years after the mineral was described by Breithaupt, Haidinger‡ gave it the name of *plattnerite*, and, a little later, Hausmann§ called it *braunbleioxyd*. In 1858, Greg and Lettsom|| used the name *plattnerite*, in describing the species in their mineralogy, and added this note:—“The authors can learn nothing more about this species, and consider it a doubtful one. The specific gravity seems too high to be correct, since it is double that of minium, and even more than that of galena. The crystals, described as being hexagonal prisms, may possibly have been pseudomorphous of pyromorphite.” In Dana’s Mineralogy,¶ under *plattnerite*, the following comment is made:—“A doubtful species. The specific gravity given is as high as that of the protoxyd of lead.”

In a paper read before the Mineralogical Society of London, June 22nd, 1886, Prof. Edward Kinch\*\* described a well authenticated specimen of *plattnerite* from Leadhills, Scotland, giving

\* J. pr. Ch. (1837), x, p. 508.

† Loc. cit.

‡ Handb. der Best. Minn. (1845), p. 504.

§ Handb. der Min. (1847), p. 202.

|| Manual of Min. (1858), p. 389.

¶ A System of Mineralogy, by James D. Dana (1868), p. 167.

\*\* Min. Mag. London, vol. vii, p. 63 (1886).

the hardness at about 5, and the specific gravity at 8.54; and its composition, PbO, 92.66; O in excess of PbO, 6.20 (by direct determination.) In another paper before the same society on March 12th, 1889, Prof. Heddle\* describes a specimen of plattnerite from Belton Grain Vein, Wanlockhead, Scotland, and a specimen from Leadhills, both of which had been in his possession some years. The specific gravity of the first is given at 8.8 to 8.96; and that of the latter, at 9.27. In May, 1889, the writer of this paper identified as plattnerite a specimen, which had been sent to the National Museum, by Mr. Waldo J. Clark, of Mullan, Idaho. A brief preliminary note, announcing the occurrence, was sent to this Journal. A reference to this note appeared in the July number,† as did, also, a note on the same subject from Prof. H. A. Wheeler, of St. Louis, giving a brief description and an analysis. In the August number of the Journal, Messrs. J. D. and E. N. Hawkins‡ described a specimen of the plattnerite, which had fallen into their hands, giving two analyses.

In the meantime, the writer had secured a considerable quantity of the material, with the view to describing, more in detail, its occurrence in Idaho; and his investigations had developed facts not referred to by Mr. Wheeler or the Messrs. Hawkins.

In a letter from Mr. Clark, who had kindly furnished the writer with the material, he says that he discovered the plattnerite in a tunnel in the "You Like" lode, Hunter mining district, three miles northwest of Mullan, Idaho, on a spur of the Cœur d'Alene mountains, at a distance of 70 feet from the surface; and that it occurred in "round knobs or bunches" in a continuous line, touching each other "for a distance of 20 feet, when the iron§ appeared to crowd it nearly out for 10 feet, then considerable of it for 10 to 15 feet farther, when it disappeared," and no more was found as far as the tunnel was run, a distance of 40 feet.

The intimate associates of the plattnerite are limonite and white pyromorphite, the former occurring in botryoidal masses and as a brown ocher; the latter, in crystals, rarely in veins, scattered through some of the nodules. The plattnerite occurs in botryoidal nodules embedded in a mixed ocher of limonite and plattnerite, which contains, scattered through it, loose crystals of pyromorphite, when the nodule, within, contains them. When this ocher is cleaned off, and the nodule is broken open, the fresh surface exhibits a small conchoidal fracture and a bright metallic-adamantine luster, which tarnishes and becomes

\* Min. Mag., London, vol. viii, p. 203 (1889).

† This Journal, xxxviii, July, 1889, p. 79.

‡ This Journal, xxxviii, Aug. 1889, p. 165.

§ Limonite.

dull on exposure to the atmosphere for a few weeks. While the outside of the nodule is a reddish-brown, the fresh fracture reveals an iron-black color and a very compact cryptocrystalline structure. The streak is chestnut-brown; hardness, 5.5; specific gravity, 8.56;\* opaque; brittle. Before the blowpipe, on charcoal, in the oxidizing flame, it decrepitates and fuses at 1, with boiling and spirting, yielding a globule of lead, which, on further heating, coats the coal yellow. It is easily soluble in cold, dilute HCl, giving off chlorine.

An analysis of an apparently pure fragment gave the writer the following results:

Lead .....	83.20
Silver† .....	trace
Copper .....	0.14
(Fe, Al) .....	1.20
Oxygen .....	12.93
Insol. residue .....	0.82
	<hr/>
Total .....	98.29

Neglecting impurities, and calculating to 100, we have

Lead .....	86.55
Oxygen .....	13.45
	<hr/>
Total .....	100.00

Calcium and magnesium, in appreciable quantities, were found both in the qualitative and quantitative analyses; but they were not estimated. The oxygen was determined directly as H<sub>2</sub>O, by passing H over the powdered mineral, heated in a combustion tube at low red heat, the H<sub>2</sub>O being caught in a series of calcium chloride tubes.

The specific gravities, as given by Breithaupt‡ and Wheeler,§ for the natural lead di-oxide, are higher than is required by its constitution; and, until the investigation by Kinch, the high specific gravity was cited as sufficient ground for doubting the authenticity of the species. That given by the Messrs. Hawkins|| was as much too low. This, however, may be accounted for in the fact that their analyses show nearly 10 per cent. of impurities in the material analyzed

\* The specific gravity was carefully determined in a pycnometer with attached thermometer, the mineral (3.1815 grams) being reduced to minute fragments, and the air being pumped from it. Determinations of the specific gravity, made, with the Jolly balance, on two other fragments, gave 8.35 and 8.86, the latter being on a very small fragment.

† 4.6463 grams of plattnerite yielded a silver button weighing 0.0022 grms.

‡ 9.392 and 9.448. § 9.411.

|| 7.25 ("the mean of three close determinations").

by them. The specific gravity of artificial lead dioxide is variously stated to be 8.902 (Herapath),\* 8.933 (Karsten),† 8.756, 8.897 (Playfair and Joule),‡ and 9.045 (Wernicke).§

The sizes of the nodules vary from  $2'' \times 1'' \times \frac{1}{2}''$  to  $8'' \times 6\frac{1}{4}'' \times 4\frac{1}{4}''$ , one of the largest masses weighing 15 lbs. 4 oz. Implanted on many of them are crystals of the white pyromorphite; and, as has been mentioned above, these nodules, when broken open, are speckled with this mineral. Some of these crystals are brown, being coated by a film of plattnerite; and, until this film was cut through and the true nature of the crystals determined, they were thought to be plattnerite crystals. As the plattnerite was originally described|| as being rhombohedral, occurring in hexagonal crystals, and as Greg and Lettsom¶ had suggested, that it might possibly be pseudomorphous after pyromorphite, thin sections were made, and, at the writer's request, these were kindly studied under the microscope by Mr. Geo. P. Merrill,\*\* who reported, that he could find no evidence that any alteration of the pyromorphite into plattnerite had taken place. One large specimen of plattnerite, when broken open, showed sharp angular fragments of milk-white quartz, which formed a breccia with the plattnerite as the cement.

In breaking open specimens to obtain the fresh fracture, the writer observed, that, here and there, would be one, which was distinctly fibrous, in part, the fibers running from the dense, black, cryptocrystalline material to irregular, small cavities, which were, more or less, filled with a bright yellow-ocher. These fibers seemed to terminate in minute jet-black crystals, penetrating slightly into the ocher. These were so imperfect, however, that the form could not be made out, even with a strong lens. The fibers, when examined, were found to be plattnerite. A few drusy surfaces, which had been the sides of small fissures, were observed; and these, on examination under the microscope, the writer found to be made up of slender crystals, to all appearances tetragonal, and strikingly like certain cassiterite crystals from the Dolcoath mine in Cornwall, except that they were opaque. Examination proved, that these crystals were plattnerite. At the writer's request, Mr. Edward F. Ayres of the U. S. Patent Office very kindly undertook the delicate crystallographic work required. His description is hereto appended.

\* Phil. Mag., London, etc., lxiv, p. 321.

† Schweigg. Jour., lxxv, p. 394.

‡ Mem. Ch. Soc., iii, p. 84.

§ Jour. Ch. Soc. (II), ix, p. 306.

|| Loc. cit.

¶ Loc. cit.

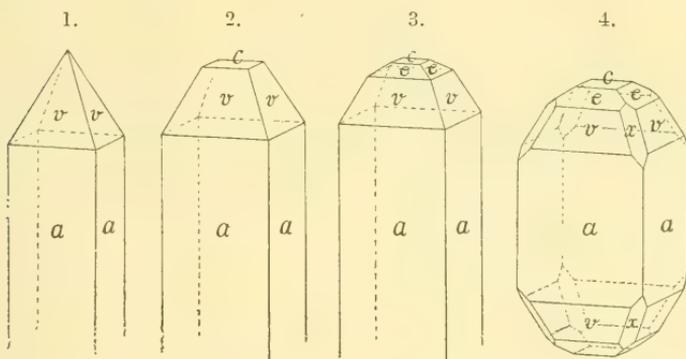
\*\* Curator, Dept. of Geology, U. S. National Museum.

In conclusion the writer desires to tender his thanks to Mr. Clark, who so generously furnished the material for study and the data for the description of its occurrence.

*Crystallographic Notes.*

From the specimens of plattnerite submitted to the writer by Mr. W. S. Yeates the following results were obtained. The crystals of plattnerite ( $\text{PbO}_2$ ), which look very much like cassiterite, are very minute, varying from  $\frac{1}{50}$  to  $\frac{1}{1000}$  of an inch in length, and are found filling crevices in the massive plattnerite. Moreover, they are tetragonal and isomorphous with rutile ( $\text{TiO}_2$ ), cassiterite ( $\text{SnO}_2$ ), and polianite ( $\text{MnO}_2$ ), all minerals which have a similar chemical composition.

The color is black, and where the planes are smooth, the crystals are very bright, having a nearly adamantine luster. No cleavage could be distinguished and the crystals are very brittle.



The prevailing form is that shown in figures 1 and 2, the basal plane being very common; many of the smaller crystals, however, have simply the steep pyramid  $v$  (301) terminating the prisms as seen in fig. 1. The crystal, which gave much the best results, was about the  $\frac{1}{50}$  of an inch long and of the form and about the proportions shown in fig. 3. The forms observed, referred to the common axial ratio of this group of dioxides, are:

$$\begin{array}{lll}
 a \ (100, \ i-i) & e \ (101, \ 1-i) & x \ (332, \ \frac{3}{2}) \\
 c \ (001, \ 0) & v \ (301, \ 3-i) &
 \end{array}$$

The plane  $x$ , (332), bevelling the edge between the pyramids  $v$ , (301) was observed in a few instances.

The prismatic faces are badly rounded and considerably striated, and though bright, could not be depended on for any correct measurements since their reflection extended over a

space of two degrees. The pyramid  $v$  (301) was very bright and quite large and well defined; and the pyramid  $e$  (101) was also bright but very small. The basal planes were rounded and apparently pitted and rough.

On account of the very minute character of the pyramidal planes, correct measurements were difficult to make, the use of the signal in a reflecting goniometer being entirely out of the question, on account of the small amount of light and reflection in the goniometer being all that could be employed. The manipulations necessary to place the crystal in position were also very delicate. The angle between 301 and  $\bar{3}01$  gave the best definition, and the mean of many measurements,  $127^{\circ} 32'$ , gives the axial ratio

$$a : c = 1 : 0.67643$$

The following are calculated and measured angles for the forms 301 and 101.

	Calculated.	Measured.
301 $\wedge$ $\bar{3}01$	* $127^{\circ} 32'$	$127^{\circ} 32'$
301 $\wedge$ 100	26 14	24 30
301 $\wedge$ 101	29 41 28"	28 1
101 $\wedge$ 100	55 55 28"	54 39 30"
101 $\wedge$ 001	34 4 32"	35 20 30

Rutile gives the axial ratio  $a : c = 1 : 0.64415$ , and though the habit of these crystals differs from that of the other members of the group, in that the diametral prism is alone present, it is to be noted that the pyramid  $v$  (301) here prominent is a twinning plane with rutile.

U. S. National Museum, Feb. 29th, 1892.

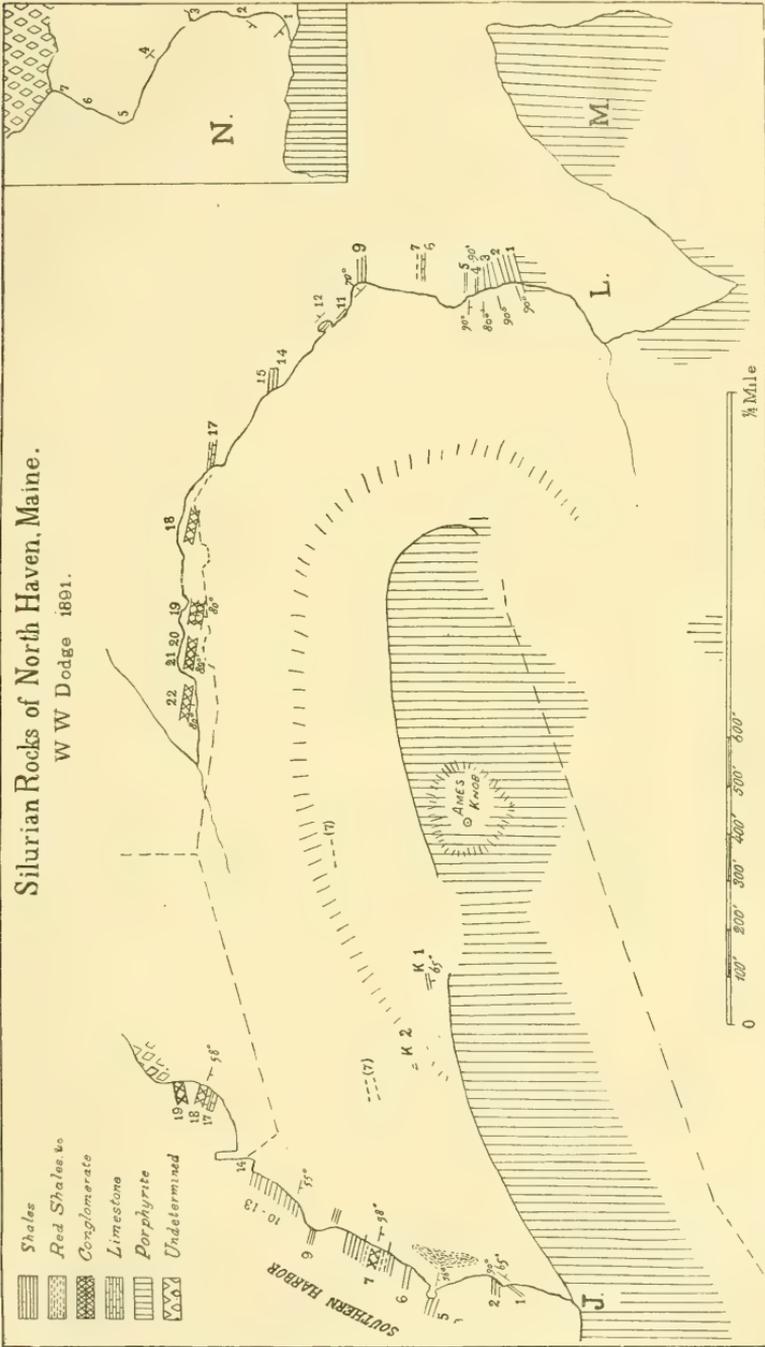
ART. LI.—*On the occurrence of Upper Silurian Strata near Penobscot Bay, Maine*; by WILLIAM W. DODGE and CHARLES E. BEECHER. (With map.)

I.

ON the island of North Haven in Penobscot Bay, there is an extensive exposure of abundantly fossiliferous rocks of Silurian age.

The region where they are found is included in United States Coast Survey chart 311a (1:20,000), Fox Islands Thoroughfare, also in 310 (1:40,000), West Penobscot Bay. The sketch map, herewith, indicates the points at which the fossils specified by Mr. Beecher in the second part of this paper were obtained, giving also strike, dip, and character of beds.

For five-eighths of a mile northward from Fox Islands Thoroughfare (the strait which separates North Haven from



Vinal Haven), the greater part of the rock between Southern Harbor and Waterman's Cove is eruptive, probably porphyrite. In many places it holds innumerable fragments of rock somewhat similar to itself, of earlier consolidation. The highest of the several hills formed by the eruptive rock (145 feet above tide), three quarters of a mile northwest of the village of North Haven, is known as Ames's Knob.

The fossiliferous strata lie immediately north of the area of eruptive rock, occupying lower ground. They run about east and west, with prevailing southerly dip, and have a thickness of about six hundred feet. Their preservation at an accessible level is due to the protection against glacial erosion afforded by the more resistant eruptive rock.

Fossils have been found at more than twenty different points in the three quarters of a mile between the shore of Southern Harbor and the road from North Haven village to Pulpit (or Northern) Harbor. Between the road and Waterman's Cove the beds are mostly covered; the outcrops have not been examined for fossils. Two miles farther east, dark bluish-gray, brown-weathering limestone, like one member of the North Haven series (J 17, L 17, O), and overlying quartzite cross the western end of Stimpson's Island obliquely from northwest to southeast, in a narrow belt between eruptive rocks. The limestone there has yielded only an indeterminable brachiopod and a crinoid disk.

In recording the localities of the fossils collected, outcrops along the shore of Southern Harbor are designated by the letter "J"; those inland along the north side of Ames's Knob are marked "K"; those along the west shore of the shallow bay that opens into Southern Harbor northeast of Ames's Knob are lettered "L"; the point that projects into the head of that bay is occupied by the eruptive rock, but is called "M"; the eastern shore of the same bay is indicated by "N"; the outcrop at the west side of the Pulpit Harbor road, near the edge of the woods, by "O." The numbers run from south to north; that is, from higher to lower beds.

The section on North Haven, beginning with the lowest beds of the group, is approximately as follows :

	Feet.
Conglomerate containing pebbles of quartz, schist, etc., J 19, concealed or absent elsewhere .....	12
Concealed (J and L), measured on J .....	59
Conglomerate with pebbles of quartz and of schist, sandstone, a few layers of shale, L 22-19, dip S. 5° W., 80°, the conglomerate fossiliferous in a few places. Coarse calcareous sandstone (fossiliferous) with alternating finer calcareous beds, J 18, dip S. 19° W., 58° .....	16

	Feet.
Brown- or ochre-weathering, dark bluish-gray, impure limestone, J 17, L 17, probably O. Fossils distinguishable only on weathered surfaces .....	21
Concealed .....	75
Light colored porphyry, J 14, L 14 .....	3
Dark bluish-gray indurated shale (J and L 13-8), slightly calcareous in places, sometimes with calcareous nodules, greenish-gray in upper portion. Many fossils at L 12 and some at L 9. The plane in which fossils lie at L 12 shows the strike at that point to be N. 55° W., dip N. 35° E., 70°. Exposure not continuous either on J or L. In detail, on J,—shale, dipping at top S. 8° W., 55°, 115 feet; concealed 22'; shale 20'; concealed 15'; shale 8'; concealed 20'; greenish-gray shale (J 8) 45' .....	203
Red shale (holding nodules of white limestone at one point), red and white sandstone and conglomerate, J 7, dip S. 9° W., 60°; L 7, low tide exposure only .....	42
Various, usually hard, argillaceous, occasionally calcareous, beds, with subordinate strata of limestone, frequently cross-bedded, with varying strike and dip (J 1, S. 35° E., 65°; J 2, vertical; J 5, S. 10° W., 56°; K 1, S. 14° E., 65°; L 1, N. 25° W., 80°; L 2, vertical; L 3, N. 20° W., 68°-85°; L 5, S. 70°); fossiliferous at J 6, 5, 2 (the first two respectively 42 and 85 feet above the red beds); K 1 (about 125 ft. above the red beds), K 2; L 5, 4, 2, 1; thickness about .....	175
Total .....	606

This is obviously a shore and shallow water deposit.

The band of porphyry low in the section, J 14, L 14, seems to follow the bedding, but at L 14 is seen to extend northward and cross the underlying strata.

The eruptive rock south of the fossiliferous beds cuts across them (N 1), and at one place (M) was seen surrounding a fossiliferous fragment of one of the highest beds in the series. Near the contact, the stratified rocks are disturbed and sometimes violently twisted and broken (N 2).

Within the mass of the eruptive rock are included some strata which appear to be higher in position than the fossiliferous rocks above described. A long band of coarse conglomerate extends from near the peak of Ames's Knob to the shore of Southern Harbor just north of a stone wall which is indicated on the Coast Survey charts. A sandstone layer in this conglomerate gave the strike N. 55° E. Still farther south, half way from the wall to the shore of the Thoroughfare, and 120 yards east from the bay east of Turnip Island, red shales and fine sandstones (strike N. 68° W., dip S. 22° W., 60°) are surrounded by the eruptive rock, which is seen crossing the beds.

Along the north shore of the Thoroughfare, east of the village, are red shales that closely resemble those north of Ames's Knob, J 7. Here also the dip is southward. They overlie a mass of diabase, which is vesicular in its upper (southern) portion. A layer of light colored porphyry lies among the shales and extends westward along the shore between the wharves at the village. Farther west, near the ferry landing, are fragmental rocks with an ash-like cement, which must overlie the red shales. In this vicinity are dykes of diabase and of light colored porphyry showing flow structure parallel to its walls.

The northern part of Vinal Haven, excepting Calderwood's Neck, is made up largely of felsophyre (laminated, sometimes spherulitic) and felsophyre-breccia, with porphyrite and diabase. The southern part, including the greater portion of the area of the island, is mainly occupied by granite. Along the northwestern side of Seal Cove, which opens into the Thoroughfare, is a limited region of altered schists, into which are intruded dykes from the granite near the head of the Cove. The schists strike N. 20°-40° E., and dip northward, 40°-55°.

The presence at North Haven of a familiar species of *Monograptus* gives an interesting item of information in regard to the geographical distribution of Upper Silurian graptolites in America, of which but little is yet known. Graptolites have been reported as occurring at a few Upper Silurian localities in New Brunswick, Nova Scotia and Newfoundland. Repts. Canada Geol. Surv., 1885, pp. 14, 15 G; 1874-5, p. 10, 1885, p. 52 E; 1886, pp. 43, 46 P; Geology of Newfoundland (1871 Rept.), p. 31. They were mentioned as occurring at Anticosti at a somewhat high level in the (Middle Silurian) Anticosti Group, Rept., 1853-7, p. 253, 1863, p. 302, but were not included by Billings in his first published list, or in his catalogue of 1866.

W. W. D.

## II.

The paleontological evidence furnished by the specimens from North Haven apparently does not admit of a distinct subdivision of the rock series into recognized periods. A large proportion of the species clearly points to a correlation with the Niagara of New York, and to this period they are here referred. The presence of quite a number of characteristic Clinton species is a disturbing element in any attempt to draw exact parallelisms with the New York subdivisions of the Upper Silurian. From present data, however, it seems justifiable to consider the fossiliferous rocks at North Haven as representing a faunal equivalent to the Clinton and Niagara,



*Summary.*

Hydrozoa,	2 species.	Brachiopoda,	27 species.
Actinozoa,	10 "	Pelecypoda,	6 "
Annelida,	2 "	Gastropoda,	6 "
Trilobita,	6 "	Pteropoda,	1 "
Ostracoda,	3 "	Cephalopoda,	7 "
Bryozoa,	2 "	Total,	72 "

Nearly all the corals are confined to the lower beds, J 18, L 19, and O 18; the first two are a conglomerate of coral fragments with pebbles of quartz and hydromica schist, while the latter is a limestone. The greatest number of species (24) is found near the middle of the series (L 12) in a slightly indurated shale. The fauna was evidently a rich one, and several of the unidentified species are probably new to science. Many of them show distinctive characters, but the majority are too fragmentary and poorly preserved for accurate description or determination.

C. E. B.

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ART. LIII.—*Zinc-bearing Spring Waters from Missouri;*  
by W. F. HILLEBRAND.

ZINC salts have been observed in the waters from La Malou in the south of France, according to Doelter,\* and in those of certain hot springs of New Zealand,† perhaps also in those of other localities, but I have as yet been unable to find any data bearing upon their contents in such salts. Durand-Fardel's Dictionnaire des Eaux Minerales, 1860, fails to include zinc as a constituent of the waters of La Malou which had been analyzed up to that time. It is therefore improbable that this element is present there in any considerable quantity.

The spring waters herein described are, it is thought, unique, in that their chief salt constituent is zinc sulphate. The following information in regard to the location and surroundings of the springs from which they flow has been obtained from Mr. W. P. Jenney of the U. S. Geological Survey, who was led to suspect a peculiarity of composition from the strong metallic astringent taste left in the mouth after swallowing, and by the slimy white precipitate which covers the walls of the springs and all vegetable matter falling into the water about them.

On the road from Joplin to Seneca, in Newton County, southwestern Missouri, about a quarter of a mile north of

\* Allgemeine chemische Mineralogie, p. 233.

† Trans. and Proc. New Zeal. Institute, 1870, vol. iii.

Shoal Creek and four and a half miles southwest of Joplin is a low bluff, perhaps 18 feet high, formed by a portion of the Burlington Chert Beds. At the base of this bluff, in a shallow depression, is a series of springs extending for a distance of perhaps 150 feet and emptying their waters into the above mentioned depression, wherein a sluggish current is produced and a deposition of a slimy white precipitate takes place. They vary in size, discharging from one-half to three gallons of water per minute, and about 30 gallons, or 150 to 160 liters, in the aggregate. So far as can be judged by the taste they vary also in composition, some waters being much stronger than others.

The two samples analyzed were taken by Mr. James A. Reeves, of Joplin, from springs about 90 feet apart, designated as the East Spring and the West Spring, which were not only the most powerful, but which also, judged by the taste, furnished the strongest water. The composition as given below is that of the water after having stood in sealed bottles for two or three weeks and having been then separated by filtration from a whitish flocculent deposit which was probably formed after collection of the samples, in which case the reported composition does not exactly represent that of the water as it issued from the spring. As received the waters were clear and limpid above the sediment, they were neutral to litmus paper, and their density differed but little from that of pure water, that of No. I being 1.0006 at 20½° C. The samples were too small and time was too valuable to admit of exhaustive examination or of duplication of determinations. The analyses are as follows :

	I.			I.		II.	
	East Spring.	West Spring.		East Spring.	West Spring.	West Spring.	West Spring.
	Parts in 1,000,000.	Parts in 1,000,000.		Parts in 1,000,000.	Percentage Composition.	Parts in 1,000,000.	Percentage Composition.
Pb	trace	undet.	PbSO <sub>4</sub>	trace	trace	undet.	undet.
Cu	.2	"	CuSO <sub>4</sub>	.5	.09	"	"
Cd	.5	?	CdSO <sub>4</sub>	.9	.17	?	?
Zn	120.5	132.4	ZnSO <sub>4</sub>	297.7	55.14	327.0	57.14
Fe	.6	.6	FeSO <sub>4</sub>	1.6	.30	1.6	.28
Mn	2.3	2.4	MnSO <sub>4</sub>	6.3	1.17	6.6	1.15
Al	.4	.5	Al <sub>2</sub> (SO <sub>4</sub> ) <sub>3</sub>	2.5	.46	3.2	.56
Ca	61.1	63.1	CaSO <sub>4</sub>	109.9	20.34	85.8	14.99
Mg	3.8	4.2	MgSO <sub>4</sub>	19.0	3.52	21.0	3.67
K	2.5	2.5	K <sub>2</sub> SO <sub>4</sub>	5.6	1.04	5.6	.98
Na	3.6	3.9	Na <sub>2</sub> SO <sub>4</sub>	5.9	1.09	6.8	1.19
Cl	2.6	2.6	NaCl	4.3	.80	4.3	.75
SO <sub>4</sub>	284.9	287.6	CaCO <sub>3</sub>	72.0	13.34	94.7	16.55
CO <sub>3</sub>	43.2*	56.8*	SiO <sub>2</sub>	13.7	2.54	15.7	2.74
SiO <sub>2</sub>	13.7	15.7					
				539.9	100.00	579.3	100.00
	539.9	572.3					

\* Calculated.

Besides the above tabulated constituents the waters held a considerable quantity of organic matter, which was not estimated, a small amount of ammonia not exceeding one part per million and which if counted as sulphate would affect only slightly the relative proportions of calcium sulphate and carbonate, and in an unconcentrated state they gave no reaction with brucine or diphenylamine for nitrates or nitrites. Although cadmium was not found in the water from the West Spring, it is possible, in view of the close similarity of the two waters, that it was somehow overlooked.

In analyzing these waters a peculiarity deserves to be mentioned, which may at the same time serve as a warning to any one who may in the future examine them. Although a portion of the calcium unquestionably exists as carbonate, as shown by the excess of bases over chlorine and sulphuric anhydride, it is nevertheless the case that *all* the carbon dioxide is expelled by simply boiling the water. The amounts found for the East and West springs respectively were 120.5 and 110.0 parts of  $\text{CO}_2$  per million. No more was obtained by acidifying the water. At the same time a precipitation of a zinc compound free from carbon dioxide and from calcium began to take place in the water as soon as the boiling point was neared, which soon ceased after ebullition set in. This precipitation furnishes the explanation of the total escape of carbon dioxide combined as well as free, from the unacidulated water; for as the calcium bicarbonate in solution becomes decomposed by heat the calcium carbonate at temperatures near the boiling point at once reacts with zinc sulphate with the formation of calcium sulphate, zinc hydrate or a very basic sulphate, and carbon dioxide. A determination of total solid constituents by evaporation of the water to dryness would involve therefore a very serious error in addition to those usually encountered.

A few remarks are here necessary in connection with the above reaction, which in one particular is so contrary to the statements which have come under my observations in chemical and geological literature bearing on the reaction which takes place between zinc salts in aqueous solution and undissolved calcium carbonate at elevated temperatures. It is generally stated that a basic zinc carbonate is precipitated while calcium sulphate goes into solution, except by Demarçay, the discoverer of the reaction, who says,\* that zinc *oxide* is thrown down. It is not to be supposed that soluble calcium in the form of bicarbonate would in any way affect this reaction except to hasten its completion. While a zinc carbonate is undoubtedly thrown down

\* Ann. d. Chemie, vol. xi, p. 250, 1834.

from a solution of the chloride by calcium carbonate, or by the bicarbonate as I have satisfied myself by experiment, this does not seem to be the case with a solution of zinc *sulphate*. An experiment, tested by repetition, with zinc sulphate and calcium bicarbonate in about the proportions shown in the above waters, *i. e.* with insufficient carbonate to throw out all the zinc, by observing which precaution no calcium carbonate can contaminate the precipitate, showed that the latter was absolutely free from carbonic acid and from calcium, but contained some sulphuric acid. If this is the normal reaction for the sulphate it is the one to be chiefly considered by the geologist, for in nature the sulphate of zinc and not the chloride, on which latter laboratory experiments seem to have been largely made, is the form in which that element is most likely to be found in solution.

The sediments from the bottles, which were very slimy, amounted when dried at 100° C. to approximately 17.0 parts per million of the water from the East Spring and to about 40.3 parts per million of that from the West Spring. They contained thus dried not less than 13 per cent of water and organic matter, while the ignition residue was about three fourths silica, and the remainder zinc oxide with a little iron, alumina, and sulphuric acid. The sediments were undoubtedly a mixture of amorphous silica, with very basic sulphates of zinc, aluminum and iron, without calcium. They had in both cases probably formed after the water was bottled, for they continued to appear in that portion of the filtered water which was retained as a reserve till completion of the analysis. As the two waters were not analyzed simultaneously the analyses are not strictly comparable, for one had deposited more sediment than the other, but it is noticeable that the water richest in salts had also deposited most sediment, showing that the differences in the analyses are not solely or in the main due to the different lengths of time that had elapsed between bottling and analyzing, but to inherent differences in composition.

With the waters was sent in a separate small bottle a sample of the precipitate deposited in the depression into which the springs emptied. It was contaminated by much decaying vegetable matter and admitted of no satisfactory quantitative examination, but after filtration and washing, qualitative tests showed it to be essentially the same as the deposit found in the bottles. Owing to its greater amount it was also possible to ascertain that cadmium, lead, and copper were to a certain extent concentrated in it.

The source of the metallic salt constituents of these waters is of course to be sought in one of the deposits of zinc blende

so numerous in that part of Missouri and across the State boundary in Kansas, although there are no known indications of zinc ores within a quarter of a mile of the springs and no large producing zinc mines within two miles of them. The limestones and cherts of the region supply the calcium and silica, and the organic matter, if not originally of surface origin, may well have come from oxidation of the bitumen which is found in quantity in the limestone. The permanent water level thereabouts is very near the surface, and it is not to be supposed that the particular waters under discussion have come from a great depth or are other than surface waters. The amount of zinc sulphate in them, however, is from two to three times as much as could have resulted under the most favorable conditions from oxidation of zinc sulphide either directly or indirectly by the sole agency of oxygen carried down by surface waters. It is probable, therefore, that the ore-bed whence the supply of metals is derived lies very near the surface, above the permanent water level of the country, where the atmospheric oxygen has direct access to it through porosity of the earth's surface. The powerful influence of oxygen thus acting on moist ore-bodies, which have been exposed by the opening up of mines in changing the character of the waters of a region, is shown by E. Haworth\* in writing of the mine waters of the adjoining county of Cherokee, in Kansas: "The well and spring waters before the mines were opened were first class, . . . . But as soon as the mines were opened all was changed, and the older the mines the worse the water. Animals of all kinds began being seriously affected," etc. He ascribes the high contents of the waters in metallic salts solely to the greater amount of oxidation rendered possible by exposure of masses of ore in the mine workings and on the dumps to atmospheric action, and gives instances to show how rapidly they succumb to it. He gives also a qualitative analysis of a mine water drawn from near the bottom of a shaft 130 feet deep which was nearly full of water at the time, and also the total weight of solids. The latter was over four times as high as in the spring waters above described, and there were found, in addition to the constituents already enumerated, ferric and ferrous sulphate in large quantity and free sulphuric acid. Carbonic acid, alkalis, and copper are not mentioned by him.

Laboratory of the U. S. Geological Survey, Washington, D. C., Jan. 1892.

\* A contribution to the Geology of the lead and zinc mining district of Cherokee County, Kansas, presented to the faculty of the Kansas State University, 1884, p. 34.

ART. LIII.—*A Meteorite from Central Pennsylvania* ;\*  
by Professor W. M. G. OWENS.

THE meteorite which I wish to describe at this time was found on or about the 25th of September, 1891, upon the east side of Bald Eagle mountain, seven miles south of the Park Hotel, Williamsport, Pa. At this point the mountain comes down to the edge of the Susquehanna river, a road-bed for the Philadelphia and Erie Railway having been cut in the mountain side. Numerous transverse depressions occur in the mountain side and some of these are filled with loose sandstone, varying in size from a few cubic inches to several cubic feet in volume.

It was in one of these depressions, several hundred feet from the railroad track, that some Italians, while getting out stones for a stone-crusher, found in a bed of loose stones about 2 meters ( $6\frac{2}{3}$  ft.) deep, something which resembled a stone in appearance; it was covered with a fungus growth as were the stones, but when picked up attracted the laborer's attention on account of its weight. He showed it to the superintendent who tried to break it and failing attempted to cut it with a cold chisel, when it proved to be soft iron. After this it was again lost but soon after found. When, several weeks later, the owner of the crusher, Mr. George S. Matlack, class of 1870, came to the works it was given to him and he, realizing its value, presented it to this University. It weighs 3.3 kilos (7 lbs. 1 oz.) In shape it resembles in general outline a human foot. The flat face, corresponding to the sole, measures  $16.6^{\text{cm}}$  ( $6\frac{1}{2}$  inches) long and  $8^{\text{cm}}$  ( $3\frac{1}{3}$  inches) wide at the broadest place. From the extremity of the heel it projects upward  $14^{\text{cm}}$  ( $5\frac{1}{2}$  inches) ending in a point. The surface is covered with a reddish brown iron rust. This easily scales off in many places, and at several points this covering is so thin that the bright metal shines through. It is pitted quite deeply in some places, and very irregular in outline. On the projection above the heel there is a cavity about  $1.5^{\text{cm}}$  ( $\frac{5}{8}$  inches,) deep entirely burned out and almost opposite a core which has been only partially consumed.

There are several surfaces upon it which would seem to indicate that the objects which it struck in falling were flat. So even was the surface corresponding to the sole of the foot that when it was cut for etching not more than  $2^{\text{mm}}$  ( $\frac{2}{25}$  in.) had to be removed to get a surface of 32 sq. cm. (5 sq. in.). At the front there is also a surface of much smaller extent,

\* Read before the Chemical Society of Bucknell University, Lewisburg, Pa.

which is perfectly flat and from it there projects a tip or point. Its specific gravity is 7.06. It is quite soft compared with iron. Most of the surface is covered with a very thin coating of rust. When polished and etched with dilute acid the Widmannstätten lines appeared very distinctly and beautifully. Chemical analysis gave: Fe 91.36, Ni 7.56, Co 0.70, P 0.09, S 0.06, Si, trace = 99.77.

Nothing is known as to the time of its fall, though as it was found covered by several feet of stones which have not moved sensibly since the Susquehanna Valley has been inhabited by white men it could not have been recent. As far as can be learned this is the only specimen of the fall which has been found.

ART. LIV.—*On two Meteoric Irons*; by GEORGE FREDERICK KUNZ and ERNEST WEINSCHENK, Ph.D. With Plate XIII.

1. *Indian Valley Township, Floyd County, Virginia.*

In the spring of 1887 a mass of meteoric iron was turned up by Mr. John Showalter, while plowing his tobacco-patch, situated in Indian Valley Township, near the Carroll and Pulaski lines, and near the base of the south side of Floyd Mountain, six miles southeast of Radford Furnace, Virginia. He made careful search in the near vicinity for other pieces, but without success. This meteorite weighs thirty-one pounds, or fourteen kilos. It measures 28×20×13 centimeters, or 11×8×5 inches. The surface of the iron is very much corroded and is entirely covered with a limonite crust, very little of the original crust being visible. On the exterior are deep depressions from two to four centimeters in diameter. The iron is highly crystalline, and a piece was readily removed from an old fracture. When etched with hydrochloric acid it did not show the Widmannstätten figures.

The following analysis was made by Mr. L. G. Eakins, through the courtesy of Professor F. W. Clarke, of Washington, chief chemist of the United States Geological Survey.

Fe .....	93.59
Ni .....	5.56
Co .....	.53
Cu .....	tr.
P .....	.27
S .....	.01
Si .....	tr.

99.96

The structure of this meteorite is very interesting, as it lies between the so-called breccia and hexahedral irons. Even on the unetched polished sides it is possible to identify the crystals of schreibersite arranged in bands lying parallel to the Neumann lines, which on the larger part of the mass are as well developed as in the Coahuila iron. Some parts of the piece exhibit a granular structure identical with that of Chattooga County.

As the Chattooga County meteoric iron was erroneously referred to the Coahuila iron by a writer\* who had not seen the mass, the writers feel it their duty to rectify this, and to state that Chattooga County is over fifteen hundred miles northeast from where the nearest of the Coahuila masses was found.

It is a question whether the granular structure is the original structure out of which hexahedral particles were formed through re-crystallization, or whether it is due to the fact that this iron, not being rich in nickel, has a lack of crystallizing power; and it is impossible to decide. In any case this iron is not rich in nickel and cobalt.

The thanks of the writers are due to Mr. Walter Wood, of Philadelphia, for his courtesy in assisting one of us to obtain this meteorite and to ascertain the facts of its discovery.

## 2. *Sierra de la Ternera, Province of Atacama, Chile.*

This meteorite was kindly loaned to us by Dr. Moricke, of Stuttgart, Germany, who obtained it on a trip in Chile, with the information that it was found in the Sierra de la Ternera. The specimen is an elongated mass, and although small—weighing but 650 grams,—is undoubtedly the entire meteorite, as the unbroken original crust, beautifully preserved, and entirely covered with deep finger-like markings, would indicate.

Having received permission from the owner, one end was cut and polished; it was then found that dilute nitric acid scarcely attacked the iron, and only after heating was it possible to obtain distinct etching. The figures, however, were not characteristic. The ground-mass of this iron indicates a very compact structure on which there is to be observed a peculiar moiré sheen, although this is not the character of the "Cape Iron," which it more nearly resembles, being a much more grained surface and by strong etching becomes easily dull. In this ground-mass are to be seen fine short sharply-drawn lines, which from their luster are very prominent. They are evidently not rhabdites, but are probably lamellæ of a nickel-iron mixture. In the chemical analysis, 0.44915 grams of this

\* *Proc. Amer. Acad. Arts and Sciences*, Oct. 10, 1888, p. 34.

material dissolved in hydrochloric acid, which has been subjected to prolonged heating, afforded Dr. Weinschenk the following results :

Fe	83.02
Ni	16.22
Co	1.63
P	0.00
	100.87

The above analysis would place this iron near the "Cape Iron Group." As the physical properties of this group of irons have been so little studied, it is impossible for us to say whether the structure coincides or not. The complete absence of phosphoric acid, of which not a trace could be detected, indicates that this meteorite is an exception to the general rule in not containing the characteristic phosphor-nickel iron. To the best of our knowledge the occurrence of an iron in this group from Chile is new. It represents a new type, and possesses none of the many characteristics of the other known Chilean meteorites.

ART. LV.—*The Molecular Masses of Dextrine and Gum Arabic as determined by their Osmotic Pressures; by*  
C. E. LINEBARGER.

PFEFFER'S *Osmotische Untersuchungen*\* have furnished until now the principal experimental support for Van 't Hoff's theory of solutions. The measurements of the osmotic pressures of cane sugar solutions agree as well as could be desired with the deductions from the theory. The monograph contains, however, the measurements of the osmotic pressures of several other compounds, such as saltpeter, potassium sulphate, cream of tartar, gum arabic and dextrine, and these determinations have been carried out with so much care and painstaking that considerable reliance may be placed on the accuracy of the results. As far as I know, no particular attention has been paid to these results. Yet the determinations of the osmotic pressures of dextrine and gum arabic afford a means for ascertaining their molecular masses. It is well established that dextrine has the formula  $(C_6H_{10}O_5)_n$ , and gum arabic is regarded as a salt resulting from the combination of several bases, as potassium, calcium and magnesium, with an acid

\* Leipzig, 1877.

having the formula when dried at  $100^{\circ}$  ( $C_{12}H_{22}O_{11}$ ) $_n$ . Nothing positive is known as to the numerical value of  $n$ . Let us see if Pfeffer's measurements will give us some information.

Pfeffer found that a 1 per cent solution of gum arabic\* exercised an osmotic pressure of  $7.2^{\text{cm}}$  of mercury at  $16.1^{\circ}$ . Applying the formula for dilute solutions,  $pv = RT$ , where  $p$  indicates pressure in grms. per  $\text{cm}^3$ ,  $v$  the volume occupied by a molecule of the dissolved substance,  $R$  the constant, 84500, and  $T$  the absolute temperature, we have  $p = 97.2$  grms. per  $\text{cm}^3$ ,  $T = 289.1^{\circ}$  and  $v = 100 x$ , where  $x$  represents the molecular mass of gum arabic. On solving, we obtain for  $x$  the value 2513. This can be regarded as only approximately correct, for probably the gum arabic employed was not chemically pure. Now the molecular mass of a substance possessing the formula  $C_{12}H_{22}O_{11}$  is 342, which multiplied by seven gives 2394. This does not differ greatly from the value obtained by experiment. As gum arabic when ignited leaves an ash amounting to 3-4 per cent of its weight and consisting of the carbonates of potassium, magnesium and calcium, the formula to be ascribed to the gum is not ( $C_{12}H_{22}O_{11}$ ) $_7$  but a similar one in which some of the hydrogen atoms are replaced by the above bases. This would so increase the molecular mass that it would approach nearer that found experimentally. We conclude then that the molecular mass of gum arabic is about 2500, and that the molecule consists of seven simpler molecules.

For dextrine,† Pfeffer found in 1 per cent solution an osmotic pressure of  $16.6^{\text{cm}}$  of mercury at  $15.6^{\circ}$  C. Applying the formula, we have  $T = 288.6^{\circ}$ ,  $p = 225.1$  grm. per  $\text{cm}^3$  and  $v = 100 x$ , solving,  $x = 1083$ . A substance of the formula  $C_6H_{10}O_5$  has a molecular mass of 162; multiplying by seven, we obtain 1134, a number which agrees well with the one obtained by experiment. The molecular mass of dextrine is therefore 1134 and its formula ( $C_6H_{10}O_5$ ) $_7$ .

I recently‡ published the results of the determination of the osmotic pressure exerted by colloid tungstic acid, from which the molecular mass was calculated to be 1750 and the molecule ( $H_2WO_4$ ) $_7$ . It is remarkable that in these three cases, which as far as I know, are the only ones yet examined, the colloid molecule is *seven* times the simple molecule. This

\* The gum arabic is stated as being "Bei  $100^{\circ}$  C. getrocknetes arabisches Gummi." Osm. Unt., p. 105.

† The following is the description of the dextrine employed. "Das Dextrin war als chemisch rein von der Fabrik bezeichnet. Da ich (Pfeffer) es aber nicht einer speciellen Reinigung unterwarf, so kann ich nur sagen, dass Traubenzucker, wenn überhaupt darin vorhanden, jedenfalls nur in minimaler Menge zugegen war." Osm. Unt., p. 112.

‡ In March number of this Journal, cxliii, 218.

seems to point to a more or less distant analogy with the periodic system of the elements, where likewise the number seven plays an important part. It will be interesting to see if subsequent determinations of the osmotic pressures of colloids will show this to be general. I am at present engaged in testing an apparatus for the rapid and accurate determination of the osmotic pressures of such substances as do not dialyze through parchment paper, etc., which will enable me to get at the molecular masses of the substances. These determinations will be carried out mostly with those substances treated of in *Physiological Chemistry*. When once the molecular masses of the complex colloid substances of animal and vegetable origin are known, a great stride in advance will have been made. As the value of an investigation of this kind depends upon the variety and number of substances examined, I take this opportunity to request those, who may have albuminoids or proteids of any kind, to kindly furnish me with a sample, in order that I may determine its osmotic pressure, and hence molecular mass. But a small quantity is necessary, two or three grams sufficing.

The results of Pfeffer's measurements fully confirm the observations made in my first paper on the nature of colloid solutions. Since its publication there has come to my notice an article by A. Sabanejew,\* who has determined the lowering of the freezing point of solutions of egg albumin. The depression is indeed slight—in the hundredths of degrees,—but quite perceptible and sufficient to enable him to deduce the molecular mass of the albumin—14000. This proves that solutions of colloids as well as of crystalloids have a lower point of solidification than the solvent alone, and hence that the difference, if it exists, is only one of degree.

Recently, too, in an article on "Solution and Pseudosolution"† it is stated as one of the theoretical results of quite a series of experiments on the behavior of various colloid solutions that "there is a continuous series of grades of solution passing without break from suspension to crystallizable solution." The continuation of this work, which is promised, will probably throw much light upon the subject.

Chicago, Ill., 240 La Salle avenue.

\* *Jour. Russ. Soc.*, ii, 7 (1891).

† *Jour. Chem. Soc.*, ccli, 171 (1892).

## SCIENTIFIC INTELLIGENCE.

## I. CHEMISTRY AND PHYSICS.

1. *On the Physical Properties of Fluorine.*—Having established the fact that when fluorine is free from hydrogen fluoride, it does not attack platinum at temperatures below  $100^{\circ}$ , MOISSAN has made use of containing vessels of this metal in order to determine the physical constants of free fluorine. By means of a platinum bottle of about 100 c. c. capacity, provided with a platinum tube passing through the stopper and having a lateral tube attached to the neck which could be closed by rotating the stopper, the density was determined. For this purpose the bottle after weighing was filled with dry nitrogen, and then with fluorine by displacement, the current being continued until the issuing gas readily ignited silicon. After a second weighing, the bottle was inverted in water, the oxygen set free by the fluorine was absorbed by alkaline pyrogallate solution, and the residual nitrogen measured. From the volume of the fluorine thus obtained, knowing the increase in the mass of the bottle, the density of the fluorine was easily found. Four determinations thus made gave values varying from 1.264 to 1.270 as compared with air; the value 1.265 being adopted by the author. Calling the atomic mass of fluorine 19.05, the theoretical density is 1.314. The color of fluorine was examined in a platinum tube a meter long and of about 200 c. c. capacity, having two lateral tubulures for the introduction of the gas, and closed at the ends with colorless plates of fluorite. Viewed against a white surface, the gas possessed a very distinct greenish-yellow color, weaker and more yellow than that of chlorine under the same conditions. No absorption bands were observed. The emission spectrum of fluorine was obtained by placing the gas in a platinum tube furnished with a lateral tube closed with a plate of fluorite, the electrodes at the ends of the main tube being insulated by the fluorite plates which closed these ends. Using an induction coil giving a  $10^{\text{cm}}$  spark in air and placing a condenser in the secondary circuit, the spark in the fluorine was examined with a spectroscope having three heavy glass prisms. Both platinum and gold electrodes were used. With the former, thirteen lines of fluorine were observed, of wave-lengths 744, 740, 734, 714, 704, 691, 687.5, 685.5, 683.5, 677, 640.5, 634 and 623. The first three of these are very weak, the last four are strong. Of these only four, of wave-lengths 704, 640, 634 and 623 appear in hydrogen fluoride under the same conditions; while in silicon fluoride, ten of these lines, in phosphorus fluoride seven, in phosphoric fluoride six and in carbon tetra-fluoride the entire thirteen are visible. No trace of liquefaction was observed when fluorine was subjected to a temperature of  $-95^{\circ}$  in a bath of solid carbon dioxide and

methyl chloride, at the ordinary pressure.—*Ann. Chem. Phys.*, VI, xxv, 125, Jan., 1892.

G. F. B.

2. *On the Expansion of Chlorine in Violet Light.*—The observation of Budde in 1871 that chlorine suffers an expansion in volume on exposure to blue or violet light, has been confirmed by RICHARDSON who finds that this expansion is independent of the heating effect produced, and that it remains constant if the light is invariable, returning to its original volume when the light is cut off. By means of a differential apparatus, consisting of two glass tubes 10<sup>cm</sup> long and of 55 c. c. capacity, connected to a graduated horizontal gauge having a small bulb at each end, this expansion was compared with the intensity of the light as determined with a Bunsen and Roscoe pendulum actinometer. The gauge and bulbs contained strong sulphuric acid, a bubble of air in the former serving as index. When these tubes, placed in a suitable box were turned so as to face the sun, it was found that when they both contained air, they were equally heated; but that when one of them was filled with dry chlorine, the expansion was greater upon this side. When the index became stationary the light-intensity was measured; and it was found that the change in the volume of the chlorine was very closely proportional to the intensity of the blue rays. By suspending such a differential apparatus on the beam of a balance so that the flow of acid from one side to the other caused this beam to move, a continuous registering apparatus was constructed by the author, the motion of the beam being communicated to a pen which produced a record on a revolving drum.—*Phil. Mag.*, V, xxxii, 277, Nov., 1891.

G. F. B.

3. *On the Dissociation of liquid Nitrogen peroxide.*—OSTWALD has applied the generalization of Van 't Hoff, that dissolved substances obey the same laws as gases, to the data obtained by Cundall in a research upon the dissociation which nitrogen peroxide undergoes when dissolved in chloroform; expecting that the laws of dissociation of binary compounds such as this which are well known in the gaseous state, will also hold good for the dissolved peroxide. Representing by the equation  $x^2/(1-x) = Kv$  the law of dissociation in the gaseous state, in which  $x$  is the amount of dissociated peroxide,  $v$  the volume of unit mass and  $K$  a coefficient constant with the temperature, the author obtains from Cundall's figures  $v = 100/c$  and  $x = 0.000468r$ , where  $c$  is the concentration and  $r$  the relative amount of  $\text{NO}_2$  produced. Substituting these values the equation becomes  $0.000468r^2.c / (1 - 0.000468r) = 100K$ . And since  $K$  is constant when the temperature does not change, the first member must be also constant. The value of  $K$  as given from Cundall's figures varies from  $2.13 \times 10^{-7}$  to  $3.12 \times 10^{-7}$ , the latter value being that at the highest concentration, and one at which Van 't Hoff's law can hardly be expected to hold with exactness. Hence it appears that nitrogen peroxide does in fact dissociate according to the same law whether it be in dilute solution or in the gaseous state,

the mean value obtained being  $2.31 \times 10^{-7}$ . To ascertain whether at equal concentrations, the ratio of dissociation is the same in the gaseous and in the dissolved state, the author quotes Natan-son to the effect that at  $0^\circ$  and a pressure of  $250^{\text{mm}}$  ten per cent of the peroxide is dissociated. Under these conditions, the absolute density of the gas is 0.0014; *i. e.*, it corresponds to a 0.14 per cent solution of peroxide in a vacuum. From Cundall's experiments it appears that a 1.44 per cent solution at  $0^\circ$  contains 0.274 per cent of dissociated peroxide; and by Van 't Hoff's law a 0.14 per cent solution would contain only about one per cent of dissociated peroxide. In the gaseous state therefore the dissociation is so much farther advanced than it is in the chloroform solution, that to reach the effect of a vacuum the solution must be diluted to more than one hundred fold the bulk of the gas.—*J. Chem. Soc.*, lxi, 242, March, 1892. G. F. B.

4. *On a new method of preparing Carbonyl Sulphide.*—When carbonyl chloride is passed over heated cadmium sulphide, NURICSÁN has observed that carbonyl sulphide is formed. The carbonyl chloride must be carefully dried by passing it through sulphuric acid, and the finely divided cadmium sulphide contained in a hard glass tube, is to be mixed with asbestos to increase its surface. Although the action is perceptible even at ordinary temperatures, the author found that the best results were obtained at  $360^\circ$  to  $280^\circ$ . The gas evolved under these circumstances contained 94.87 per cent carbonyl sulphide, 3.98 per cent carbon monoxide and 1.15 per cent air. The tubes contained brilliant crystals which on analysis were found to be cadmium chloride. The reaction appears, therefore, to be a simple double decomposition according to the equation  $\text{COCl}_2 + \text{CdS} = \text{COS} + \text{CdCl}_2$ .—*Ber. Berl. Chem. Ges.*, xxiv, 2967, October, 1891. G. F. B.

5. *On the Preparation and Properties of Cæsium.*—BEKETOFF has observed that cæsium is readily prepared by the action of aluminum upon its hydroxide. On heating 114 grams of the hydroxide with 27 grams of aluminum in a nickel retort and collecting the distilled metal in glass receivers, he obtained 25 grams of the metal. Its heat of combination with water was found to be from 50 to 52 calories. Cæsium hydroxide was prepared by precipitating pure sulphate with barium hydroxide and concentrating the filtrate in a silver dish placed a metal retort. On fusion, the dish was slightly attacked. It has a density of 4.0178 and a molecular volume of 37.3. Its heat of solution in water is 15876, which is higher than that of the other alkali hydroxides. Its heat of neutralization with hydrogen chloride is 13790.—*Bull. Acad. St. Petersbourg*, II, ii, 169, 171; *J. Chem. Soc.*, lxii, 274, March, 1892. G. F. B.

6. *On the Color of Cobalt-Solutions.*—ETARD has shown that the solubility-curves both of cobaltous chloride and cobaltous iodide consist of two portions intersecting at about the point where with increasing concentration the color changes. Hence

he concludes that they belong to two different hydrates. Moreover, CHARPY finds that the vapor-pressure curve for a 32 per cent cobaltous chloride solution also consists of two portions, the one belonging to the red solution extending to about  $40^\circ$ , while that of the blue solution begins at about  $75^\circ$ .—*C. R.*, cxiii, 699, 794, Nov., 1891.

G. F. B.

7. *A method of showing Electrical Waves.*—LECHER has studied electric waves by means of a Geissler tube which is slipped along between parallel wires which are connected with condenser plates. At certain points the Geissler tube glows, and at nodal points it remains dark. L. ARONS encloses a portion of the parallel wires, employed by Lecher, in a long vacuum tube of about  $250^{\text{cm}}$  with a diameter of  $6^{\text{cm}}$ . When the tube is exhausted to about  $10^{\text{mm}}$  pressure, it is filled with light and dark spaces, which indicate electric waves. These waves are produced when there is a certain relation between the capacity of the condenser and the self induction of the wires.—*Ann. der Physik and Chemie*, No. 3, 1892, pp. 553–559.

J. T.

8. *Permanent Magnetic Field.*—W. HIBBERT points out the use of a permanent magnetic field for various magnetic measurements, and gives the result of a peculiar arrangement which he has employed and which he recommends for testing purposes. A straight bar magnet is supplied at one end with a hemispherical pole-piece of soft iron, at the other end a soft iron disc is screwed which forms the cover of the hemispherical bowl. A circular air space of  $\frac{1}{16}$  of an inch wide separates the cover of the bowl from its edges. A helix of wire surrounds the straight steel bar magnet in the interior of the bowl. By means of this helix the bar can be magnetized to any strength desired. A little coil of fine wire can be quickly thrust through the air space of  $\frac{1}{16}$  of an inch which intervenes between the top of the bowl and its edges, thus cutting lines of force in a permanent magnetic field. Mr. Hibbert gives some figures which show the great constancy of this apparatus. There is practically no evidence of magnetic decay in seven months.—*Phil. Mag.*, March, 1892, pp. 307–314.

J. T.

9. *Dielectric Constant and Conductivity.*—From experiments conducted by M. E. BOUTY, it appears that the dielectric constant only varies slightly under conditions which change the values of conductivity very greatly; thus water and ice have sensibly the same dielectric constant while the conductivity may vary from 1 to  $10^5$  or  $10^6$ .—*Comptes Rendus*, March 7, 1892.

J. T.

10. *Aberration.*—In a valuable paper on this subject, Lord RAYLEIGH reviews the work of experimenters on the subject of the hypothesis of a stationary ether or the reverse and thus speaks of Michelson's experiments to determine whether the ether is carried with the earth in its motion through space.

“It has recently been pointed out by Lorentz that Michelson has overestimated the effect to be expected according to Fresnel's views. The ray which travels perpendicularly to the earth's motion is not affected thereby, but is retarded to the amount repre-

sented by  $Dv^2/V^2$ . The outstanding relative retardation is thus only  $Dv^2/V^2$  instead of the double of that quantity. Accepting this correction we have to expect, according to Fresnel's views, a shift of only .024 of a band in Michelson's experiment. Under these circumstances Michelson's results can hardly be regarded as weighing heavily in the scale. It is much to be wished that the experiment should be repeated with such improvement as experience suggests. In observations spread over a year, the effects, if any due to the earth's motion through space would be separated. On the whole, Fresnel's hypothesis of a stationary ether appears at the present time the more probable, but the question must be considered to be an open one."—*Nature*, March 24, 1892. J. T.

11. *Kirchhoff's Law and the radiation of Gases.*—Kirchhoff's law is the theoretical fundamental law for the spectrum analysis of stars. It states that bodies emitting light absorb light of that wave length for which their emission spectrum shows a maximum. E. PRINGSHEIM draws attention in an exhaustive article to the fact that the spectra of gases are generally studied by means of electrical discharges in Geissler tubes and that we have no direct evidence that mere increase in temperature suffices to make a gas glow. W. Siemens says in regard to this point: "To my knowledge investigations upon the question whether pure gases raised to a high temperature emit light rays have not been made." Siemens has shown that oxygen, carbonic acid, nitrogen and hydrogen, do not emit light rays even when heated to 1500° C.

Pringsheim therefore sets himself to determine:

1. Have gases the power to emit light merely from high temperature.

2. Can we form gaseous sources of light, which satisfy the conditions of Kirchhoff's law.

The conclusions he arrives at after much experimental work are the following:

1. There is no gaseous source of light which satisfies Kirchhoff's law.

2. Glowing gases, the temperature of which is below 150° C. can be obtained (cold flames).

3. The salts of sodium glow in flames only by means of chemical processes (reduction).

4. Metallic sodium heated in neutral gases, glows only from a chemical process.

5. The hypothesis that gas merely through rise in temperature can be made luminous, can be supported neither experimentally or theoretically.—*Ann. der Physik und Chemie*, No. 3, 1892, pp. 428-459. J. T.

## II. GEOLOGY AND NATURAL HISTORY.

1. *Note on the distribution of the upturned Cretaceous beds of British America*, by Dr. GEORGE M. DAWSON. (Editorial Correspondence.)—To the north of the International Boundary

on the 49th parallel, the Cordilleran belt consists of four mountain systems, known, from northeast to southwest, as the Rocky Mountains proper, the Gold Range, the Coast Range, and the Vancouver Range, the last named being represented in a partially submerged form in Vancouver and the Queen Charlotte Islands.

This fourfold division does not continue in a definite manner as far as the 60th parallel, and still farther northward the ranges completing the Cordillera become even more diffuse and irregular. There is, however, throughout, and as far as the Arctic Ocean, an easterly bordering range, which though not entirely continuous, is homogeneous in general structure and is apparently identical in respect to the period of its main elevation, which must have occurred at a time immediately succeeding the Laramie.

This outer system is known as the Rocky Mountain Range proper. It has been most carefully examined in that portion of its length included between the parallels of  $49^{\circ}$  and  $51^{\circ} 30'$  and particularly along the transverse line of the Bow River Pass, near the northern of the above limiting parallels. In this region the Cretaceous rocks, including the Laramie, have participated in the general upturning of the older strata, which has resulted in the definition of this system of mountains; and the Cretaceous rocks are often very violently flexed and disturbed and occasionally overturned.

Following the same mountain system to the northwestward, the still unconnected observations made in the vicinity of the Peace River, Liard River and again to the westward of the Mackenzie delta near the Arctic Ocean, show that the Cretaceous rocks have in all cases participated in the general uplift and disturbance, though in none of these places has the Laramie actually been recognized as a member of the folded strata. In the most northern and last-mentioned line of section, the Rocky Mountains are indeed almost entirely represented by flexed Cretaceous rocks.

Between the Rocky Mountain Range proper and the Pacific Coast, large tracts of the Cordillera appear to have resisted flexure and disturbance at this time, and it is practically certain that the Gold Ranges of the Southern part of British Columbia, together with many other considerable insular areas, have never even been covered by Cretaceous strata of any kind.

In the Coast Ranges, however, and for a variable distance inland from them, Cretaceous rocks, of a date at least as recent as the Dakota, have been subjected to violent flexure; and on the Lewes River, in the Yukon District, (Lat.  $62^{\circ} 20'$ , Long.  $136^{\circ} 10'$ ), the Laramie is also present, and the older Cretaceous rocks appear to pass conformably up into this formation. In this northern region it is in fact clear that the Cretaceous sea at one time extended completely across the Cordillera, and rocks of Cretaceous age are frequently found to be upturned in association with older rocks, all having been affected by a common disturbance, apparently the latest of importance which has occurred.

On the seaward side of the Coast Ranges, the Cretaceous rocks, where they occur, are found likewise to have participated, to a considerable degree at least, in an upturning of the older strata; and on the inner side of Vancouver Island some of these rocks are probably of a date as recent as that of the typical Laramie.

2. *Preliminary Report on the Coal-deposits of Missouri from field work in 1890 and 1891*, by ARTHUR WINSLOW, State Geologist. 226 pp. with a map of the area of the coal measures and many wood-cut illustrations.—The area occupies the western and northwestern parts of the State and covers about 23,000 square miles. The rocks are sandstones and shales of various colors, the shales predominating, and they are horizontal or nearly so. The maximum thickness of the measures is 1900 feet. The coal beds are thin, and about a fourth of the annual Missouri supply, which amounted in 1891 to about 2,680,000 tons, comes from those that are not more than two feet thick. The Report treats of the origin of the coal measures and the special characters of the Missouri coal, and gives detailed descriptions of the beds that are worked.

3. *Baltimore, with an account of the Geology of its environs*. 140 pp. 12mo, with three maps and other illustrations. Prepared by the Local Committee of the American Institute of Mining Engineers, Baltimore meeting, February, 1892.—Nearly one-half of this little volume treats of the geology of the vicinity of Baltimore: the part on the crystalline rocks and their products is by Prof. GEORGE H. WILLIAMS of Johns Hopkins University, and that on the sedimentary rocks, by N. H. DARTON, of the U. S. Geological Survey.

The broad belt or plateau of crystalline rocks, lying to the eastward of the Appalachians,—the Piedmont plateau, as it has been called—is described by Prof. Williams as consisting of an eastern belt made up mainly of highly crystalline rocks and a western of semi-crystalline rocks. Of the latter it is stated there is reason to believe that they will yet afford fossils and have their age determined thereby. Small areas of the latter rocks occur also among the former. The conclusion reached with regard to the origin of the rocks is that the eastern rocks are in the main the older, and that over a floor consisting of such rocks, the beds of the western were deposited. The upturning and metamorphism of the latter are referred with a query to the time of the Appalachian mountain-making, but without mentioning evidence. The eastern lie within the range of the Archæan Appalachian protaxis. They include gabbro, both massive and schistose, pyroxenite and peridotite (rocks without any feldspar), with their alteration products, serpentine and steatite, granite, gneiss, crystalline limestone and quartzitic schist. All the massive rocks are made eruptive. Both the granite and gneiss contain coarse granite veins (pegmatite), and, on very doubtful evidence, those in the granite are believed to be eruptive. Mr. Darton's contribution occupies 15 pages and treats of the formations of the

coastal plain. Two colored geological maps, by the U. S. Geological Survey, based partly on Mr. Darton's work, accompany the volume.

4. *Annuaire Géologique Universel: Revue de Géologie et Paléontologie*, dirigée par Dr. L. CAREZ et H. DOUVILLÉ.—The second and third parts of this very valuable Geological Annual, for the year 1890, have been published.

5. *Supplementary Appendix to Travels amongst the Great Andes of the Equator*, by EDWARD WHYMPER. 147 pp. 8vo, London, 1891, (John Murray.)—This Zoological appendix to Mr. Whymper's great work, contains contributions from fourteen zoologists, and four pages on the rocks by Prof. Bonney. The figures of insects are admirable. The highest flying butterfly and (with the exception of three or four beetles) the highest insect of any kind obtained, barring stragglers, is a *Colias*, described by Messrs. Godman and Salvin as *C. alticola*; it is the same species that was seen by Humboldt and Boupland. It was collected at heights between 12,000 and 16,000 feet, and was observed still higher, or above the mean snow-line, which is about 16,000 feet in Ecuador. The Siluroid fish, *Pimelodus (Cyclopium) cyclopium* of Humboldt's Travels, and afterward described under half a dozen different names, was found to be of one species by Dr. F. Day, confirming thus the view expressed by Dr. Putnam in the American Naturalist, for 1871, p. 694. Five figures are given of it.

Prof. Bonney states that the specimens examined by him of the rocks of the volcanic mountains of the Western Andes, Cotocachi, Rucu-Pichincha, Corazon, Carihuairazo, Chimborazo and of the Eastern Andes, Cayambe, Antisana, Sincholagua, Cotopaxi and Altar were augite-andesytes containing more or less hypersthene; those of Pichincha, hornblende-andesyte, with micaceous andesyte at summit; of Iliniza, hornblendic augite-andesite, and the same for much of the Cayambe rock.

6. *Concerning principles which accompany chlorophyll in leaves*. ÉTARD (C. R. 1892, Feb. 15).—This paper points out the existence, in chlorophyll-bearing cells, of a triatomic alcohol, *Oenocarpol*, of a diatomic alcohol, *Vitoglycol*, and a monatomic alcohol, *Medicagol*. It shows, further, the presence in such cells, of a series of new crystallizable substances resembling cholesterine. There occur even crystallized paraffins; mixtures of these latter doubtless constitute the extractive matters which have been vaguely placed under the general appellation, "wax of leaves."

G. L. G.

7. *On the structure of the ovule and the development of the embryo-sac in Vincetoxicum*. CHAUVEAUD (Comptes rendus, 1892, Feb. 8).—The ovule in this plant appears on the placenta first of all under the form of a minute papula covered by epidermis. When this elevation has about five cells, the subepidermal cell in its axis increases very much in size, and its protoplasm acquires properties which distinguish it from its

neighbors. It becomes transformed directly into the embryonal sac. From the point of view of physiology, this ovule behaves nearly like ordinary ones, but examined from the point of view of morphology, it is wholly different from them, since it never has any true integument. It is absolutely naked.

In a subsequent paper, the author considers the fact of *polyembryony* in this plant. This phenomenon has recently excited considerable interest from the discovery of its occurrence in certain Leguminous plants (GUIGNARD, Ann. Sc. nat. 6 ser., t. XII, p. 35), in *Iris Sibirica* (DODEL, 1891, Zurich), and in *Lilium Martagon* (OVERTON, same date). The author is satisfied that the multiple impregnation in the case observed by him, was due to the division of the pollinic nucleus after its passage into the embryonal sac. He regards this as indicating that the pollen-grain of *Vincetoxicum* is comparable to a single antheridium producing the equivalents of antherozoids, here two or more generative nuclei. The author calls attention to the relations which this subject bears to the accepted notion as to the part played by the synergides. He points out also the greater symmetry of development of the embryos when there is only one present in the embryonal sac, and suggests that the suppression of polyembryony is on the direct line to the more perfect development of the species. G. L. G.

8. *Researches regarding the effect of leaf-removal in the case of grape-vines.* A. MUNTZ (C. R. 1892, Feb. 22.)—The author has sought to ascertain whether the practice of removing the leaves of the grape-vine just before the ripening of the grapes, is warranted by the results. His observations were made at Vergnes and Beaulieu, (Gironde), a district where this practice has been in vogue from time immemorial, and where it is regarded as indispensable to the proper ripening of the fruit. In general, his experiments show that defoliation is not followed by favorable results when the season is dry (like that of last autumn). It may be remembered that experiments by others have given conflicting results. In view of this M. Muntz inclines to hold his judgment in suspense as regards wet seasons, at least.

Among his incidental results are some which are truly surprising as to the elevation of temperature of the fruits exposed to the direct rays of the sun. But this elevation is not associated with a commensurate increase in the amount of sugar. In some instances there is no increase; there is on the other hand, a falling off in the amount of acidity. Pasteur has noted the latter fact with regard to wine placed in direct sunlight. G. L. G.

9. *The Italian Botanical Society* invites the botanists of every nationality to a general assembly in Genoa in order to communicate and to discuss the latest discoveries and new ideas and to increase good feeling amongst scientific men.

This Botanical International Congress will be held in Genoa from the 4th to the 11th of September this year 1892.

Nearer the time fixed a paper will be sent to botanists to which those wishing to attend will sign their names; at the same time they will receive a detailed program of the projected meetings as well as of the public excursions and festivities offered by the Municipality of Genoa to their visitors; the Italian Botanical Society will also offer its colleagues various excursions on the shores of the Mediterranean and in the Maritime Alps.

At the time of the Congress will also take place the inauguration of the new botanical institute built and presented to the University of Genoa by the munificence of the Comm. Thomas Hanbury, as also the opening of an exhibition of Horticulture, and of products exchangeable between America and Italy.

Italian botanists cordially invite their colleagues of every nation in order that their presence may render this Congress more important, and give it an essentially cosmopolitan character, for above all things it aims at strengthening by the powerful influence of science the bonds of fraternity between nations.

All enquiries and communications concerning the botanical congress should be addressed to Professor O. PENZIG, R. Università, Genoa.

### III. MISCELLANEOUS SCIENTIFIC INTELLIGENCE.

1. *Latitude Observations at Waikiki, on the island of Oahu, Hawaiian Islands.*—A recent number of the Hawaiian Gazette (March 8, 1892), contains the following account of the Latitude observations\* now being carried on at Waikiki. The account is by Mr. E. D. Preston, of the U. S. Coast Survey, who is associated in the work with Dr. Marcuse of Berlin.

The latitude observations now going on at Waikiki were undertaken for the purpose of making a more exhaustive study of the motion of the earth's axis. German astronomers had recently detected a new movement of the pole from independent observations at several of their observatories, and in order to test certain theories in regard to the possible cause of the phenomenon it was proposed to make simultaneous observations on opposite sides of the world. The United States government was invited to join in the work, and, besides sending an observer to Honolulu, they enlarged the original plan by establishing stations at Washington and San Francisco. To the German government, however, belongs the credit of having first made a systematic study of the subject.

The motion of the pole is of course extremely small, and the effect is that here in Honolulu we are about fifty feet nearer the equator now than we were some months ago. This change does not, however, go on indefinitely, but the motion is such that the pole returns at the end of a year to nearly its original position. Besides this annual movement, there seems to be reason to believe

\* See this Journal, xlii, 470; 1891, xliii, 163, 1892.

that there is a secular change extending over a period of at least sixty years.

It is evident that if observations on opposite sides of the earth show opposite phases, that is to say, if the Hawaiian Islands approach the equator at the same time that places in Europe recede from it, there is a strong presumption that the phenomenon is not a purely local one, but results from a real motion of the pole, affecting all places on the earth's surface. Indeed this latter fact now seems to be conclusively demonstrated from the observations up to date.

The method of work consists in observing, on every clear night, a list of stars in pairs whose positions are very well known; preference being given, other things being equal, to ones that were observed in England more than one hundred years ago, and whose motion since that time is therefore well determined. The stars, as far as they relate to the latitude work, were adopted in Berlin, and their selection was made the subject of careful study. In order to get the best possible result, certain relations must exist between the stars chosen, and this complicates the problem and makes their selection correspondingly difficult. For instance, in order that refraction may be small, nothing is taken beyond, say, 25 degrees from the zenith. In order that the image of the star be fine and well defined, only faint stars are admitted; and stars composing the same pair must be of about the same magnitude. Besides, if there is a certain relation between the distances of the stars from the zenith, the result is entirely free from any effect arising from an imperfect knowledge of the measuring apparatus. It is very desirable for several reasons to eliminate this effect. Then, again, the stars must not succeed each other too rapidly, in order that the measurements be carefully and deliberately made, nor on the other hand must they be too far apart. All these conditions should be satisfied at the same time, as far as practicable, which makes the selection of a perfect list of stars a somewhat tedious operation.

The great degree of refinement to which observations of this class are now brought, may be judged from the fact that although the observatories at Waikiki are only about thirty feet apart, this distance has a very perceptible effect on the result, and the observations continually show a difference of just this amount in the determined latitudes. However, for the study of the law of change of latitude, this is of no moment, for whatever the relative position of the points of observation they both change equally and verify the same law. The method employed, which is known as that of equal zenith distances, was first practically developed in the United States Coast Survey and is now universally adopted in work of this kind.

When the government at Washington was asked to coöperate in the Honolulu observations, it was seen that the occasion would be a favorable one for the study of several kindred subjects and the American representative in addition to the international lati-

tude work was charged with researches in gravity, magnetism, meteorology, etc. One of the theories proposed to explain the changes of latitude was that of transfers of large masses of molten matter in the earth's interior. In order to test this it was decided to measure the force of gravity every night that latitude observations are made, and this is now being done at Waikiki with an accuracy capable of detecting changes no greater than the one hundred thousandth part of the quantity measured. Practically stated we may say that a body falling toward the earth passes over about sixteen feet in one second; if from some unknown cause the force of gravity should change so as to increase this distance by only one-five hundredth of an inch, this slight increase would be easily detected by the methods employed.

To arrive at these results it is necessary to have a very accurate means of measuring time. This is done by referring all comparisons to the movement of the stars whose passages across the meridian are registered electrically on a revolving cylinder. A button is pressed when the star crosses a spider-thread stretched vertically through the field of the telescope, and instantly the fact is registered on the chronograph. The exact moment of transit can easily be known to within one-hundredth of a second. During the entire evening a pendulum is allowed to oscillate under the influence of the force of gravity. Means are used by which the duration of one vibration may be known with no greater error than a few millionths of a second. The gravity investigations are made for the sake of discovering whether there is any change in the force from day to day, and not for the purpose of knowing what the actual force is; in other words, the question is not how far a body will fall in a second, but whether it falls faster at one time than at another.

The methods followed are similar to those employed on Haleakala in 1887, which gave such conclusive evidence in regard to the formation of Maui, and which bore out Prof. Dana's geological theories. The same operations will be conducted next summer on Mauna Kea, and will throw light on its density and internal structure. This way of weighing the mountains has been employed many times in recent years. During the last cruise of the U. S. S. *Pensacola* to Africa, investigations were made on many of the islands of the Atlantic, which gave the interesting result that they are all comparatively light. The same instruments that were used in the African work were employed in these islands in 1887 and were sent to the South Seas with the U. S. Solar Eclipse Expedition in 1883, so that a fair portion of the earth's surface has been studied by the same method, which adds much to the strength of the result.

The present operations will close this fall, but the complete discussion of the observations will require probably a year more, so that the definitive results will not be known before the latter part of 1893.

2. *National Academy of Sciences.*—The following is a list of the papers entered to be read at the meeting of the Academy held in Washington, April 19–22.

G. K. GILBERT: An American Maar.

R. S. WOODWARD: The form and efficiency of the iced-bar base apparatus of the U. S. Coast and Geodetic Survey.

C. ABBE: On atmospheric radiation of heat in Meteorology. The astronomical, geodetic and electric consequences of tidal strains within an elastic terrestrial spheroid. Biographical memoir of William Ferrel. Biographical memoir of J. Homer Lane.

F. H. BIGELOW: On the deflecting forces that produce the diurnal variation of the normal terrestrial magnetic field.

C. A. SCHOTT: Abstract of results from the U. S. Coast and Geodetic Survey Magnetic Observatory at Los Angeles, Cal., 1882–1889, part III. Differential Measures of the horizontal component of the magnetic force.

A. S. PACKARD: On the anatomy and systematic position of the Mecoptera.

S. C. CHANDLER: On the laws of the variation of latitude. On the causes of variations of period in the variable stars.

T. C. MENDENHALL: On the force of gravity at Washington. On the recent variations of latitude at Washington.

A. M. MEYER: On the acoustic properties of aluminum, with experimental illustrations. Exhibition of Chladni's acoustic figures transferred to paper without distortion.

M. CAREY LEA: Disruption of the silver haloid molecule by mechanical force.

E. D. COPE: On the homologies of the cranial arches of the Reptilia. On the osteology of the genus *Anniella*.

E. S. MORSE: Asiatic influences in Europe.

M. I. PUPIN: On electrical discharges through poor vacua, and on coronoidal discharges.

J. W. POWELL: A definition of Institutions.

THEO. GILL: The partition of the North American Realm.

F. W. PUTNAM: Exhibition of teeth of a gigantic bear, probably an extinct species, found in ancient mounds in Ohio.

J. HOMER LANE: A means of measuring the difference between the tidal change in the direction of the plumb line and the tidal deflection of the Earth's crust. (A posthumous paper read by C. ABBE.)

#### OBITUARY.

SERENO WATSON.—The distinguished botanist, Sereno Watson, died at his home in Cambridge, Massachusetts, on the 9th of March. His career was a somewhat remarkable one because of the long period and varied discouragements during his early life before his distinctively botanical career began, and its contrast with the eminence he at last attained in this science. Mr. Watson was one of a large family of children, and was born at East Windsor Hill, Connecticut, December 1st, 1826. He graduated at Yale in the largest class up to that date, and which has given to American botany two other earnest students, Professor Henry Griswold Jessup of Dartmouth College, and John Donnell Smith of Baltimore, the latter widely known for his investigations of the flora of Guatemala. He entered college the third term of freshman year in the spring of 1844. Inquiry among his classmates shows that he was so retiring and reticent that they remember little about his college life other than that he was of gentle and retiring disposition, a diligent student, and that he

took prizes in Latin composition and Latin translation. After graduating he taught school, first in Scantic, Conn., and then on Long Island, and later in Rhode Island. While at Scantic he studied medicine two months with Dr. Watson of that place and again in the summer of 1849 with Dr. Sill of Windsor, and the next winter, attended lectures on medicine at the New York University. He left there in the spring of 1850 with, as he writes a friend, a diminished respect for medical practitioners, but with a high respect for the science. We next hear of him as teaching school in Allentown, Pa., and then in Tarrytown, N. Y. His diffidence made this work very uncongenial to him, and no one was more conscious of this than himself.

In 1852 his uncle, the Rev. Dr. Julius A. Reed of Davenport, Iowa, one of the founders and Trustees of Iowa College, invited him to that institution, where he remained as tutor two years. Before he had gone to Iowa, an elder brother, Dr. Louis Watson, a physician in practice in Quincy, Ill., had invited him to study in his office and enter practice there. He went there in July, 1854, studied with his brother, practiced medicine to some extent, and handled his cases well. But the practice was probably distasteful to him, for he gave it up in 1856, much to the regret of some of his patients. He then went to Greensboro, Ala., as Secretary of the Planters' Insurance Company of which his brother Henry Watson was President. He remained there until after the war broke out in 1861, and then came North and was engaged with Dr. Henry Barnard of Hartford in literary work, chiefly on the *Journal of Education*. When Dr. Barnard went to Washington as Commissioner of Education this service ceased, and in January, 1866, Mr. Watson entered the Sheffield Scientific School of Yale and pursued the studies of chemistry and mineralogy until the close of that college year and returned for a short time in the autumn. Here he worked very diligently in his scientific studies, but held little intercourse with his fellow students. Botany formed no part of his instruction while here. His studies were probably undertaken with reference to a possible residence in California, to which his thoughts were then turned, and he sailed for that State by way of Panama probably in March, 1867. He was at Sacramento late in April, and spent two or three months in the Sacramento Valley.

The Pacific Railroad was then in process of construction, and Clarence King had just entered upon the geological exploration of the 40th parallel. His party had left Sacramento in June, and had begun active work in the western part of the Great Basin. While Mr. Watson was in New Haven in 1866 Mr. King was also there a part of the time, and the proposed exploration of the region to be crossed by the much talked of Pacific Railway was the subject of frequent comment with the professors and students. The next year when Mr. Watson was at Woodville in the Sacramento Valley he heard that the expedition had set out, and he resolved to join it. From the terminus of the rail-

road he set out alone and on foot, crossed the Sierra Nevada and found his way to the camp of the party, which was then on the Truckee River below the present town of Wadsworth. The trip had been a hard one, and he was unused to mountains and deserts. He reached the camp weary, dust covered, and so foot-sore with his hard tramp that he carried his heavy boots with his luggage over his shoulder. The camp men were struck with his condition as he inquired for Mr. King, and he in turn was taken aback by the very youthful appearance of the commander of the party. He brought a letter of introduction from Dr. Barnard, whom Mr. King had known in Hartford, and was so earnestly anxious to join the expedition that he offered to accept any position the camp offered if there was no scientific work for him. He was engaged to assist in topography, observe the barometer and make himself useful as he could, at first on a mere nominal salary. Mr. W. W. Bailey was the botanist of the expedition, but he was already weakened by fever and could ill stand the hardships of collecting in a desert region. Watson began to collect plants immediately in connection with his topographical work. He had a general knowledge of botany, probably picked up years before while studying medicine, but the plants of that desert region were all new to him, and excited his intense interest. His untiring diligence, his keen observation of plants, his cheerful endurance of the discomforts and hardships of desert campaigning soon gave evidence of his scientific zeal, and personally endeared him to the whole camp, and when finally, before the close of that season, Mr. Bailey succumbed to the hardships of the work, Mr. Watson was chosen to succeed him.

That season and the following winter was spent in the western part of the Basin and the summer of 1868 in the Humboldt mountains and other parts of eastern Nevada. The next winter he spent at New Haven in the Herbarium of Professor Eaton at work upon his collection. He returned to the field and spent the summer of 1869 in Utah. He apparently was happier in this field work than he had ever been before. His comrades speak of his enjoyment of the wild natural scenery of the region he was exploring, and of the various natural phenomena there occurring. He was particularly and intensely interested in the desert vegetation. He was fearless and intrepid in his work; sometimes bivouacked in solitude over night in the mountains, returning the next day with his botanical treasures, always calm and cheerful and undemonstrative.

He returned to New Haven in the fall of 1869, and remained with Professor Eaton about a year, at work on his collection, and went to Cambridge late in 1870 to finish the work at the Gray Herbarium.

His Report was finished in 1871, and was the most complete and extensive botanical report of any of the exploring expeditions on the Pacific slope.

From this time on he remained at Cambridge, and soon became the Curator of the Gray Herbarium. Here was a sphere just

fitted to his nature and training, the working up of some of the more difficult problems of North American Botany. His keen observation and untiring industry, his long and varied training and diversified experience peculiarly fitted him for the work which had at last fallen to him. His intensely conscientious devotion to truth showed itself alike in his scientific work and in his personal life and habits.

After his report was finished the writer, who was then at work on the Botany of California, induced him to finish and publish a list of references he had begun, and later to finish the work on the Botany of California which had been begun by others.

The results of his botanical work during the last twenty-one years of his life are published in too many papers to be given in detail here. They may be summed up as follows: (1) The Report of the Botany of the 40th Parallel; (2) Bibliographical Index to North American Botany; (3) In coöperation with others, The Botany of California; (4) Eighteen contributions, mostly monographs, published in the proceedings of the American Academy of Arts and Sciences; (5) In coöperation with President Coulter of Indiana, a Review of Gray's Manual; (6) A Manual of the Mosses of North America; a work left unfinished by James and Lesquereux; (7) The Botanical definitions in the earlier part of the Century Dictionary. Dr. Watson made only two considerable botanical trips during these later years; one to the Northwest in connection with the forest work of the Census of 1880, and a trip to Guatemala in 1885.

After the death of the lamented Asa Gray he took up the task of completing the Synoptical Flora. For this, his long companionship with Dr. Gray eminently fitted him, but like his illustrious predecessor he was not spared to finish the work. An attack of the prevailing influenza followed by pneumonia and cardiac complications brought his eminently useful and laborious life to an end on March the 9th.

Had he died twenty years after graduation the world would have known little of him, and his classmates would have considered his life a failure. That long period was, however, years of diversified preparation, which fitted him to bring to his chosen work most thoroughly trained powers, and gave him a wide range of knowledge drawn from the study of several sciences, and a personal knowledge of the aspects of the flora of many and widely separated parts of the country. The reserve which characterized him in college, and which lasted through life, left him all the more free to prosecute his chosen work without the distractions of society. But his reticence was not that of the misanthrope. He endeared himself to all who were brought in close relations with him. This was as strikingly shown in the trials and hardships of camp-life, as among the inner circle of his friends in the University, and in the few families that had the privilege of his acquaintance. His death has left a gap among the American systematic botanists which will not soon be filled. W. H. B.

## APPENDIX.

ART. LVI.—*A New Order of Extinct Eocene Mammals (Mesodactyla)*; by O. C. MARSH.

DURING explorations in the lower Eocene deposits of New Mexico, carried on by the writer in 1876–1880, some of the first fossils discovered were remains of small mammals about as large as a fox, and of much scientific interest. The teeth are somewhat similar to those of Ungulates, but the rest of the skeleton, and especially the limbs and feet, are of a generalized type quite distinct from any of hoofed animals known, recent or extinct. Some parts of the structure seem to indicate an affinity with *Hyrax*, but the limbs and feet show characters resembling those of the Primates, especially the extinct forms, and likewise seen in Insectivores, and even in some of the Rodents. A large collection of these remains was secured, and when examined was found to include several distinct forms, all of small size, and forming together a natural group.

One of these forms was described by Cope, under the name *Meniscotherium chamense*, the type being a portion of an upper jaw, with the molars in place.\* This specimen was subsequently described and figured by that author, who regarded it as belonging to the Perissodactyles.† Later, he defined two additional species, and proposed for the family the name *Meniscotheriidae*; and more recently has described and figured various parts of the skull and skeleton.‡

Several other authors since then have discussed the affinities of this peculiar family, but mainly without presenting any new facts bearing on the question, the general opinion being that these animals are primitive forms of *Perissodactyla*, more or less related to *Chalicotherium*, Kaup, which genus they resemble in dentition. A comparison of the feet would have been more important, but those of *Meniscotherium*, at least, were unknown.

\* Report of Chief of Engineers for 1874, pt. ii, p. 596.

† Extinct Vertebrata, p. 251, pl. lxvi, 1877.

‡ Tertiary Vertebrata, 1884.

The large collection of the remains of this group secured by the writer contains almost every part of the skull and skeleton, pertaining to many individuals. Among these are specimens which agree closely with the types described and figured by Cope, as well as a number of others that are evidently quite distinct. Besides *Meniscotherium*, a second genus is represented, which may be called *Hyracops*, and its typical species is described below. This genus is more specialized than *Meniscotherium*, and may be from a somewhat higher horizon of the lower Eocene, but the two genera are found in the same region, and may perhaps occur together.

An investigation of all the specimens represented in this collection of the writer makes it evident that they pertain not merely to a distinct family, but to a separate order, which may be called the *Mesodactyla*. The skull and teeth resemble strongly those of the *Ungulata*, especially some of the early Perissodactyles, but the limbs and feet prove these fossils to be quite distinct from any hoofed animals hitherto known.

The skull of *Hyracops*, in its general form, resembles that of *Didelphys*. The premaxillaries do not reach the frontals. The latter are wide between the orbits, and there is a small postorbital process, behind which the skull is much constricted. There is a strong sagittal crest. The malar reaches the lachrymal. The palate is complete, and the posterior nares extend forward to the penultimate molar. The brain was of moderate size, with the olfactory lobes and the cerebellum especially developed, and not at all covered by the cerebral lobes.

The dentition of the *Mesodactyla* is of special interest. The teeth are brachydont, the molar series lophodont, with external and internal crescents and intermediate cusps, with deep valleys. In one genus, with which the type specimen of *Meniscotherium* best accords, the premolars are unlike the molars. In the genus *Hyracops*, the last premolar is nearly or quite like the molars.

A striking feature in the dentition of both genera is the succession of the teeth. The first series of incisors, canines, and premolars, appears to be retained for a long period. This is certainly the case with the premolars, which continue in use until long after the three true molars have come into service. This fact confirms the recent researches of Kükenthal on *Didelphys*, and indicates that the supposed true molars may belong to the first dentition.

The vertebræ have their articular faces nearly or quite flat, and in the cervical region, these are oblique. The sacral vertebræ are firmly coössified, and are three in number in *Meniscotherium*, while in *Hyracops* there are four. The sternal bones are flat.

The fore limbs were somewhat shorter than those behind. The humerus is stout, of moderate length, with its distal end much flattened, and a supracondylar foramen. It resembles the humerus of a carnivore rather than that of an ungulate. The radius and ulna are nearly equal in size. The head of the radius is expanded transversely, and closely applied to the ulna, indicating but little rotation. The ulna is a stout bone, with the distal end compressed and pointed. The carpal bones resemble in general form and position those of *Hyrax*, and a central bone is present in the same place as in that genus. The five metacarpal bones are all well developed, and their position with reference to the carpals that support them is shown in the fore foot of *Hyracops* represented below in figure 1.

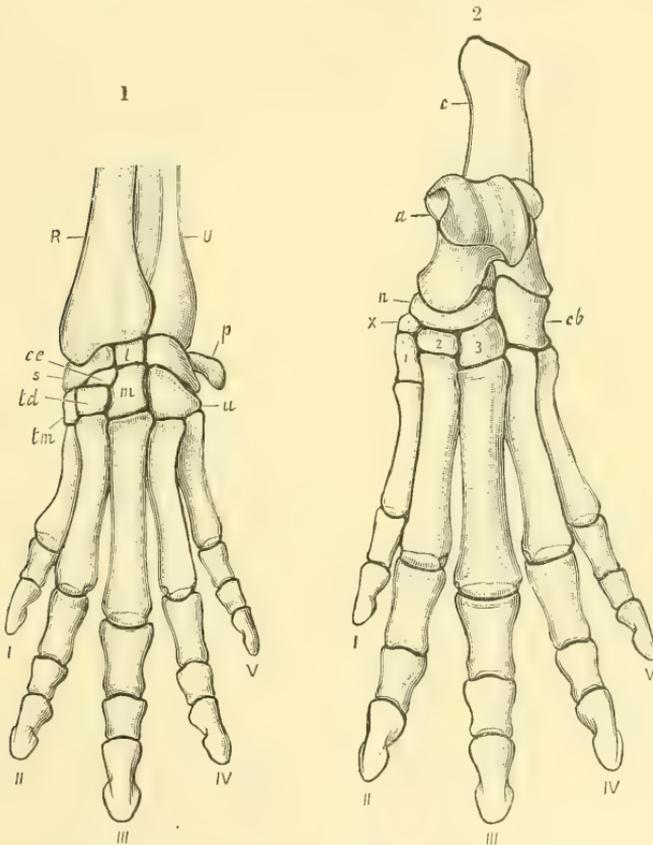


FIGURE 1.—Left fore foot of *Hyracops socialis*, Marsh.

FIGURE 2.—Left hind foot of same species. Both natural size.

a, astragalus; c, calcaneum; cb, cuboid; ce, central bone; l, lunar; m, magnum; n, navicular; p, pisiform; R, radius; s, scaphoid; td, trapezoid; tm, trapezium; U, ulna; u, unciform; x, epicuneiform.

The feet are primitive in type, and were apparently digitigrade, yet the terminal phalanges were not encased in hoofs or in claws, but possessed an intermediate character, which has suggested the ordinal name. Their extremities are thin, somewhat expanded, and more like those of Primates than of any other group. They were apparently covered by thin nails.

The femur has a third trochanter, near the middle of the shaft. The tibia resembles that of a carnivore. The fibula is complete, well developed, and at its distal end is expanded, and meets both the astragalus and the calcaneum.

The hind foot is represented in figure 2, and presents several points of interest. The astragalus and calcaneum are very similar to those in Rodents. The navicular is supported entirely by the astragalus, and the cuboid by the calcaneum. On the tibial side below the navicular, and supported by it, is a small bone (*x*) having beneath it the entocuneiform. It meets the middle cuneiform also. This bone has apparently not been known hitherto, and may be called the epicuneiform. It may, perhaps, correspond to what is known as the tibial sesamoid in Rodents and Carnivores, but its position and connection in the present tarsus are quite different. Moreover, a distinct tibial sesamoid is also present inside and behind the epicuneiform, and hence not shown in the figure.

In the feet of *Meniscotherium*, there are five well-developed digits in manus and pes. The structure of the carpus and tarsus agrees in general with that of *Hyracops*, but in some points, there appear to be differences of importance.

The order *Mesodactyla* contains at present the two genera *Meniscotherium* and *Hyracops*, which include primitive mammals of small size, having the full number of forty-four teeth in continuous series, with the premolars and molars similar in type to mammals known as Ungulates. The limbs and feet are primitive in type, unlike those of any known Ungulates, and resemble those of Carnivores, or the early Primates.

This order stands in somewhat the same relation to the typical Ungulates that the *Tillodontia* do to Rodents, and the *Chalicotheria*\* to Edentates. Very briefly defined, the *Mesodactyla* may be considered as having the ungulate type of dentition, with the limbs and feet of early Primates; the *Chalicotheria* as combining an ungulate dentition with the feet of Edentates; while the *Tillodontia* unite with the rodent dentition the extremities of primitive Carnivores. These three orders are quite distinct from each other and from the remain-

\* The name first proposed for this order, *Chalicotheroidea*, Gill, 1872, may appropriately be shortened to *Chalicotheria*. The term *Ancylopoda* more recently given is preoccupied. The genus *Moropus* is not identical with *Chalicotherium* as has been stated, and *Morotherium*, which has also been referred to the latter genus, is a true Edentate allied to *Myiodon*.

ing *Mammalia*. All three have certain points of resemblance, but differ widely in other respects. Their exact relations to each other and to other mammals are still uncertain, but future discoveries may at any time clear the matter up.

One fact is becoming more and more evident, the near affinity of the early Primates, Carnivores, Ungulates, and Rodents, with each other and with the Insectivores, and more remotely with Marsupials. The key to the mystery lies concealed in the great break between the lower Wahsatch, at the base of the Eocene as now known, and the Laramie beds of the Cretaceous. In the latter, none of the above placental mammals have been found, but in the early Eocene occur, side by side, Carnivores, Rodents, and Ungulates, the last represented by both typical Perissodactyles and Artiodactyles, and even some of their subdivisions. The *Amblydactyla* of large size, the *Tillodontia* also large, and the diminutive *Mesodactyla*, all apparently lived together in this period, and a comparison of their special characters points out their probable lines of descent. The convergence of these lines makes every discovery in the earlier geological horizons of importance, and a connection with the Mesozoic *Mammalia* may at any moment be demonstrated. The Edentates are evidently a later development, as are also the Sirenians and Cetaceans.

New Haven, Conn., April 16, 1892.

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ART. LVII.—*Notice of New Reptiles from the Laramie Formation*; by O. C. MARSH.

AMONG the extensive collections of vertebrate fossils secured during the last few years from the Ceratops beds along the eastern base of the Rocky Mountains, remains of reptiles largely predominate, and many have already been described by the writer. A number of new forms of much interest have recently been secured, and some of these are briefly noticed below. The presence of Ophidians and true Lacertilians among the gigantic forms of *Dinosauria* is especially noteworthy, as their discovery has long been expected. The new Dinosaurs described confirm previous indications, that this subclass, before its extinction, developed into many highly specialized forms, of which suggestions, at least, were seen in those from lower horizons. The large number and variety of these specialized forms could hardly have been anticipated, and they make prominent the probability that the Reptilian age reached its culmination near the close of the Cretaceous.

*Coniophis precedens*, gen. et sp. nov.

The earliest serpents hitherto known in this country are included in the genera *Titanophis* (*Dinophis*) from the marine Eocene of New Jersey, and *Boavus* from the fresh-water Dinoceras and Coryphodon beds of the West, both described by the writer.\* None have hitherto been found in the American Cretaceous, and but one species is known from Europe.† The type specimen of the present genus and species is the vertebra represented below in figure 1. Several others were found at the same locality, but may not pertain to this individual.

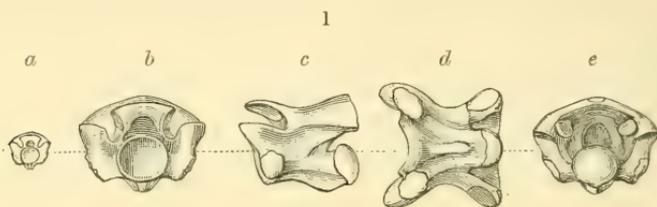


FIGURE 1.—Vertebra of *Coniophis precedens*, Marsh.  
a, natural size; b, c, d, e, three times natural size.

In the type specimen figured above, the zygosphene articulation is fully developed, and all the characteristic Ophidian features are distinctly shown. The nearer affinities of the genus will be discussed in a later communication. All the known remains of the species are from the Ceratops beds of Wyoming.

*Chamops segnīs*, gen. et sp. nov.

The type specimen of the present genus is the maxillary bone with teeth represented in figures 2 and 3 below. Various other parts of the skull and skeleton have been found at different localities in the same horizon, but it is not certain that they pertain to the same species. Dentary bones with precisely similar teeth, and corresponding in size with the jaws figured, have been secured, and there can be little doubt of their identity. Among the other portions of the skull obtained is the upper part of the cranium. This has the surface very rugose, and is perforated by a large parietal foramen.

\* This Journal, vol. xlviii, p. 397, November, 1869; and vol. i, p. 322, May, 1871.

† Sauvage, Comptes Rendu, t. xci, p. 671, 1880.

Various vertebræ found at the same localities may be referred to this species. They are procœlian, with the cup and ball transverse, and oblique. These are all without the zygosphene articulation.

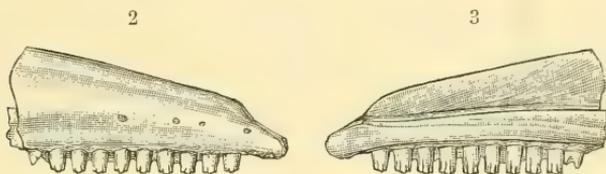


FIGURE 2.—Maxillary of *Chamops segnis*, Marsh; outer view.  
 FIGURE 3.—The same bone; inner view. Twice natural size.

The remains of the species here described are all from the Laramie of Wyoming.

*Iguanavus teres*, sp. nov.

Another Lacertilian, much smaller than the above, left its remains in the same horizon. The specimens best preserved are vertebræ, which agree in general form of the centra with those just described, but possess the zygosphene articulation. They are about the size of the Ophidian vertebra above described, but may readily be distinguished by the oblique and transversely expanded articular faces, and by the smooth under surface of the centrum. The type specimens are all from the Laramie of Wyoming.

*Ornithomimus sedens*, sp. nov.

The remarkable Dinosaurs described by the writer, and referred to the present genus, representing a distinct family, were mainly from fragmentary remains, but differed widely from all forms then known.\* Since then explorations in the same horizon further north have brought to light various other specimens, which prove the group to be of great interest, but make it probable that they should be referred, not to the *Ornithopoda*, but to the *Theropoda*.

The present species is based upon the nearly complete pelvis, with various vertebræ, and some other parts of the skeleton. The most striking feature of the pelvis is the fact, that the ilium, ischium, and pubis are firmly coössified with each other, as in recent birds. This character has been observed

\* This Journal, vol. xxxix, p. 84, January, 1890.

hitherto among Dinosaurs, only in the genus *Ceratosaurus* described by the writer from the Jurassic of Wyoming.\* The present pelvis resembles that of *Ceratosaurus* in its general features, but there is no foramen in the pubis.

There are five vertebræ in the sacrum, firmly coössified with each other, as are also the sacral spines. The sacral vertebræ are grooved below, with the sides of the centra excavated. The caudals have the diplosphenal articulation, and the first caudal bears a chevron. All the bones preserved are very delicate, and some of them, at least, are apparently pneumatic. The sacrum measures fifteen inches in length, and the twelve caudals following occupy a space of thirty-one inches. The known remains indicate a reptile about eight or ten feet in length.

In the same horizon occur the remains of a very minute species, which agrees in all its characters, so far as determined, with the members of this genus. The most characteristic portions secured are the metatarsal bones, and these show the same features exhibited in the type species of the genus, *O. velox*. They are, however, so much smaller as to suggest that they may pertain to a bird. Various portions of the second, third, and fourth metatarsals are known, and the distinctive feature is seen in the third, which has the upper part of the shaft so attenuated that it may not reach to the tarsus. The second and fourth metatarsals are very long and slender. This unique fossil, when alive, was about the size of the common fowl. The species may be called *Ornithomimus minutus*.

The large species described by the writer as *Ornithomimus grandis* belongs in essentially the same horizon. Portions of two other skeletons have since been obtained, which apparently pertain to this species. In one of these, the femur, tibia, and fibula are in good preservation, and they clearly demonstrate that this reptile was one of the largest of the *Theropoda*. The femur and tibia have each a very large cavity in the shaft, with well-defined walls. Even the fibula has a cavity in its upper portion. In the other specimen, the second metatarsal is in fair preservation, and shows the same form as in the type of the genus.

There is much probability that this gigantic carnivore was one of the enemies of the *Ceratopsidæ*, and the discovery of the entire skull and skeleton will be awaited with interest, as they will doubtless show special features for offense, which the peculiar defensive armor of the *Ceratopsidæ* was designed to meet.

The known remains of all the above species are from the Ceratops beds of Wyoming.

\* This Journal, vol. xxvii, p. 329, April, 1884.

*Claosaurus annectens*, sp. nov.

The reptiles of the Laramie allied to *Hadrosaurus* are numerous and highly specialized. One of the forms most distinct, but not abundant, is here described, and the type specimen is a nearly complete skull and skeleton. This will be fully described by the writer, but as the pelvis presents some points of interest it is represented in figure 4 below. The ilium exhibits no special characters of importance, and agrees in the main with the corresponding bone of the type of the genus. The ischium is especially elongated, and very straight. The pubis is represented by a very large, expanded prepubis, and a mere remnant of the postpubis, as is well shown in the figure.

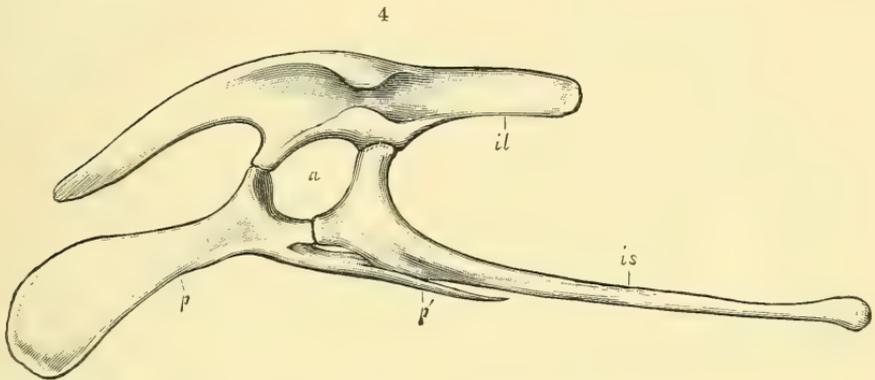


FIGURE 4.—Pelvis of *Claosaurus annectens*, Marsh. One sixteenth natural size.  
*a*, acetabulum; *il*, ilium; *is*, ischium; *p*, pubis; *p'*, postpubis.

This important specimen is from the Laramie of Wyoming.

The fossils described in the present article were all collected by Mr. J. B. Hatcher, whose discoveries in the Rocky Mountain region are well known to paleontologists.

New Haven, Conn., April 18, 1892.



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NEW HAVEN, CONN.: **J. D. & E. S. DANA.**

1892.

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THE  
AMERICAN JOURNAL OF SCIENCE

[THIRD SERIES.]

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ART. LVIII.—*On Subdivisions in Archæan History*; by  
JAMES D. DANA.

1. *Subdivisions based on Kinds of Rocks.*

WERNER'S idea that kinds of rocks and grade of crystallization afford a basis for the chronological subdivision of crystalline rocks is more or less apparent in nearly all attempts that have since been made to lay down the general subdivisions of Archæan terranes. The "fundamental gneiss" has gone to the bottom and the thinner schists to the top. There is a degree of truth in the idea. But the assumptions are so great that at the present time little reason exists for the earnestness sometimes shown by advocates of such systems. The idea has little to sustain it in the known facts of geology. The following are sufficient to decide the question.

According to the thorough petrological and geological study of the rocks of the Bernardston region by Prof. B. K. Emerson\*—a region in the Connecticut valley, in the towns chiefly of Bernardston, Massachusetts, and Vernon, Vermont—there are the following rocks: granite, largely feldspathic; dioryte, so like intrusive dioryte that it had been pronounced trap; quartz-dioryte; granitoid gneiss faintly foliated with biotite and passing into the granite; hornblende schist; quartzite; quartzite porphyritic with feldspar crystals; staurolitic and garnetiferous mica schist; hydromica schist; argillite; massive magnetite, making a bed of magnetite rock;

\* A description of the "Bernardston Series" of Metamorphic Upper Devonian Rocks, by Ben K. Emerson, this Journal, III, xl, 263, 1890.

along with coarsely crystalline limestone and quartzitic limestone containing Crinoids, Corals and Brachiopods: all together making one series of rocks of later Devonian age. My own observations in the region confirm the conclusions of Prof. Emerson. Such facts prove, moreover, that "massive" as applied to crystalline rocks does not signify *igneous*. The granite is not eruptive granite, but part of a stratum which is elsewhere quartzite, the quartzite graduating into granite; the latter was never in fusion.

Again: on the borders of New England and New York there are schists of all gradations from massive Cambrian gneiss to Cambrian and Hudson River hydromica schist and argillyte, the age fixed by fossils. Becker reports similar facts from the Cretaceous of California. Such observations, and others on record, make it hazardous to pronounce any gneiss in an Archæan area "fundamental gneiss," or any associated slaty schist the younger of the two. It may be true; but it may not be. It is probable that the thin-bedded schists are absent from the older Archæan, but not that the thick-bedded and massive are absent from the later Archæan.

The little chronological value of kinds of crystalline rocks in the later Archæan comes out to view still more strongly if we consider with some detail the length and conditions of Archæan time.

The earth must have counted many millions of years from the first existence of a solid exterior, when the temperature was above  $2500^{\circ}$  F., to the time, when, at a temperature below  $1000^{\circ}$  F.,—probably near  $500^{\circ}$  F., supposing the atmospheric pressure to have then been that of 50 atmospheres—the condensation of the waters of the dense aerial envelope had made such progress that an ocean, moving in tides and currents, had taken its place on the surface.\* There were other millions afterward along the decline in temperature to the  $180^{\circ}$  F. mark— $180^{\circ}$  F. the mean temperature of the ocean—when, according to observations on living species, the existence of plants in the waters became, as regards temperature, a possibility†; and still other millions from the  $180^{\circ}$  F. mark to that of  $120^{\circ}$  F., or nearly, when marine animal life may possibly have begun its existence. And since cooling went on at a decreasing rate toward the end, time was also long from the

\* R. Mallet estimated, in view of the density of the atmosphere—over 200 atmospheres to the square inch—that the first drops of water may have been condensed on the earth's surface when the temperature was that of molten iron. *Phil. Mag.*, Jan., 1880.

† They live now in waters having a temperature of  $200^{\circ}$  F., Brewer, at Pluton Creek, California;  $185^{\circ}$ , W. H. Weed, Yellowstone Park. Moreover germs of Bacilli have germinated after having been boiled for an hour.

120° F. mark to that of a mean oceanic temperature of 90° F., or below it, when Paleozoic life found congenial conditions in the water. The mean temperature now is about 60° F.

The ocean, sooner or later after its inaugural, began the work of making permanent sediments, that is sediments that were not speedily recrystallized; and these sediments, through the millions of years that followed must have been of all kinds and of great thickness.

The conditions became still more like the present after the introduction of life with the further decline of temperature. Even before its introduction, iron oxides, iron carbonate, calcium carbonate, calcium-magnesium carbonate and calcium phosphate had probably commenced to form, for the atmosphere, although it had lost the larger portion of its water-vapor, still contained, as writers on the "primeval earth" have stated, the chief part of its carbonic acid, amounting to all that could be made from the carbon of the limestones, coal and carbonaceous products now in the world. It had also a great excess of oxygen—all that has since been shut up in the rocks by oxidations. And these most effectual of rock-destroying agents worked under a warm and dripping climate.

The amount of carbonic acid, according to published estimates, has been made equivalent in pressure to 200 atmospheres, or 3000 pounds to the square inch. 200 is probably too high, but 50 atmospheres, which is also large, is perhaps no exaggeration. Hence, the destruction of rocks by chemical methods must have been, as Dr. Hunt and other writers have urged, a great feature of the time; and long before the introduction of living species, the temperature had so far declined that the making of silicates must have given way in part to the making of deposits of carbonates and oxides.

But with the existence of life in the warm waters, through the still later millions of years, there should have been, as Weed's study of the Yellowstone Park has rendered probable, abundant calcareous secretions from the earliest plants, and, additions later, through the earliest of animal life. Great limestone formations should have resulted, and large deposits of iron carbonate, and perhaps iron oxides, over the bottom-sediments of shallow inland or sea-border flats, besides carbonaceous shales that would afford graphite by metamorphism.

In fact, long before the Archæan closed, the conditions as to rock-making were much like those that followed in the Paleozoic. Surely then, all attempts to mark off the passing time by successions in *kinds* of rocks must be futile. Some *varieties* of the various kinds of rocks are probably Archæan only; but not all those of its later millions of years. Even crystalline and uncrystalline may not be a criterion of chronological value.

The beds of the upper Archæan, under the conditions existing, may well, over some regions, be uncrystalline still, and may include carbonaceous shales that hold to this time their carbonaceous products. Such uncrystalline beds may now exist over the Continental Interior; for the great Interior has generally escaped when metamorphic work was in progress on the Continental borders.

The amount of carbonic acid is most readily estimated by first obtaining the probable amount for all post-Archæan sources, and then adding to this that which is indicated by Archæan terranes. The calculation is here given in detail that others may use it for deductions from other estimates.

For the estimation there are the following data. A cubic foot of pure limestone which is half calcite and half dolomite and has the normal specific gravity 2.75, weighs 171.4 pounds; and this, allowing for  $\frac{1}{12}$ th impurity, becomes 157 pounds and corresponds to 72 pounds of carbonic acid. A cubic foot is equal to an inch-square column 144 feet in height. Since 72 is half of 144, each foot of the column of such limestone contains half a pound of carbonic acid. Hence a layer of the limestone one foot thick would give to the atmosphere, on decomposition, half a pound of carbonic acid for each square inch of surface.

A foot layer of good bituminous coal containing 80 per cent of carbon,  $G=1.5$ , will give to the atmosphere by oxidation 1.9 pounds of carbonic acid per square inch of surface.

If the mean thickness of the limestone over the whole earth's surface, that of the oceans included, reckoned on a basis of  $\frac{1}{12}$ th impurity, is 1000 feet, the contained carbonic acid amounts according to the above to 500 pounds per square inch, or 34 atmospheres (of  $14\frac{3}{4}$  pounds), and if the mean thickness of the coal is one foot, the carbonic acid it could contribute would be 1.9 pounds per square inch. Adding these amounts to the carbonic acid corresponding to the carbon in the mineral oil and gas and other carbonaceous products of the rocks and organic life, supposing it to be six times that of the coal, the total is 513.5 pounds, or 35 atmospheres. The mean thickness of Archæan calcium, magnesium and iron carbonates is not a fourth of that of post-Archæan. Estimating the carbonic acid they contain and that corresponding to the graphite of the rocks at ten atmospheres, the whole amount becomes 45 atmospheres.

To bring the amount up to the estimate for early Archæan time of 200 atmospheres of carbonic acid, the mean thickness of the limestone for Archæan and post-Archæan time should be taken at nearly 6000 feet.

Part of the limestone of post-Archæan terranes was derived from the wear and solution of Archæan limestones, iron carbonate, etc., and hence all the 35 atmospheres to the square inch were not in the atmosphere at the commencement of the Paleozoic. But if we reduce the 35 atmospheres on this account, to 25

atmospheres it is still an enormous amount beyond what ordinary life, even aquatic life, will endure. Reducing the estimated mean thickness for the limestone layer over the globe from 1000 to 500 feet would make the amount nearly one half less.\*

The making of carbonates early began the work of storing carbonic acid and purifying the atmosphere; and the introduction of life increased the amount thus stored, and added to it through the carbonaceous materials from living tissues contributed to the earthy deposits. But with all the reductions that can be explained, the excess is still very large. It has been proved by experiment that an excess also of oxygen diminishes the deleterious influence of carbonic acid on plants; and that if the amount of this gas is made equal to that of the oxygen in the present atmosphere, plants will still thrive. How far this principle worked in early time cannot be known.

## 2. *Subdivisions based on Stratification.*

The stratification in an Archæan region affords the only safe and right basis for subdivisions. This method has been used in the separation of the Huronian from the older Archæan; and recently, with good success, by Irving and Van Hise in the study of the Penokee-Marquette region, or the Huronian belt of Wisconsin and Michigan. The intimate relation of the beds in the series has been worked out and their unconformability with the lower rocks thus ascertained, besides the stratification and constitution of the iron-ore series within the belt. This is the first step toward that complete study which should be carried on throughout all Archæan areas, however "complex." The distribution of the rocks and their apparent or real stratigraphic succession, whether massive or schistose, the positions of the planes of foliation or bedding, the unconformities in superposition, and those of mere faulting, and all structural conditions, should be thoroughly investigated. Correlation by likeness of rocks has its value within limited areas, but only after much questioning.† The work is

\* A right estimate is very desirable. If made for North America, it could not be far out of the way to assume it to be a mean for like areas of the other continents as regards the limestone. But with the best possible result for the continents, the oceanic area, three times that of the continents, and out of the reach of investigation as to depths of bottom deposits, remains a large source of doubt.

† As a preliminary in the study of any such region, thousands of dips and strikes of planes of foliation or bedding should be taken (in imitation of Percival's work before 1842, mentioned in the note on page 440 of the last volume of this Journal), and all should be plotted on maps of large scale by means of symbols with affixed numbers recording the dips and strikes, for full comparison in the final elaboration. Even the Penokee-Marquette region needs further investigation with a clinometer-compass in hand.

Before commencing the study of any crystalline rocks, models of flexures should have been studied until the fact is fully appreciated that a flexure having an inclined axis—the commonest kind—ranges through  $180^\circ$ , or nearly, in its dips and strikes, and until the characters of the bedding in different transverse

easy in its methods, yet perplexing because in North America the uplifts and flexures of different periods have in general taken place in parallel directions, so that unconformabilities are disguised, especially when the two formations are nearly alike in grade of metamorphism. Follow along the overlying to places where its metamorphism is of low grade, and there may be success.

There is a first point of special importance to be accomplished by Archæan investigation. The Huronian of the Penokee-Marquette region is partially metamorphic. To the east, the iron ore, according to the describers, is mainly metamorphic magnetite and hematite; to the west, especially in the Penokee region, it is largely iron carbonate, or the ore in its original state. Other facts show a diminishing grade of metamorphism to the westward. In the Penokee district, the ore is underlaid by a bed of "cherty limestone," the chert of which, like the interlaminated jasper of the iron-ore bed, is regarded by Van Hise as probably of organic origin, like later chert. It has among the overlying beds carbonaceous shales containing, according to Chamberlin, 40 per cent of carbon, bearing thus evidence of very large organic carbonaceous contributions when in process of formation. The great beds of iron ore, the upward gradation eastward in metamorphism, the relations in position to the admitted Archæan adjoining it on the south, seem to prove the Huronian series to be Upper Archæan, as it has been generally regarded, but in a non-metamorphic and partially metamorphic condition. The question thence arises: Are the ore-bearing rocks of the Archæan of eastern Canada, New York, New Jersey and other parts of the Appalachian chain Huronian in a state of *high-grade* metamorphism? Are the chondritic limestones, which in some localities, occur in and with the ore, part of the Huronian formation? Does the eastern iron-bearing series rest unconformably on inferior Archæan?

The *Algonkian* (or Agnotozoic) beds belong either to the Archæan or to the Paleozoic.

The Archæan division of geological time is of the same category with the Paleozoic, Mesozoic and Cenozoic; all are

sections of flexures are well apprehended. A good model for studying flexures may be made from a cylindrical stick of coarse-grained wood having the bark on (if of a smooth kind); it may be about four inches in diameter and 12 to 15 long. Draw a straight line through the center of one end; and from this line saw across obliquely to the edge at the opposite end. After planing smooth the sawed surface, the layers of the wood may then be colored by groups; and three colors, or two besides that of the wood, are better than more. The model of a flexure having an inclined axis is then complete. Cross-sections of the model may be cut and the colors added to the new surfaces. For models of overthrust flexures, this method is not practicable, as wood of elliptical section would be required. They may be made of paper-pulp of three colors.

grand divisions based on the progress of life, and they include together its complete range. There is no room for another grand division between Archæan and Paleozoic any more than for one between Paleozoic and Mesozoic. In contrast, the Algonkian division is not above the Cambrian in grade, it being based on series of rocks. Its true biological relations are in doubt, because fossils representing the supposed life of the period are unknown, or imperfectly so. The discovery in any rock so-called of Trilobites, Crustaceans, Mollusks, Brachiopods, or Crinoids, whatever the species, would entitle such rocks to a place in the Paleozoic, and either within the Cambrian group or below it. Walcott has already reported such fossils from the beds at the bottom of the Colorado cañon referred by him to the Algonkian, namely: besides a Stromatoporida, a small Patella-like or Discina-like shell, a fragment of a Trilobite and a small Hyolithes—forms which make the beds Paleozoic beyond question.

3. *Subdivisions based on Physical and Biological conditions.*

Although the physical and biological conditions of the early globe are not within the range of observation, there are generally admitted facts which afford a basis for a philosophical division of the time; and from it geology may derive instruction. The subdivisions to which we are led are the following:

I. The **ASTRAL** æon, as it has been called, or that of liquidity.

II. The **AZOIC** æon, or that without life.

1. The *Lithic era*, commencing with completed consolidation: the time when lateral pressure for crust-disturbance and mountain-making was initiated, and when metamorphic work began.
2. The *Oceanic era*, commencing with the ocean in its place: oceanic waves and currents and embryo rivers beginning their work about emerged and emerging lands, and the tides, the retarding of the earth's rotation.

III. The **ARCHÆOZOIC** æon, or that of the first life.

1. The *era of the first Plants*: the Algæ and later the aquatic Fungi (Bacteria); commencing possibly with the mean surface temperature of the ocean about 180° F.
2. The *era of the first Animal life*; the Protozoans, and forms related to the embryos of higher invertebrate species; commencing possibly with the mean surface temperature of the waters about 120° F., and ending with 90° F. or below.

The subdivisions, as is evident, mark off great steps in the progress of the developing earth, although the rocks bear no marks of them that can be distinguished.

The Huronian period covered, probably, much of Archæozoic time; and this is all in the way of correlation that can be said. It is well to note here that if the Eozoon is really animal in origin, the "Laurentian" rocks of Canada in which it occurs must be Huronian, or the later of Archæan terranes.

Respecting the Oceanic period it is observed above, "*commencing with the ocean in its place.*" It appears to be almost a physical necessity that the oceanic depression should have been made in the first forming of the solid crust, if the globe cooled to the surface from the center outward; that is, unless a liquid layer remained long afterward beneath the crust.

The depression was certainly made long before the close of Archæan time. For the enormous amount of rock-making of the Archæan over the continent implies the existence of emerged rocks within reach of the decomposing, eroding and denuding agencies of the atmosphere and atmospheric and oceanic waters. A submergence in the ocean of 50 feet is almost a complete protection against mechanical and chemical wear. Moreover North America has its Archæan lands not only in the great nucleal mass, 2,000,000 square miles in area, but also in the series of Archæan ranges parallel to the outlines of the nucleus, which extend eastward to the eastern limit of Newfoundland, and westward to the Pacific. And it has correspondingly shallow-water Cambrian deposits lying between these ranges from eastern Newfoundland and the coast-region of New Brunswick and Massachusetts, westward across the continent about most of the Archæan outcrops, to within 300 to 400 miles of the Pacific Ocean, as shown by Walcott.

There is hence reason for the conclusion that, at the close of Archæan time, the continent of North America was present not merely in outline, but also in general features, and at shallow depths where not emerged.

This fact with reference to North America means much. It means that by the end of Archæan time, the continents generally were essentially in a like condition—outlined and at shallow depths where not emerged; that, therefore, the oceanic depression was then large and deep enough to hold the ocean. Further, this last fact indicates, if the mean level of the continents was coincident with the water's surface, that the oceanic depression had already a depth of 12,000 feet, or that of the present mean depth of the waters; and that, the lowering, through later time, of the bed 1500 feet on an average (or 2000 feet according to other estimates) would give the continents their present mean height. And it is a fact of deep geogenic significance, that nearly 1000 feet of this mean height was received after the beginning of the Tertiary.

[To be continued.]

ART. LIX.—*On Electrical Discharges through poor Vacua, and on Coronoidal Discharges* ;\* by M. I. PUPIN, P.H.D., Columbia College. With Plate XIV.

## INTRODUCTION.

THE behavior of electrical discharges through poor vacua does not seem to have received the attention of experimental investigators which it deserves. This may seem strange in view of the uncertainty of our knowledge of the process by which the transfer of electricity through gases takes place. Considering, however, that it was generally customary to employ in experimental investigations of this kind a vacuum jar with metal electrodes in connection with an electric generator of small capacity, it is easily explained why the discharges through poor vacua should have received so much less attention than the discharges through high vacua and the spark discharges through gases at ordinary pressures. Neither the vacuum jar, nor the working of the electric generators ordinarily employed, admitted of rapid, easily adjustable, but essential variations in the conditions of the experiment; as for instance, variations of the size and shape of the electrode, of the frequency of the discharges, of the strength of the electromotive force, etc. But, as I shall point out in the course of this paper, it is through these very variations that certain fundamental features in the character of an electrical discharge through poor vacua are brought out prominently.

The fact that electrical discharges in poor vacua resemble in many characteristic details the appearance and behavior of the solar corona attaches additional interest and importance to that class of experimental investigations which are pointed out, only, in this paper. Neither time nor facilities permitted me to aim at anything approaching completeness. The principal aim in my presenting this paper was to recommend my subject and my method of investigating it to those who command over a larger experience and skill in experimental investigations, and who also have more leisure and greater experimental facilities than I could even pretend to possess.

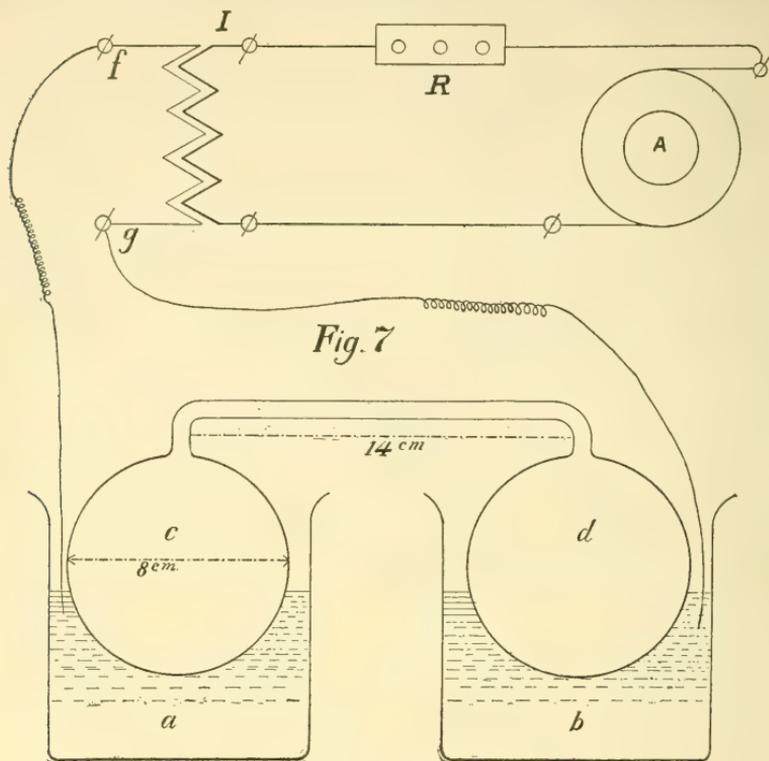
## DESCRIPTION OF THE EXPERIMENTAL METHOD.

A brief description of the method by which I obtained my vacuum discharges seems in place now. It consists in producing an electrical current in a vacuum by means of the con-

\* Read before the National Academy of Sciences, Washington, April 22nd, 1892.

denser effect of tinfoil coatings or other conductors placed on the outside of a vacuum jar.

The following experiment which I performed over a year ago will explain my meaning more fully. The poles *f g* (fig. 7,) of a small Ritchie induction coil were connected to two glass



beakers *a b* containing water. The primary was fed by a  $\frac{1}{4}$  h. p. alternator *A*, giving an alternating current of about 80 periods. A resistance box *R*, regulates the strength of the primary current. The speed of the motor which drives the alternator regulated the periodicity of the current.

A vacuum jar *c d*, consisting of two glass bulbs (each about 8 cm in diameter) connected by a tube of narrow bore, was immersed into the beakers, one bulb in one beaker the other into the other. The jar contained rarefied air at about 5 mm pressure.

As soon as the bulb reached a certain depth a discharge took place producing a perfectly steady and continuously diffused crimson luminosity. The intensity of the luminosity increased with the increase of the surface of contact between the water and the bulbs. The same effect was produced by substituting

a Holtz machine for the induction coil and the alternator. In this case the effect was due, of course, to the oscillations produced by the spark discharge between the poles of the machine. The two vacuum bulbs with the water surrounding them act like two condensers connected in series by the narrow tube. It seems superfluous to describe the obvious experiments which I had to perform to prove the following relation :

The intensity of the luminosity increases with the condenser surface of the bulbs, with the frequency of alternations, and with the effective electromotive force of the charging apparatus. Other things being equal the total amount of light produced will increase with the increase of the conductivity of the vacuum. This relation may have been understood before, but to my knowledge it was never clearly stated.

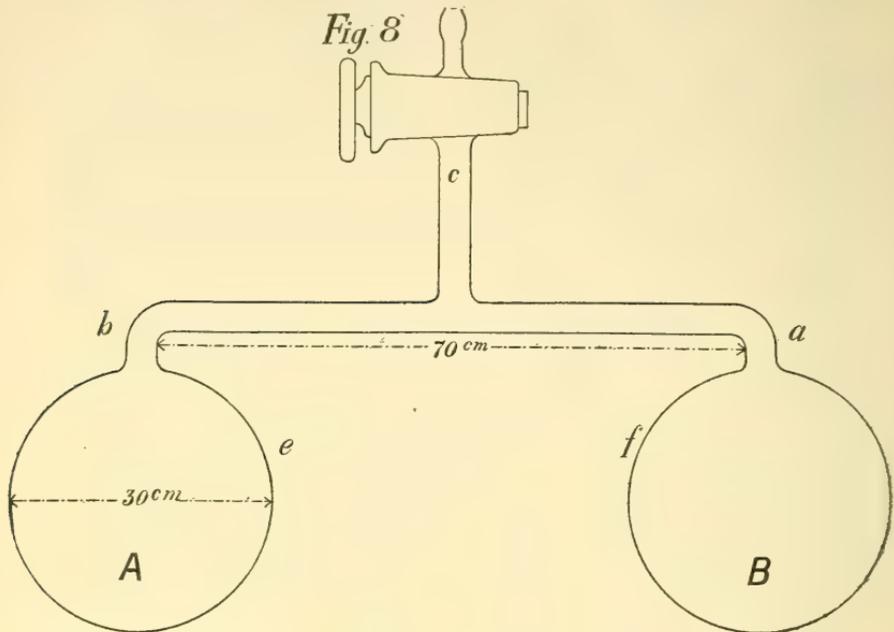
The luminous effects which I succeeded in producing in the manner described were so powerful, that I thought it worth while to construct an electrical lamp on this principle. I mention this for the purpose of pointing out that this method of producing very powerful vacuum discharges was worked out by me several months before the publication of Nikola Tesla's and Professor J. J. Thomson's magnificent experiments. A considerable number of results which I obtained in my experiments are simply repetitions, on a small scale, of the results obtained by these scientists. There is, however, one line along which there seems to be but very few points of contact between their work and mine. This line runs in the direction of investigating the relation between the character of the discharge, the pressure in the vacuum, and the effective e. m. f. which produces the discharge. The following experiments will show some of the characteristic features of this relation.

#### I. ON THE CRITICAL POINTS OF THE DISCHARGE.

A vacuum jar of the form and dimensions as given in fig. 8, was substituted for the small double bulb *c d*, in fig. 7. The bulbs A and B were totally immersed in large glass beakers containing clear, distilled, acidulated water. The air pressure in the bulbs was a little less than  $2^{\text{mm}}$ . Instead of the small alternator a large alternating current machine fed the primary. On closing the primary circuit the discharge between the bulbs started long before the resistance box R, indicated that the e. m. f. in the secondary coil had reached its maximum. The crimson luminosity was very soft, steady, and distributed in accordance with the distribution of the potential which one would expect in an electrical system of the above description.

Touching the narrow tube at any point increased the luminosity below the point touched ; evidently due to the increase

of the static capacity at that point. Diminishing gradually the e. m. f., the luminosity of the discharge diminished with it and then stopped suddenly as if a critical point had been suddenly reached. Reducing the e. m. f. gradually to zero



and then gradually increasing it again, it was found that the discharge would cease at a point much lower than the point at which it would start again, the difference between the two points diminishing considerably with the rapidity with which these variations were made. The discharge will start at a much lower e. m. f. if solicited, that is to say if the long tube is touched at one or more points. A wire bent in the shape of a Leyden jar discharger does very good service as a discharge "solicitor."

The discharge was similarly affected by varying the capacity. Performing the last experiment, but with the small vacuum jar *c d* given in fig. 7, it was found that with a given potential (just above the critical point) the discharge did not start until the bulbs *c d* had reached a certain depth and then it started suddenly. Raising the bulbs gradually, and therefore diminishing the capacity, the discharge became fainter and fainter, but it did not cease until the bulbs were entirely lifted out of the water. On immersing again, the discharge did not start until a certain depth was reached. The depth at which the dis-

charge would start this time was smaller than in the first case and the smaller the shorter the interval between the time of taking the bulbs out and immersing them again. This difference is, of course, due to the improved conductivity of the gas and this again may in a certain measure be due to the rise in temperature of the gas on account of the heating effect of the discharge; but only in a small measure, for the bulbs were under water, so that the rise in temperature must have been very small. Besides, heating the bulbs with a Bunsen burner before immersion did not diminish the depth at which the discharge would start nearly as much as a previous discharge would, no matter of how short a duration. As stated above, the discharge may be started far below the critical point by touching the connecting tube. But if the touch lasts only a very short time (a fraction of a second) the discharge ceases as soon as the touching conductor leaves the tube. In this manner the vacuum tube may be made to blaze up in quick successions.

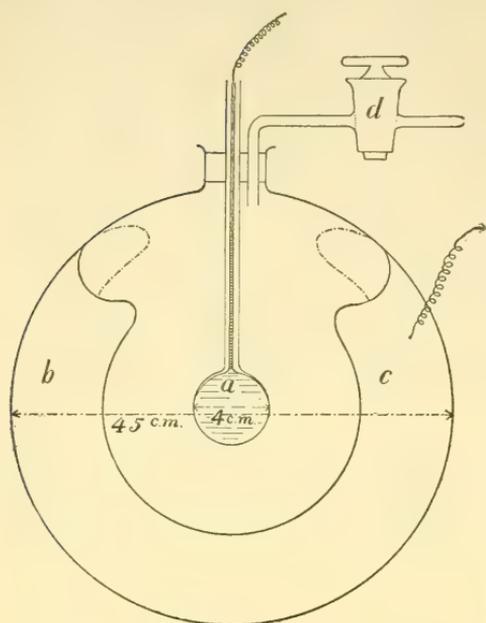
This behavior of the discharge at all pressures, but very much more striking at pressures higher than the pressure under consideration, seems to support the dissociation theory of Prof. J. J. Thomson (*Phil. Mag.* 1891, vol. xxxii, pp. 329, 454, 455).

## II. PHENOMENA INDICATING A DISSOCIATION OF THE MOLECULES.

The following phenomenon appears to be an additional support of this theory :

A close inspection of the discharge going on in the bulbs A and B, fig. 8, seemed to reveal the strange fact that the electrical flow was confined to a thin layer of the rarified gas which is in immediate contact with the inside surface of the bulbs, especially when the e. m. f. was not too far above the critical point and therefore the supply of the current not too plentiful. To all appearances there was a gliding film of luminous gas in each bulb extending from the mouths of the connecting tube, spreading over the inside surfaces and ending at the bottom of the bulbs in violently agitated luminous clouds which gave the discharge a hazy appearance. When the vacuum was very good both the film and the clouds were absent. There was no suggestion of a motion on the part of the gas, and the discharge had a clear luminosity. To study this phenomenon more closely the following experiment was performed :

A glass bulb *a*, fig. 9, blown out at one end of a thick glass tube of narrow bore was filled with acidulated water and

**Fig. 9**

placed at the center of a large glass bottle, as indicated in the figure.

A wide strip (*c b*) of tinfoil was placed on the outside of the bottle, covering about one-third of the surface. The air was exhausted through the tube *d*, until the pressure was about  $3^{\text{mm}}$ . The liquid in the bulb *a* and the tinfoil were connected to the secondary poles of the induction coil. When the e. m. f. was not too far above the critical point the discharge was in form of numerous, quivering streamers, which looked like the generators of a conical surface with the center of bulb *a* as vertex and the edge

of the tinfoil as directing curve. There was no visible discharge between the bulb and the central parts of the tinfoil. But the discharge spread out and gradually approached these parts and at the same time the streamers became less numerous and steadier, giving the discharge a more diffused appearance as the potential gradually increased. When the e. m. f. was gradually brought back to its original value the discharge diminished in intensity but did not return to its original form of distribution. It did that when the e. m. f. was considerably lowered below its initial value, which showed that the original distribution was not altogether due to the fact that at any moment the density of the electrostatic charge of the tinfoils was considerably larger near the edges. In this experiment as well as in the preceding one the number of streamers, their definition, their quivering motion, and their preference for the paths along which the discharge started, increased with the increase of pressure in the vacuum. A discharge (especially in vacua of poor conductivity) will always start between parts of highest electrical density and each successive discharge prefers the passage along the path of the first discharge on account of the increased conductivity along this path.

But if this increase in the conductivity is due to a rise in the temperature of the gas along the path of the first discharge and to nothing else, how can the fact be explained that a long, thin, discharge streamer when forced through a poor vacuum can be maintained steady, and permanent in form, even if the discharge continues for several minutes? It should broaden out continually and become more and more diffused as the adjacent particles of the air get heated. In my experiments on solitary discharge streamers in poor vacua (see this Journal, April, 1892), I did not observe any appreciable widening out, but I did observe a phosphorescent halo around the streamer which, as Prof. J. J. Thomson assumes, (l. c.) was *very probably* due to dissociated oxygen molecules that were ejected from the path of the discharge. (See further below the effect of a blast on a discharge streamer).

Still another experiment which shows that something of the nature of a dissociation of the gas molecules is going on along the path of the discharge. A thick German silver wire, 60<sup>cm</sup> long, was bent zig-zag fashion into 12 zig-zag parts and placed in horizontal position at the bottom of a bottle like the one in fig. 9. A wire passing through a rubber stopper in the neck of the bottle connected this zig-zag electrode to one of the poles of the induction coil. The other electrode, a small brass sphere, was vertically above the zig-zag electrode, immediately under the rubber stopper. The shortest distance between the two was about 30<sup>cm</sup>. The vacuum was about 3<sup>mm</sup>. The discharge started between *the nearest points of the electrodes*, that is between the lowest point of the sphere and one extremity of the zig-zag electrode. It had the form of a band about 3<sup>cm</sup> wide, intensely luminous at each end, but only very faintly luminous along the intervening three-fourths of its length. The length of the less luminous interval increased with the decrease of the e. m. f., but diminished with the increase of the gas pressure; it also seemed to have a different color, but I did not care to examine this point more closely. The phenomenon that interested me more was the gradual creeping of the discharge along the zig-zag electrode from one of its extremities towards the other. It did not increase in breadth but left its trail along the zig-zag electrode in form of a faintly luminous halo which surrounded this electrode just like a narrow luminous tube. Both the color and the gradual lateral motion of the discharge reminded me very much of the aurora borealis of Feb. 13th, 1892. (In this connection it is well to remark that when the e. m. f. is below the critical point this auroral discharge can be started by powerful disruptive discharges of a Leyden jar in its vicinity. This in connection with observations on coronoidal discharges given in the

latter part of this paper may perhaps furnish a clue in tracing the connection between sunspots and auroral discharges).

### III. PHENOMENA INDICATING A TRANSLATIONAL MOTION OF THE GAS.

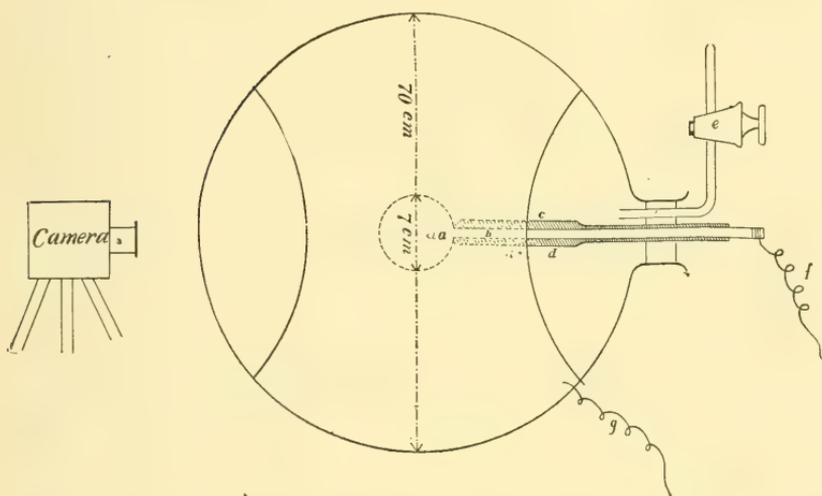
An interesting phenomenon was observed in the experiments with bulbs A, B, fig. 8, when the vacuum was diminished by turning a stop-cock C several times around. The vacuum pressure was about  $20^{\text{mm}}$ . The induction coil had to be strained considerably to force a discharge through the long glass tube. The discharge looked like a luminous jet shooting from the tube into the bulbs, and in its path around the corners it seemed to strike against the necks of the bulbs at *a* and *b* from which points it was reflected and glided along the surface towards the points *e* and *f*. Inside of the bulbs the jet oscillated rapidly; it was also split up in several parts, each part consisting of numerous more or less intense streamers. A slight modification in the curvature of the necks modified the general outline of the luminous jet without changing its general character. With the increase of the gas pressure the phosphorescence appeared and seemed to be strongest at *a* and *b*. It was very strong in the tube C, leading to the stop-cock, although this tube was entirely free from the discharge proper. The height to which the phosphorescence rose in this tube increased with the current. Every slight variation in the current strength caused a simultaneous variation in the height of the phosphorescent column in C. (When the discharge ceased there was a strong phosphorescent after-glow all along the long tube). A similar behavior on the part of the phosphorescent gas, which I observed in the experiment described in this Journal, April, 1892, leads to the conclusion that the phosphorescent gas must have a translational motion due to its being ejected from the path of the discharge proper. This strengthened my belief in a translational motion of the gas along the path of the discharge proper, which belief was due to the phenomena in the experiment just described. It was also strengthened by the phenomenon observed in the experiment described by me in the paper cited above, the phenomenon namely that a discharge streamer made to curve out (by the repulsive action of another parallel streamer) so as to strike against the walls of the vacuum jar will rebound from this wall just as a curved jet of water would if it struck against a rigid surface. In another experiment with an apparatus similar to that described in the above paper a thin rectangular sheet of mica was suspended between and parallel to two discharge streamers and it was found that it prevented their action which I described in that paper, but

it was made to swing back and forth as if acted upon by a wind coming from the path of the discharges. This action was hardly perceptible in high vacua but increased quite considerably with the increase of the gas pressure. It may, however, be due to a great variety of causes, like peculiar distribution of pressures due to a peculiar distribution temperature; so-called apparent (in my case continually varying) electrostatic charge over the surface of the mica, etc.

IV. ON CORONOIDAL DISCHARGES.

Wishing to perform additional experiments which could throw some more light on this particular feature of the discharge, I constructed the apparatus given in fig. 10. A large

Fig. 10



glass bulb was coated with tin foil along those parts of its external surface which would approximately correspond to its temperate zones, its neck being one of the poles. This tinfoil coating had a wire *g* attached to it by means of which it could be connected to the pole of the induction coil, and serve as an electrode of the bulb. The other electrode was a brass sphere *a* attached to a brass rod *b*. This brass rod was surrounded by a glass tube *c d* and the space between the two was filled with sealing wax. In this arrangement the pressure could be varied between very wide limits (up to about 100<sup>mm</sup>) without running the risk of refusal on the part of the induction coil to force a

discharge through. A camera was placed in front of the bulb as indicated in fig. 10, and the discharges photographed. Figs. 1, 2, 3, 4, 5, 6, (in the plate facing p. 462) are photographs of the discharges obtained in this manner but in various degrees of rarification.

I shall discuss the discharge given in fig. 6 first. In this case the vacuum was very poor (about 60<sup>mm</sup> pressure). The discharge started in the form of four large streamers together with a very large number of short luminous jets, which were more or less uniformly distributed over the sphere. In consequence of these jets the appearance of the sphere reminded one very much of the granular structure of the sun's disc as revealed by Rutherford's, Janssen's, and Vogel's photographs of the sun. Very luminous spots appeared from time to time at several points of the surface, which reminded one very much of the sun's faculæ. Both the jets and the large streamers rotated rapidly. This rotation is indicated very plainly in the photograph; for the number of streamers in each wing represents the number of maxima in the alternating discharge during the time of the exposure, which was a small fraction of a second. The thickest streamers indicate the place where the discharge started. It is evident that the streamers were distributed nearly symmetrically over the sphere at the start of the discharge and that then one-half of them were gradually and almost uniformly displaced in the direction of motion of the hands of a watch, the other held in the opposite direction. The peculiar curvature of some of these streamers indicates the presence of two kinds of motion, one a translational along the prolongation of the radii of the small sphere and the other a rotational. It was this rotational motion which led me to assume that there must be some sort of repulsive action between the streamers of a vacuum discharge. The existence of this action was demonstrated conclusively by the experiment described in the paper cited above. Additional researches in this direction lead me to the conclusion that two discharge streamers tend to blow each other out owing to the motion of the cooler gas between them, this motion being produced by the enormous heating effect of the discharge. The result is that the particles of the gas which at any moment form the path of a discharge are continually displaced (particularly in a discharge through a poor vacuum), and since every successive discharge prefers the particles through which the preceding discharge passed (for reasons given above) it follows that a sort of rotary motion is set up in the various parts of the discharge.

An additional evidence in favor of a translational motion along the paths of the streamers is furnished by the fact that

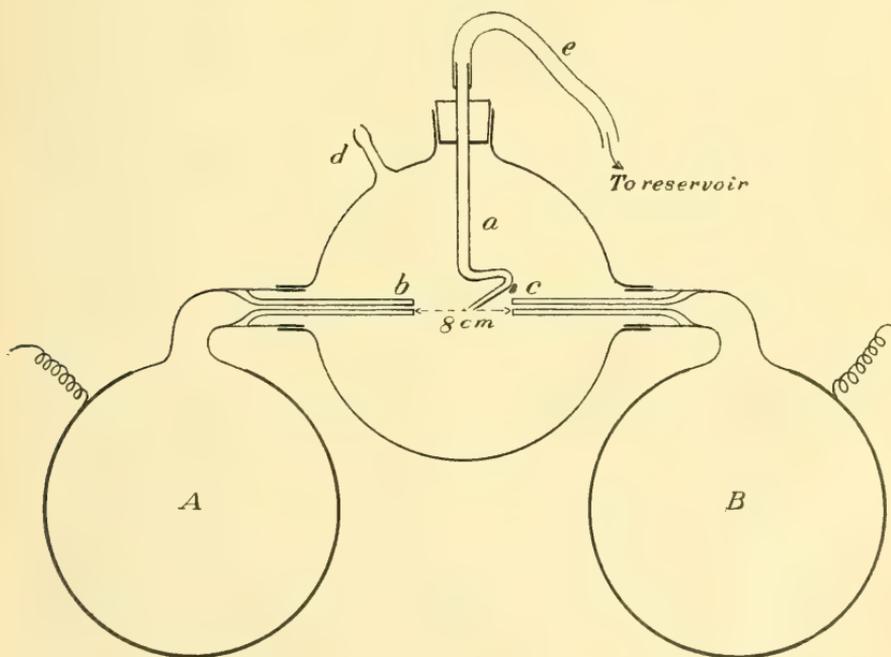
all along the inside surface of the large glass bulb, which is below the tinfoil coating, there is a hazy luminosity which increases with the increase of the discharge, and which to all appearances is due to an accumulation of incandescent gas molecules which had impinged against and were reflected by the surface of the bulb.

If the inside end of the exhaust tube *e*, fig. 10, is lowered, so that it reaches the region of the discharge it is observed that from time to time the incandescent gas shoots through this tube toward the stop-cock way out of the bulb.

EFFECT OF A BLAST ON A DISCHARGE STREAMERS.

Granting that there is a translational motion along the path of the streamer it follows that a rectilinear streamer may be transformed into a curved one by imparting to the gas in each part of its path a component velocity perpendicular to its original velocity. This inference was confirmed by the following experiment :

*Fig 11*



Two bulbs A B (fig. 11) coated with tinfoil on the outside (the electrodes of the system) communicated with a reservoir (which I call the principal reservoir) by means of glass tubes

*b c* of narrow bore. An L-shaped tube *a* with a small orifice was fitted by means of a rubber stopper into the neck of the reservoir. By means of this tube and the tube *d* of the principal reservoir communicated with two other reservoirs, which I call the external reservoirs.

The external reservoir connected with *d* communicated with a mercury pump. When the exhaustion had reached the point at which a steady rectilinear discharge could be forced from *b* to *c*, a stopcock connecting *d* to its external reservoir was shut off and the exhaustion continued until a good vacuum was obtained in the external reservoir *d*. The discharge was then started. It was a perfectly steady, narrow, rectilinear column of crimson luminosity, surrounded by a phosphorescent ellipsoidal column. But as soon as the above mentioned stopcock was turned on, the blast coming from the orifice *a* played up the column and the rectilinear path became curved at the point where the blast was acting. The discharge acted as if it bent around to get out of the way of the blast. The observation that the effect of the blast upon the phosphorescent column was incomparably stronger than upon the crimson column needs no comment. The weaker the discharge the stronger is the effect of the blast, and *vice versa*. The effect of a blast upon the oscillatory spark discharge of a powerful Leyden jar battery is not perceptible.

In discharges through very poor vacua the heating effect is very unequally distributed throughout the vacuum jar. The temperature at certain points is enormously higher than at others. The result is that a very violent motion of the gas is set up, which motion may sometimes, on account of the effects pointed out in the last experiment, produce streamers of double curvature.

During an experiment with the apparatus given in fig. 10, which I performed on February 8th, 1892, before the astronomical section of the New York Academy of Sciences, a leak occurred so that the vacuum was exceedingly poor by the time I was ready to start the discharge. Finding that the discharge gave no sign of starting, I risked turning the whole power of the 10 h. p. alternator on the induction coil. Long sparks shot immediately from almost every point of the edge of the tinfoil. The discharge between the brass sphere and the tinfoil looked like a black-faced Medusa with fiery serpents dancing all around her head. On repeating this experiment I found that in very poor vacua the discharge streamers very often assume the form of spirals of very long pitch.

All these phenomena suggested to my mind a very strong similarity between the streamers of an electrical discharge

through poor vacua and those of the solar corona, and for the purpose of pointing out this similarity to others otherwise than by verbal description, only, I resolved to photograph these discharges under conditions similar to those under which the solar corona is observed. Photographs 1, 2, 3, 4, 5, 6 are the result.

The discharges were obtained with the apparatus given in fig. 10. The only additions were that a circular tinfoil disc was pasted on the outside of the large bulb, in the line of sight between the camera and the brass sphere *a*. The diameter of this disc was about equal to that of the brass sphere. Also, the inside surface of the large bulb which formed the background of the brass sphere was blackened by means of camphor smoke to avoid reflections. The discharge in fig. 1 is that of a good vacuum (about 2<sup>mm</sup>), the succeeding ones represent discharges in poorer vacua, the pressures varying between 2<sup>mm</sup> and 60<sup>mm</sup>.

The bearing which these experimental results may have upon the theory of the solar corona I prefer to leave to others to decide. That they may prove a suggestive guide in the study of solar phenomena seems not unreasonable to expect.

I am greatly indebted to Professor John K. Rees for the interest which he took in my work, and to Mr. Mann of the Columbia College Observatory, for the very valuable service which he rendered me in photographing the coronoidal discharges.

Department of Electrical Engineering, Columbia College,  
March 31st, 1892.

ART. LX.—*On the Rubidium and Potassium Trihalides*;  
by H. L. WELLS and H. L. WHEELER. *With their Crystallography*; by S. L. PENFIELD.

THE discovery of a series of caesium trihalides\* has led the writers to investigate the analogous rubidium and potassium compounds. The following table gives a list of the bodies which we have been able to prepare, together with the caesium series for comparison. The compound KI. I<sub>2</sub> had been previously prepared by Johnson.†

\* On a Series of Caesium Trihalides, by H. L. Wells; including their Crystallography, by S. L. Penfield. This Journal, III, xliii, 17.

† J. Chem. Soc., 1877, 249.

CsI. I <sub>2</sub>	RbI. I <sub>2</sub>	KI. I <sub>2</sub>
CsBr. I <sub>2</sub>	-----	-----
CsBr. BrI	RbBr. BrI	KBr. BrI
CsCl. BrI	RbCl. BrI	-----
CsCl. ClI	RbCl. ClI	KCl. ClI
CsBr. Br <sub>2</sub>	RbBr. Br <sub>2</sub>	-----
CsCl. Br <sub>2</sub>	RbCl. Br <sub>2</sub>	-----
CsCl. ClBr	RbCl. ClBr	-----

It is to be noticed that there is but one member lacking in the rubidium series to make it as complete as that of caesium. We have repeatedly tried to prepare this compound, RbBr. I<sub>2</sub>, using alcoholic solutions of varying strength and great concentration at low temperatures, but with no success. The failure to make this body doubtless depends upon the comparative instability of the rubidium series. We have even attempted to prepare RbCl. I<sub>2</sub> and RbCl. Cl<sub>2</sub>, corresponding to which no caesium compounds could be made, but, as was anticipated, these efforts were entirely without success.

In the potassium series only those bodies could be prepared which correspond to the more stable caesium and rubidium compounds. They show a great decrease in stability in comparison with the rubidium compounds. A product was obtained at a very low temperature, which was probably KBr. Br<sub>2</sub>, but we did not make a satisfactory analysis of it.

We have attempted to prepare a number of sodium and lithium trihalides. There is no doubt that some of them exist, but they are so extremely soluble and unstable that we have abandoned work in this direction.

*Method of Preparation.*—The rubidium and potassium compounds are made, like the caesium series, by dissolving a normal halide with the proper halogen or halogens in water with the aid of heat and cooling to crystallization. The members of the rubidium series, being very soluble, require very concentrated solutions for their preparation. The potassium compounds, being still more soluble, require the greatest possible degree of concentration and are usually best obtained by exposing the solutions for a considerable time to a winter temperature, evaporation in the desiccator being sometimes also necessary.

*Color.*—The colors of the rubidium and potassium compounds are very similar to those of the corresponding members of the caesium series, but since they usually form larger crystals their apparent color is generally somewhat darker. They vary in color from brilliant black in RbI. I<sub>2</sub> and KI. I<sub>2</sub>, through various shades of yellowish-red and orange to bright yellow in the compound RbCl. ClBr. In all the compounds

that have been prepared the color becomes lighter as the sum of the atomic weights of the three halogen atoms decreases.

*Stability.*—It has been found by experiment that the potassium trihalides are much less stable on exposure to the air than the corresponding rubidium compounds, while these in turn are less stable than the members of the caesium series. The same relative stability of the three series is shown by the temperatures at which they are completely decomposed by rapid heating as given below :

*Approximate temperature of whitening.*

CsI. I <sub>2</sub> 330°	RbI. I <sub>2</sub> 270°	KI. I <sub>2</sub> 225°
CsBr. BrI 320°	RbBr. BrI 265°	KBr. BrI 180°
CsCl. ClI 290°	RbCl. ClI 265°	KCl. ClI 215°
CsCl. BrI 290°	RbCl. BrI 200°	-----
CsBr. Br <sub>2</sub> 160°	RbBr. Br <sub>2</sub> 140°	-----
CsCl. ClBr 150°	RbCl. ClBr 110°	-----
CsCl. Br <sub>2</sub> 150°	RbCl. Br <sub>2</sub> 80°	-----

*Fusibility.*—The melting-points of the analogous compounds become lower from caesium to potassium. In the open capillary tube RbI. I<sub>2</sub> melts at 194° and RbCl. ClI at 208°, while all the other rubidium compounds whiten without melting. The potassium compounds give practically the same melting-points in open as in sealed tubes. The following table gives the approximate melting-points in sealed tubes :

CsI. I <sub>2</sub> 201°–208°	RbI. I <sub>2</sub> 190°	KI. I <sub>2</sub> 38°*
CsBr. BrI 243°–248°	RbBr. BrI 225°	KBr. BrI 60°
CsCl. ClI 225°–230°	RbCl. ClI 180°–200°	KCl. ClI 60°
CsCl. BrI 225°–235°	RbCl. BrI 205°	-----
CsBr. Br <sub>2</sub> 180°	RbBr. Br <sub>2</sub> whitens	-----
CsCl. ClBr 205°	RbCl. ClBr whitens	-----
CsCl. Br <sub>2</sub> 191°	RbCl. Br <sub>2</sub> 76° ?	-----

*Behavior with Solvents.*—The extreme solubility of the rubidium and potassium trihalides in water has already been referred to, and it has been pointed out that the members of the potassium series are the most soluble. The rubidium compounds which contain iodine can be recrystallized from water without difficulty. These four bodies containing rubidium and iodine are sufficiently stable to be soluble in alcohol, while the remaining rubidium compounds, as well as all the potassium compounds, are more or less readily decomposed by alcohol with the separation of normal halides. Ether decomposes all the rubidium and potassium compounds, leaving normal halides undissolved.

\* Johnson gives 45° for the melting-point of this compound (l. c.)

## Crystallography.

The rubidium trihalides crystallize in the orthorhombic system and are isomorphous with the corresponding caesium compounds, showing a close similarity both in crystalline habit and in axial ratios.

The forms which have been observed are

$a$ , 100, $i\bar{i}$	$\alpha$ , 011, $1\bar{1}$
$b$ , 010, $i\bar{i}$	$f$ , 021, $2\bar{1}$
$c$ , 001, $O$	$e$ , 102, $\frac{1}{2}\bar{1}$
$m$ , 110, $I$	$p$ , 111, $1$ .

With the exception of the pyramid  $p$ , which was observed as a small face only on  $\text{RbI} \cdot \text{I}_2$ , these are the same as were observed on the caesium trihalides, while the brachydome  $g$ ,  $012, \frac{1}{2}\bar{1}$  which was found only on  $\text{CsI} \cdot \text{I}_2$ , was not observed on any of the rubidium compounds.

Of the three potassium trihalides, which were examined, only one,  $\text{KBr} \cdot \text{BrI}$ , was orthorhombic, like the caesium and rubidium compounds. The others,  $\text{KI} \cdot \text{I}_2$  and  $\text{KCl} \cdot \text{ClI}$ , are monoclinic, but they can be referred to axes which are similar to those of the orthorhombic series.

The cleavage of the rubidium trihalides is perfect parallel to  $c$ , less perfect parallel to  $a$ ; neither is easily produced. The crystals are very brittle and usually break with a conchoidal fracture. The potassium trihalides are exceedingly brittle and no cleavage was observed. The optical properties were not studied, owing to the difficulty of preparing orientated sections.

In the following table the axial ratios of all of the alkali-metal trihalides are given, arranged as in the caesium paper. In the table of angles, those which were chosen as fundamental are marked by an asterisk.

	I.	Series with iodine.	II.
	$a : b : c$		$a : b : c$
$\left\{ \begin{array}{l} \text{CsI} \cdot \text{I}_2 \\ \text{RbI} \cdot \text{I}_2 \\ \text{KI} \cdot \text{I}_2 \end{array} \right.$	0·6824 : 1 : 1·1051		1 : 1·4655 : 1·6196
	0·6858 : 1 : 1·1234		1 : 1·4582 : 1·6381
	0·7065 : 1 : ----		1 : 1·4154
	} Monoclinic, $\alpha = 86^\circ 47\frac{1}{2}'$		$\alpha = 86^\circ 47\frac{1}{2}'$
$\text{CsBr} \cdot \text{I}_2$	0·6916 : 1 : 1·1419		1 : 1·4460 : 1·6511
$\left\{ \begin{array}{l} \text{CsBr} \cdot \text{BrI} \\ \text{RbBr} \cdot \text{BrI} \end{array} \right.$	0·7203 : 1 : 1·1667		1 : 1·3882 : 1·6196
	0·7130 : 1 : 1·1640		1 : 1·4025 : 1·6325
$\left\{ \begin{array}{l} \text{KBr} \cdot \text{BrI} \\ \text{CsCl} \cdot \text{BrI} \end{array} \right.$	0·7158 : 1 : 1·1691		1 : 1·3970 : 1·6333
	0·7230 : 1 : 1·1760		1 : 1·3831 : 1·6268
$\left\{ \begin{array}{l} \text{RbCl} \cdot \text{BrI} \\ \text{CsCl} \cdot \text{ClI} \end{array} \right.$	0·7271 : 1 : 1·1745		1 : 1·3753 : 1·6153
	0·7373 : 1 : 1·1920		1 : 1·3563 : 1·6167
$\left\{ \begin{array}{l} \text{RbCl} \cdot \text{ClI} \\ \text{KCl} \cdot \text{ClI} \end{array} \right.$	0·7341 : 1 : 1·1963		1 : 1·3622 : 1·6296
	0·7335 : 1 : 1·2204		1 : 1·3633 : 1·6638
	} Monoclinic, $\alpha = 83^\circ 20'$		$\alpha = 83^\circ 20'$

Series without iodine.

{ CsBr. Br <sub>2</sub>	0·6873 : 1 : 1·0581	1 : 1·4550 : 1·5395
{ RbBr. Br <sub>2</sub>	0·6952 : 1 : 1·1139	1 : 1·4384 : 1·6023
{ CsCl. Br <sub>2</sub>	0·699 : 1 : ----	1 : 1·430 : ----
{ RbCl. Br <sub>2</sub>	0·70 : 1 : 1·1269	1 : 1·43 : 1·61
{ CsCl. ClBr	0·7186 : 1 : 1·1237	1 : 1·3917 : 1·5638
{ RbCl. ClBr	0·7146 : 1 : 1·1430	1 : 1·3994 : 1·5995

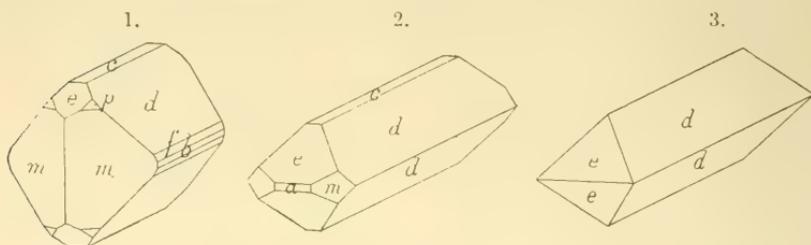
	$m \wedge m, 110 \wedge \bar{1}\bar{1}0$	$d \wedge d, 011 \wedge 0\bar{1}1$	$e \wedge e, 102 \wedge \bar{1}02$
RbI. I <sub>2</sub>	*68° 53'	*96° 39'	78° 38'
KI. I <sub>2</sub>	*70 34		
RbBr. BrI	70 58	*98 40	*78 27
KBr. BrI	71 12	*98 55	78 28
RbCl. BrI	72 2	*99 10½	*77 51
RbCl. ClI	72 34	*100 13	*78 21
KCl. ClI	72 54		*79 8
RbBr. Br <sub>2</sub>	*69 37	*96 10	77 24
RbCl. Br <sub>2</sub>	*70 approx.	*96 58	76 approx.
RbCl. ClBr	71 6	*97 38	*77 18

A comparison of the axial ratios of the trihalides shows that the replacement of caesium by rubidium, and in one case by potassium, has little or no effect on the form, while in two of the compounds potassium causes a change in symmetry without much change in the axes. It is evident that the rubidium salts like those of caesium may be arranged in two symmetrical series, one with and the other without iodine, in which the ratio of two axes remains nearly constant throughout while the third varies, and the conclusions which were arrived at in our previous paper concerning the constitution of the caesium trihalides, are confirmed by the rubidium compounds.

The rubidium trihalides have a strong tendency to crystallize and the solubility is such that, from solutions of not over 50 c.c. in volume, large and magnificent crystals, several centimeters in length, can readily be obtained. The size of the crystals seems often dependent only upon the volume of the solution and the size of the vessel containing it. Many of the large crystals are complex, being built up of smaller ones in parallel position. Some of the crystallizations were as beautiful as any that we have ever seen.

The rubidium trihalides containing iodine were measured at ordinary temperatures; those without iodine and the potassium trihalides at about 0° C. It was found that the stability of the compounds increased very rapidly with a diminution in temperature and, by working in the cold, no difficulty was experienced in making accurate measurements of the more unstable salts. It is not considered necessary to give with each trihalide

a table of measured and calculated angles, but in all cases, where a series of accurate measurements were obtained, they agreed closely with the calculated.



*RbI. I<sub>2</sub>*. The forms *b*, *c*, *m*, *d*, *f*, *e* and *p* were observed. Of these *f* and *p* were always small and frequently wanting. The habit is shown in fig. 1.

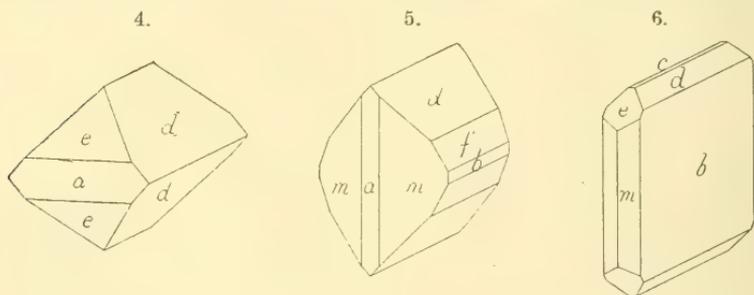
*RbBr. BrI*. The forms of *a*, *c*, *m*, *d* and *e* were observed. The habit is shown in fig. 2.

*RbCl. BrI*. The forms *a*, *d* and *e* were observed. The pinacoid *a* is usually wanting and the simple habit shown in fig. 3, prevails.

*RbCl. ClI*. The forms *a*, *d* and *e* were observed. The habit is shown in fig. 4.

*RbBr. Br<sub>2</sub>*. The forms *a*, *b*, *m*, *d* and *f* were observed. The habit is shown in fig. 5.

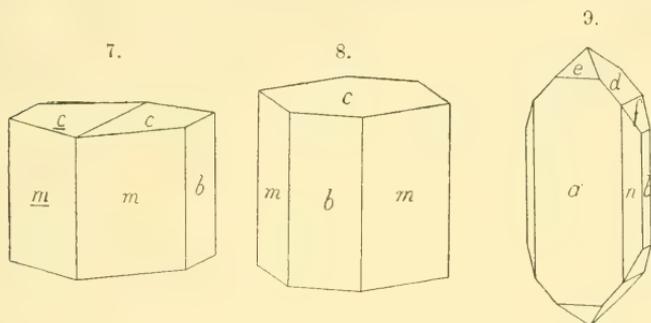
*RbCl. Br<sub>2</sub>*. The forms *b*, *c*, *m*, *d* and *e* were observed. The habit is shown in fig. 6. The tendency of this salt is to crystallize in small scales; it is also the most unstable of the rubidium



series, so that we considered it fortunate that we were able to make out the axial ratio. The only faces which yielded good reflections were *b* and *d*, which established accurately the relation between the  $\bar{b}$  and  $\bar{c}$  axes, while only approximate measurements were obtained from the other faces.

*RbCl. ClBr*. The forms *a*, *b*, *m*, *d* and *e* were observed. The habit is like fig. 2, except that *c* is wanting.

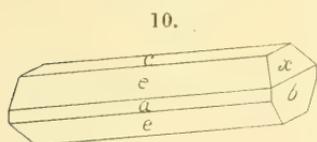
*KI. I<sub>2</sub>*. This occurs in very simple monoclinic crystals. If the solution is cooled slowly it forms in stout prisms, but by rapid cooling a net work of fine needles is obtained. In order to make this salt and the monoclinic KCl. CII conform to the position which has been adopted for the orthorhombic trihalides it is necessary to deviate from the ordinary custom and make the clino-axis slope from right to left instead of from back to front. The faces are taken as *b*, 010, *i*-*i*; *c*, 001, *O* and *m*, 110, *I*. The crystals are not sufficiently modified to determine more than two axes, but taking as fundamental measurements,  $b \wedge m, 010 \wedge 110 = 54^\circ 43'$  and  $e \wedge c$  (reëntrant angle of twin crystal) =  $6^\circ 25'$  the following axial ratio is obtained  $a : b = .7065 : 1$ ;  $a = 0\bar{1}0 \wedge 001 = 86^\circ 47\frac{1}{2}'$ . The angle  $m \wedge c, 110 \wedge 001$ , was measured  $91^\circ 55'$  and  $91^\circ 50'$ , calculated  $91^\circ 51'$ . Fig. 7 represents a twin crystal in the above position. Fig. 8 represents a simple crystal in the ordinary monoclinic position,



with *a* as the clino axis. The axial ratio for this position is,  $a : b = 1.4154 : 1$ ;  $\beta = 86^\circ 47\frac{1}{2}'$ .

*KBr. BrI*. The forms *a*, *b*, *n*, *d*, *f* and *e* were observed. The habit is shown in fig. 9. This salt differs from all of the other alkali-metal trihalides in having the brachy prism *n*, 120, *i*- $\bar{2}$ , instead of the unit prism *m*. The fundamental measurements were  $a \wedge n, 100 \wedge 120 = 55^\circ 4'$  and  $d \wedge d, 011 \wedge 0\bar{1}1, = 98^\circ 55'$ .

*KCl. CII*. This crystallizes in long needles belonging to the monoclinic system, fig. 10. Taking *b* as the clino axis, the forms are *a*, 100, *i*-*i*; *b*, 010, *i*-*i*; *c*, 001, *O*; *x*, 032,  $\frac{3}{2}\bar{i}$ , and *e*, 102,  $\frac{1}{2}\bar{i}$ . The measurements taken as fundamental are  $c \wedge b, 001 \wedge 010 = 96^\circ 40'$ ,  $e \wedge e, 102 \wedge \bar{1}02 = 79^\circ 8'$ , and  $c \wedge x, 001 \wedge 032 = 66^\circ 35'$  from which the following axial ratio was calculated,  $a : b : c = .7335 : 1 : 1.2204$ ,



$a = 83^\circ 20'$ . If taken in the ordinary monoclinic position with  $e$  as the prism 110 and  $x$  as the orthodome  $\bar{1}01$ , the axial ratio from the above measurements becomes  $a : \bar{b} : c = .8319 : 1 : .4544$   
 $\beta = 83^\circ 20'$ .

*Method of Analysis.*

The methods used for the analyses of the potassium and rubidium trihalides were exactly the same as those mentioned in the article on caesium trihalides.

The crystals were prepared for analysis by pressing between papers and at the same time crushing them somewhat. In some cases, where the bodies were very easily decomposed, this was done in cold weather out of doors, but even with this precaution it was not possible to dry them very thoroughly or to avoid a considerable amount of decomposition.

*RbI. I<sub>2</sub>.*

This body can be prepared by dissolving 55 g. of rubidium iodide in enough water to make a solution of 50 c.c., adding 60 g. of iodine, warming until solution takes place and cooling to ordinary temperature. A mass of large crystals in parallel position, forming steps, is usually formed.

	Analysis gave		Calculated for RbI. I <sub>2</sub> .
Rubidium .....	18.32	18.32	18.33
Iodine .....	81.07	---	81.67

A specific gravity determination, made in the mother-liquor at  $22^\circ$  gave the number 4.03. This cannot be considered very exact on account of the difficulty of obtaining the mother-liquor in such a condition that it neither dissolves nor deposits the substance. A sample of mother-liquor, of specific gravity 2.19, was found to contain 1.61 g. of RbI. I<sub>2</sub> in 1 c.c. The compound therefore dissolves in about one third its weight of water at  $22^\circ$ . It is interesting to notice here that under nearly the same conditions, the corresponding caesium compound, CsI. I<sub>2</sub>, requires more than one hundred parts of water to dissolve it. It is expected that this great difference in solubility will form the basis of a useful method for separating the two metals.

*RbBr. BrI.*

This compound can be readily made by dissolving, with the aid of heat, 30 g. of iodine and 20 g. of bromine in a saturated aqueous solution of 40 g. of rubidium bromide and cooling. The facility with which this body crystallizes is remarkable. The large crystals have a color and luster much like the mineral pyrrargyrite, "ruby-silver."

	Analysis gave	Calculated for RbBr . BrI.
Rubidium-----	22·79	22·95
Bromine-----	45·19	42·95
Iodine-----	31·11	34·10

An approximate specific gravity determination, made with the mother-liquor, gave the number 3·84. An analysis of the mother-liquor showed that it contained about 44 per cent of RbBr . BrI. The mother-liquor of the corresponding caesium compound contained only 4·45 per cent of CsBr . BrI.

*Rb Cl . Br I.*

This body can be made by adding 27 g. of bromine and 42 g. of iodine to a saturated aqueous solution of 40 g. of rubidium chloride, warming until all is in solution and cooling. It forms magnificent crystals which can be readily recrystallized from water. Unlike the corresponding caesium compound, it does not change its composition by recrystallization, hence it is probable that it is a true chemical compound and not a mixture of the isomorphous bodies RbBr . BrI and RbCl . ClI.

	Analysis gave,		Calculated
	Original crystals.	6th recryst- tallization.	for RbCl . BrI.
Rubidium-----	26·67	27·34	26·66
Chlorine-----	10·65	----	10·82
Bromine-----	24·89	----	24·39
Iodine-----	38·13	----	38·72

*Rb Cl . Cl I.*

A convenient method for preparing this compound is to pass chlorine into a warm, concentrated solution of rubidium chloride, containing the calculated amount of iodine, until the iodine is just dissolved. If too much chlorine is used, the compound RbCl<sub>2</sub>I is formed, which we shall describe in a future article. It is best to stop adding chlorine while the solution is still colored red by iodine. On cooling the liquid the compound separates, usually in large flat groups of parallel crystals.

	Analysis gave	Calculated for RbCl . ClI.
Rubidium-----	29·85	30·15
Chlorine-----	24·68	25·04
Iodine-----	44·68	44·79

*Rb Br . Br<sub>2</sub>.*

This can be prepared by adding 49 g. of bromine to 45 c.c. of an aqueous solution containing 50 g. of rubidium bromide, warming gently until bromine dissolves, then cooling. It usually forms a mass of large, brilliant, red crystals in parallel position.

	Analysis gave	Calculated for RbBr. Br <sub>2</sub> .
Rubidium .....	25.86	26.26
Bromine .....	73.09	73.73

*RbCl. Br<sub>2</sub>.*

This body is prepared by adding bromine to a warm, saturated solution of rubidium chloride until some bromine remains undissolved and cooling to a low temperature. The compound crystallizes well, but it is the most unstable of the seven rubidium trihalides that have been prepared, and, although it was not fully dried, the sample used for analysis suffered a considerable amount of decomposition.

	Analysis gave	Calculated for RbCl. Br <sub>2</sub> .
Rubidium .....	32.57	30.42
Chlorine .....	14.46	12.63
Bromine .....	49.04	56.93

In one attempt to prepare this trihalide too much water was used and it was necessary to evaporate off the bromine and concentrate the solution. This operation was repeated several times, after fresh additions of bromine, before the proper conditions were arrived at, and the product finally obtained was contaminated with RbBr. Br<sub>2</sub>, as is shown by the following analyses :

	Found.	Calculated for RbCl. Br <sub>2</sub> .	Calculated for RbBr. Br <sub>2</sub> .
Rubidium .....	28.78	30.42	26.26
Chlorine .....	7.66	12.63	0.
Bromine .....	60.92	56.93	73.73

We have found by experiment that rubidium chloride is partly changed to bromide by evaporating an aqueous solution of it with bromine.\* This explains the formation of the RbBr. Br<sub>2</sub>.

*RbCl. ClBr.*

This compound can be prepared by adding 33 g. of bromine to a saturated solution of 50 g. of rubidium chloride, passing chlorine to saturation into the slightly warmed solution, and cooling to a low temperature. The substance is usually deposited in the form of very large, light yellow prisms.

	Analysis gave		Calculated for RbCl. ClBr.
Rubidium .....	35.42	35.41	36.15
Chlorine .....	29.27	28.96	30.02
Bromine .....	31.56	31.39	33.82

\* This is in accordance with the results of Potilzin referred to by Mendelejeff in his "Grundlagen der Chemie" (German ed., 1891) p. 538.

*KI. I<sub>2</sub>.*

This body can be made in a few hours by dissolving the theoretical amount of iodine in a hot saturated aqueous solution of potassium iodide and exposing the resulting solution to a winter temperature. It can also be made as Johnson states\* by evaporating the solution in a desiccator for a long time. Johnson states that he always obtained a crop of potassium iodide before the tri-iodide separated. We have never obtained such a product, undoubtedly because we have invariably used a sufficient amount of iodine.

It was not considered necessary to make a new analysis of this body.

*KBr. BrI.*

This compound can be prepared by making a very concentrated, warm solution of the calculated amounts of potassium bromide, bromine and iodine, and exposing it for some time to a low temperature. The product used for analysis was well crystallized, but it suffered rapid decomposition on exposure to the air.

	Analysis gave		Calculated for KBr. BrI.
Potassium.....	12·21	-----	11·99
Bromine.....	51·25	51·61	49·06
Iodine.....	30·42	29·11	38·94

*KCl. ClI.*

To prepare this substance, chlorine is passed into a warm mixture of calculated quantities of potassium chloride and iodine in the presence of an amount of water insufficient to dissolve the potassium chloride even when hot. The stream of chlorine is stopped as soon as the iodine has been converted into the monochloride, for otherwise Filhol's well-known compound  $KCl.Cl_2I$  will be formed. Everything is then dissolved by warming and cautiously adding water if necessary and the solution is exposed to a low winter-temperature. The crystals are very unstable, but apparently not quite as much so as  $KBr.BrI$ .

	Analysis gave		Calculated for KCl. ClI.
Potassium.....	15·29	15·35	16·49
Chlorine.....	27·53	27·50	29·94
Iodine.....	50·37	50·12	53·56

*Other Double-halides.*

The double-salt  $CsI.AgI$  was described in connection with the caesium trihalides as being isomorphous with them as far

\* Loc. cit.

as the crystals could be measured. Much work has since been done, without avail, in the hope of obtaining better crystals of this compound. Unsuccessful efforts have been made to obtain measurable crystals of all the corresponding silver double halides (except the fluorides) with caesium, rubidium and potassium. Two or three of these compounds had already been described and it is probable that we could have proven the existence of all the rest of them, but the poorly crystallized products obtained had no interest in this connection and were not analyzed. Repeated efforts also failed to produce from potassium iodide and cuprous iodide a double salt that could be measured.

#### *Theoretical.*

Arguments were given in the article on the caesium series which have led us to regard the trihalides as belonging to the class of bodies called double halides. We have indicated this view in the present article by using the usual formulæ for such compounds.

The well-known idea of a linking group of two halogen atoms as an explanation of the structure of double halides was advocated for the caesium trihalides, and, since the rubidium and potassium compounds are entirely analogous, it is unnecessary to give their structural formulæ here. We believe, however, that the trihalides throw some light upon the constitution of the diatomic linking group. Remsen says,\* "I cannot see that at present we have any evidence which justifies us in the use of the expression  $-\text{Cl}=\text{Cl}-$  rather than  $-\text{Cl}-\text{Cl}-$ ." If, as we believe, the structure of rubidium tri-iodide is expressed by the formula  $\text{Rb}-(\text{II})-\text{I}$ , the structure of the linking group probably cannot be  $-\text{I}-\text{I}-$ ; for in that case a single bivalent iodine atom could do the linking as well as a group of two, and we should expect the existence of di-iodides, no evidence of which, or of any other dihalide has been found in the course of an elaborate investigation of the alkali-metal polyhalides. Moreover, with the assumption of bivalent halogen atoms, there would be no difficulty in supposing four halogens to be linked together and the existence of tetrahalides would be anticipated. Our investigations, however, have shown the existence of only tri- and pentahalides.† The double linking seems therefore the more probable of the two forms mentioned by Remsen, but it may be added that any union weaker or stronger than the others in the molecule, and

\* Am. Chem. Jour., xi, 312.

† The pentahalides will be described in a future article.

*different from them*, would also explain the non-existence of dihalides and tetrahalides.

Assuming that there is a linking group of two halogen atoms in the trihalides, the view advanced, from a consideration of the caesium compounds, that the most stable bodies have identical atoms in this group is confirmed by the study of the rubidium and potassium analogues. For, on this assumption, all the potassium compounds which could be made contain a group of identical atoms, while in the missing rubidium compound they are dissimilar.

Sheffield Scientific School, March, 1892.

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ART. LXI.—*On the Clinton Iron Ore*; by C. H. SMYTH, JR.

RECENT articles discussing the minute structure and the mode of formation of the Clinton iron ore have suggested the publication of certain observations made upon this peculiar deposit, particularly as it appears at the type locality, Clinton, N. Y.

At this point there are three beds of ore, associated with green and gray shales and thin-bedded sandstones sometimes so coarse as to become conglomerates. The character of the sediments and their rapid changes both vertically and laterally, the presence of ripple marks and mud cracks throughout the series, and the abundant fossils, all indicate deposition in shallow water with constantly shifting conditions. The dip of the strata toward the southwest is so slight as to be hardly noticeable at the exposures.

The upper bed of ore, locally known as "red flux," varies in thickness from four to six feet, and appears to be made up of pebbles and irregular fragments of organisms coated with ferric oxide, cemented by calcite. Twenty-five feet below this is a two foot bed of workable ore, and one to two feet lower still, the third bed.

The ore in both of the lower beds is wholly made up of small round grains, usually flattened to lenticular shape, but often nearly spherical, and averaging perhaps 1<sup>mm</sup> in diameter. The entire mass thus presents, aside from its color, the appearance of an oölitic limestone.

After studying numerous thin sections, from various localities, Dr. A. F. Foerste\* has concluded that the oölitic appearance of the Clinton ore is due to its being made up of rounded fragments of Bryozoa in which the lime is replaced by iron.

\* On the Clinton Oölitic Iron Ores; this Journal, III, xli, p. 28.

He states that "in no case, however, was anything noticed leading to the opinion that concretionary segregation of iron had taken place either around the bryozoan fragments or otherwise." Had Dr. Foerste's observations extended to the two lower beds of ore at Clinton, he would have been led to modify this statement, for in these the concretionary structure is very marked. It is unnecessary to employ the microscope to observe this. If the ore be coarsely broken and the separated spherules placed on a steel plate and tapped lightly with a small hammer, each spherule will break into a series of concentric shells, and finally a nucleus will be reached, which is nearly always a rounded fragment of quartz. In thin sections, owing to the opacity of the material, this structure may be easily overlooked, unless the section is ground extremely thin (a difficult matter with this ore), or is examined by reflected, as well as transmitted, light. Thin sections show well the character of the quartz around which the iron is segregated. The fragments are all well rounded, having been subjected to the attrition of the waves along a coast line. Inclusions of liquid and gas are very abundant, besides long needles of rutile and scales of micaceous hematite. The derivation of the quartz from granitoid or schistose rocks is evident.

On treating the spherules with hydrochloric acid the iron is dissolved, and there is left a perfect cast of the spherule in silica, containing a little argillaceous material. This siliceous cast or skeleton of the spherule is, of course, transparent and in it the concentric structure can be seen more perfectly than in thin sections. The number of layers is seen to be large, often ten or more. With polarized light the silica appears sometimes to be amorphous, but usually gives aggregate polarization, like that often seen in chalcedony. Thus, the two lower beds of ore at Clinton are truly oölitic, consisting of grains of sand enclosed in concentric shells of intimately associated ferric oxide and silica.

A sample of the Clinton ore from Dodge County, Wis., kindly furnished by Dr. W. H. Hobbs, gives similar results. This ore is an almost incoherent mass of spherules, associated with rocks quite different from those at Clinton, but the spherules have the same concentric structure, and give the same siliceous skeleton with hydrochloric acid. There is one marked difference, however; the quartz nucleus is greatly reduced in size in the Wisconsin oölite, or is more often entirely absent. Samples of Clinton ore from Rochester and Ontario, N. Y., Chattanooga, Tenn., Dade County, Ga., and Birmingham, Ala., have been examined, and though none of these are strictly oölitic in appearance, still, the spherules in varying proportion are scattered through them. Moreover, when the ore consists

chiefly of bryozoan fragments more or less completely replaced by iron, as described by Dr. Foerste, there is often a coating of the fragments with layers of iron associated with silica, precisely as in the oölites.

The treatment of these samples with hydrochloric acid further shows that the lime of the bryozoa has often been replaced not by iron alone, but by iron and silica, for there is left as a residue from the treatment a siliceous cast of each fragment. In most cases, the iron is removed from this by the acid, but in some samples the silica prevents the complete solution of the iron, even with prolonged digestion. Apparently there is an intimate association in the deposition of iron and silica.

The above facts, together with others gathered in the field, seem to have some bearing upon the question of the origin of the Clinton ore. Most of the recent writers on this subject seem to agree that the ore is formed by the replacement of limestone strata by iron derived from the overlying rocks. The iron is taken into solution by circulating meteoric waters containing carbon dioxide and other products of organic decay. This solution coming into contact with limestone, chemical action ensues, the iron is precipitated, and the lime passes away in solution.

While there can be no doubt that many ore bodies have been formed in this way, and among them portions of the Clinton ore, still, several facts lead to the conclusion that other portions of this deposit require a different explanation. Compared with the great extent of Clinton ore, the writer's observations have been so limited as to make it, perhaps, unwise to base upon them any broad generalizations. The following discussion will, therefore, be confined almost entirely to the type locality and such other localities as have been examined in person.

As above stated, the ore at Clinton is associated with undoubted shore deposits, and though all of the rocks are calcareous, there are none that could be called limestones.

During that portion of Silurian time represented by these strata, the region was one of shoal waters or extensive mud-flats. These conditions are favorable for the formation of an iron ore by sedimentation, and it seems unnecessary to bring in the idea of replacement. If the ore represents an oölitic limestone, each spherule has been altered from the outside toward the center. This alteration has been by the replacement of the calcite by silica and iron carbonate. It would seem as though, after the exterior layers were thus altered, they must, to a greater or less extent, protect the interior layers from change, and that there would often be some trace of the original calcite. In no case has this been seen, even in the leanest ores, although

the layers of silica and iron are often so dense and impervious that hydrochloric acid cannot dissolve all of the iron present.

Further, it is difficult to account for the present chemical condition of the ore on the substitution theory. This theory postulates that the iron is taken into solution in the overlying rocks by circulating waters containing organic matter. The iron would thus be brought to the limestone in the form of carbonate and would be precipitated in that form. In highly tilted strata it is easy to see that currents of water coming more directly from the surface, along the dip, might contain oxygen instead of the products of organic decomposition and thus cause the precipitation of the iron as hydrated oxide, or convert to that form a previously precipitated carbonate, as described by Professor Van Hise in his paper on the Marquette ores.\* But when, as in New York State, the strata are horizontal, such an explanation will not suffice. Yet in no case has there been seen anything to indicate that the ore was once a carbonate. If this ore was once a carbonate, what agent has so completely altered it to the peroxide?

The character of the overlying rocks presents another stumbling block in the way of replacement. Both shales and sandstones are very calcareous. It is difficult to understand why meteoric waters should dissolve iron from some calcareous strata and deposit it in others lower down. The two actions are incompatible. As a matter of fact, the waters that soak through these overlying rocks are so heavily charged with carbonate of lime that they deposit it wherever there is an opportunity, and layers of calcite are abundant on outcropping ledges and in small veins. How can such water be the bearer of iron salts that are supposed to be precipitated by lime carbonate at a lower level? There is nothing to indicate that the percolating waters have not always been thus charged with carbonate of lime.

The character and relations of the so-called "bottom tier" are of interest. If it be a substitution product, the iron must have passed through the two-foot bed of rich ore and the one to two feet of shale separating the two beds. This shale is so hard and dense that it would seem almost impervious to water. Any iron-bearing solution which may have passed through this rock must have done so very slowly and the conditions for the complete replacement of calcite were most favorable, and yet there is some five per cent of calcite still present and no indication of replacement. The "bottom tier" ore is quite lean, about thirty per cent iron, but this is due to an increased percentage of silica, rather than of lime. It is, in fact, a fer-

\* C. R. Van Hise: *The Iron Ores of the Marquette District of Michigan*; this Journal, III, xliii, p. 116.

ruginous sandstone, differing from the richer ore in that the grains of sand which form the nuclei of the spherules are much coarser, and the deposit of iron around them correspondingly thinner. The difference in the richness of the ores is not, then, dependent chiefly upon a greater or less amount of water action, but is inherent in the two layers as deposited.

Associated with the ores are many irregular patches and layers, both calcareous and argillaceous, containing a varying proportion of spherules. Though the rock may not contain ten per cent of iron, still the spherules are just as ferruginous as in the purer ore. If they resulted from replacement, they would naturally be only partially changed. If thin sections be prepared from these specimens, it is seen that the spherules are identical with those of the ore, though completely surrounded by pure calcite. How is it possible for an iron bearing solution to pass through this compact calcite until the spherule is reached, and then begin to deposit the iron and replace the calcite? It is not uncommon to see spherules of which the outer layers have partially separated from the core, the space thus formed being filled in by the clear calcite cement.

Such occurrences as these can be explained only by the supposition that the spherules were ferruginous when incorporated into the rock. In samples of this character, iron oxide is also present in the form of flakes or scales scattered through the cement. These scales have sharply defined borders and do not pass gradually into the calcite. If the rock were igneous, the iron oxide would, without doubt, be considered an older constituent than the enclosing calcite, and there seems to be no reason for thinking that this is not equally true in the sedimentary rock. Let the proportion of oörites and scales of iron oxide be increased in these hard layers, or, let the calcareous cement be dissolved out by meteoric waters, and the result will be an ore precisely like the two oölitic beds.

The foregoing facts have led the writer to the conclusion that the oölitic ores at Clinton are not of secondary origin, but were deposited as hydrated peroxide of iron in the shoal waters of wholly, or partially enclosed basins along the coast of the Silurian sea. The intimate association of silica with the iron of the spherules seems to indicate that they were deposited together. Doubtless a greater or less amount of the iron was in suspension rather than in solution, and it seems possible that even in this condition it would take the oölitic form, being cemented in the layers of silica. Plausibility is lent to this idea by the fact that the silica is usually more or less stained by grains of argillaceous material; and occasional

masses of oölite are seen, made up wholly of such material, cemented by silica, and yet with the concentric structure just as perfect as in the iron oölite. This would seem to indicate that it is only necessary to have the silica in solution, in order to form oölites. That the silica has not been substituted for calcite by the action of circulating waters, is indicated by the fact that the spherules are inclosed in calcite showing no sign of alteration.\*

The formation of oölitic iron ores under conditions somewhat similar to those of the Clinton shore is going on in many places at the present time,† and these ores have but to be dehydrated to resemble closely the Clinton ores. There seems to be no doubt that dehydration takes place slowly at ordinary temperature,‡ but even if this be not so, the Clinton ores may easily have been subjected to the comparatively slight rise of temperature necessary for rapid dehydration.

Some years ago Professor H. S. Williams called the writer's attention to a thin layer of oölitic iron ore in Cuba, Allegany Co., N. Y., which is of especial interest in this connection. The ore forms a very thin bed, perhaps an inch or two in thickness, and often entirely wanting, in a series of arenaceous and argillaceous shales of Devonian age. The rocks are of shallow water origin, as stated by Professor Williams,§ and there is not the slightest evidence that the ore was ever an oölitic limestone. In fact, the character of the ore and of the associated rocks plainly indicates that the conditions under which they were formed were most unfavorable for the production of limestone of any kind. The ore was undoubtedly deposited in its present form. This ore differs from the Clinton only in the smaller size of the spherules. The quartz nucleus is not relatively so large and is sometimes absent, but there is the same perfection of concentric structure, and the same silica skeleton left by hydrochloric acid. That the two widely separated ores were formed in the same way seems certain; that they are not derived from preëxisting limestone seems, to the writer, almost equally certain.

Thus far the discussion has been limited to the oölitic ores, as these, perhaps, present the greatest difficulties in the way of accepting the replacement theory. But much that has been said of them applies with equal force to the non-oölitic varieties.

\* See E. H. Barbour and J. Torrey, Jr.: Notes on Microscopic Structure of Oölite with Analyses; this Journal, III, xl, p. 246.

† J. S. Newberry: The Genesis of the Ores of Iron: School of Mines Quarterly, November, 1880.

‡ W. O. Crosby: On the Contrast in Color of the Soils of High and Low Latitudes. American Geologist, viii, p. 72.

§ H. S. Williams: On the Fossil Faunas of the Upper Devonian, the Genesee Section, New York: Bulletin 41, U. S. Geological Survey.

It seems to be generally assumed that if an ore becomes hard and calcareous below drainage level, it must be a result of replacement of a calcareous layer by iron. While this is, doubtless, often true, there are many cases where the evidence is against it. That there has been a replacement of the calcite of various organic forms by iron there is no doubt, for the ore is often largely made up of such casts. But there seems to be good reason for believing that this replacement, in many cases, occurred before the fossils were incorporated into the rocks of which they now form part, or, at least, before the rock was lithified by the calcareous cement. The replacement of bryozoa, etc., is just as complete in the hard, calcareous ores, as in the softer varieties. The completely replaced fragments are often found scattered through, and surrounded by, pure calcite. As in the case of the oölites, how is it possible that the calcite of the fossils could have been replaced by iron, after the fossils had been cemented together in this way? Even assuming the fragments to consist of aragonite, and therefore more readily attacked than the calcite cement, it would be impossible for the ferruginous solution to reach them, completely enclosed as they are in the cement. Many specimens collected not only in New York, but also in Tennessee, Georgia and Alabama illustrate these facts on both a macroscopic and microscopic scale. There seems to be no relation between the richness of the ores and the completeness of replacement of organic forms.

These points are well illustrated by the mode of occurrence of the ore at Ontario, Wayne Co., N. Y. Here there is a bed of ore some two feet thick, capped by six feet of fairly pure limestone with shale partings. All above this has been removed by erosion. The replacement theory supposes the iron to have passed through this limestone, replacing the lower two feet. It is difficult to understand why the upper portion should not cause precipitation as readily as the lower two feet, but its light gray color shows that it has not. This might possibly be explained by assuming that an impervious layer at the bottom checked the water, and thus allowed more time for the reaction. Granting this to be the case, we should expect a gradual transition from the ore to the limestone. But, as a matter of fact, the only sense in which this is true, is that some of the fragments of which the ore is composed are scattered through the lower portion of the limestone; they are just as ferruginous as in the ore below and are inclosed in pure limestone. Thus, there is a mechanical, but in no sense, a chemical transition such as would result from replacement. The contact is exactly similar to that of a limestone and fine conglomerate, the lower portion of the former including some

of the pebbles of the latter. The conclusion seems inevitable that the ore was in its present condition when the limestone was deposited upon it.

If these ores are altered limestones, it is as difficult as with the oölitic variety to account for their complete oxidation.

These facts suggest that the calcareous remains were subject to the action of waters containing iron and silica resulting in a replacement of the calcite, before the fragments were cemented into rock form. Such an action would take place only near shore, and that it was near shore that they were deposited is shown by the fragmental and rounded character of the fossils. This substitution may have taken place partly while the fragments were being rolled about on the bottom, and partly after they were massed together and covered with thin layers of mud or sand. Under these conditions ferrous carbonate formed would be quickly oxidized. Associated with this material would be a varying amount of iron oxide deposited from suspension. The coarser particles would supply the scales seen in the ore, while the finer portions might enter into the replacement, being cemented by the silica. Let such a layer as this be covered by other strata and be cemented by calcite, partly derived from a foreign source and partly from solution and crystallization of unaltered shells, bryozoa, etc., and the result would be the non-oölitic Clinton ore. When an ore formed in this way is elevated and inclined at such an angle that surface water may work down through it, there is, of course, a solution of the calcareous cement while the iron is untouched and as a result the amount of iron is relatively increased. Thus, above drainage level the ore becomes soft, porous, and rich, while below, it remains hard and calcareous. The character of an ore then depends, first, upon the amount of iron originally deposited, and secondly, upon the amount of lime removed by leaching. In many, perhaps in most, cases where the ore is said to run into limestone below drainage level, the limestone is decidedly ferruginous and is, in fact, a lean ore, requiring only the removal of its lime to make it available for working.

Samples taken at the Eureka mine, Oxmoor, Ala., illustrate well this relation. The ore at the surface is soft and porous, while a specimen taken 158 feet down the dip is hard and compact, showing cleavage faces of calcite. Subject the latter sample to the action of water containing carbon dioxide, and the result would be an ore indistinguishable from the surface piece. When the ore is in a horizontal position, as in New York and Wisconsin, and covered by a mass of rocks more or less calcareous, it would seem doubtful if there has been even this relative increase in iron. For by the time surface waters

reach the ore they must be so loaded with lime as to be able to take up little, if any, more. At Clinton, wherever the ore has been broken in any way, this abundance of lime in the waters is shown by a deposit of calcite, filling cracks and cavities.

This idea of replacement of organic forms before they were incorporated into the rocks, or, at least, before the mass of which they form part was buried under any considerable amount of sediment, raises the question, 'Was not the oölitic ore originally calcareous, the spherules being altered in the same way, before consolidation?' While there is nothing to absolutely disprove such a supposition, and further study may lead to its acceptance, it seems, on the whole, rather improbable. In the first place, the conditions seem to have been more favorable for the formation of an iron, than of a lime oölite, and so there is good reason for accepting the simpler and more direct explanation. As before stated, the absence of any traces of calcite in the spherules precludes the idea. Further, the analogy of the Cuba ore suggests direct deposition. In the truly oölitic ores seen by the writer there is a marked absence of fossils, while the non-oölitic types are full of traces of life. This indicates some decided difference in the conditions under which they were deposited. The simplest explanation seems to be, that while the non-oölitic ores formed along shore lines subject to wave and current action by means of which the organic remains were concentrated and brought within the influence of the ferruginous waters, the oölitic ores were deposited in partially or wholly enclosed basins, in which the water was too strongly charged with mineral matter to support much life. As both varieties would often be forming simultaneously quite close together, it is not strange that they show a tendency to grade into each other. The oölitic ores, then, were precipitated as such in shallow basins, while the non-oölitic varieties are a substitution product, but this substitution of iron for lime took place while the organic fragments were being rolled about in the shoal waters, or after they were loosely aggregated in a mass somewhat resembling the coquina of the Florida coast.

These suggestions as to the origin of the Clinton ore, of course, apply only where it is associated with shore deposits. But even with such conditions, it is highly improbable that the explanation will suffice for every case. On the contrary, it seems certain that, with a large amount of ferruginous material brought into sediments forming along several hundred miles of coast, iron deposits would be accumulated by various processes. Probably some beds of Clinton ore were formed by replacement, as ordinarily understood; others by original deposition as outlined above; and still others by a combination of

both processes. The objection has often been raised against the theory of original deposition that it does not account for ores associated with deep sea rocks.\* But why should not the shore and deep sea deposits of ore be formed by entirely different processes? If the drainage waters of any area discharge so much iron into the sea that sediments formed at long distances from shore contain sufficient iron in twenty or thirty feet vertically to form two feet of the ore by concentration, these same drainage waters must deposit great quantities of iron both chemically and mechanically along the shore line. Thus, the accumulation of both shore and deep-sea deposits of iron would go on simultaneously, but the latter would require a secondary concentration to render them of practical value.

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ART. LXII.—*Wilde's Explication of the Secular Variation Phenomenon of Terrestrial Magnetism*; by L. A. BAUER, C. E.

[Read before the Philosophical Society of Washington, Feb. 27, 1892.]

IN 1871 Prof. Hornstein of Prague made known his discovery of a periodic change in the magnetic elements of  $26\frac{1}{3}$  days, almost exactly equal to the synodic rotation of the sun, as deduced from the equatorial sun-spots. It was then said that "this method of discovering the time of rotation of the unseen solid body of the sun by its effects on the magnetic needle was the first installment of the repayment by Magnetism of its debt to Astronomy." And true it was. For three centuries a vast amount of time and money has been spent on terrestrial magnetism. It has engaged the most brilliant minds. Money and industry have not been wanting. Zeal and enthusiasm have not been wanting. The numerous magnetic observatories already established and the vast bulk of observations already accumulated will bear ample witness. We are, however, still only on the threshold of this mighty subject and have not yet learned its very alphabet. "The field of investigation into which we are introduced by the study of terrestrial magnetism is as profound as it is extensive," says Maxwell. "What cause," inquires he, "whether exterior to the earth or in its inner depths, produces such enormous changes in the earth's magnetism, that its magnetic poles move slowly from one part of the globe to another?"

\* J. P. Kimball: Genesis of Iron Ores by Isomorphous and Pseudomorphous Replacement of Limestone. *American Geologist*, viii, p. 352.

When we consider that the intensity of the magnetization of the great globe of the earth is quite comparable with that which we produce with much difficulty in our steel magnets, these immense changes in so large a body force us to conclude that we are not yet acquainted with one of the most powerful agents in nature, the scene of whose activity lies in those inner depths of the earth, to the knowledge of which we have so few means of access." The time is at hand for another Halley, or another Gauss, to put new life into this most fascinating subject and give birth to a new and more productive terrestrial magnetism.

Hornstein's discovery has been abundantly verified since, and now we are to consider an attempt equally as bold as his, for its author believed he had reached such results that he felt able to declare himself thus confidently: "From the various movements of the declination and inclination needles, correlated with each other in time, direction and amount, on different parts of the earth's surface, the theory of a fluid interior may now be considered to be as firmly established as the doctrine of the diurnal rotation of the earth on its axis." If this be true more than one science has become the debtor to terrestrial magnetism.

The experiments upon which this bold declaration was based were announced in a paper read before the Royal Society, June 19, 1890, by Mr. Henry Wilde, F.R.S., entitled "On the Causes of the Phenomena of Terrestrial Magnetism, and on some Electro-Mechanism for exhibiting its Secular Changes in its horizontal and vertical Components." This paper having evidently been well received was followed six months later by another, embodying further investigations, "On the Unsymmetrical Distribution of Terrestrial Magnetism," and on June 11, 1891, still another was read "On the Influence of Temperature upon the Magnetization of Iron and other Substances."

These three papers have now been combined and the pamphlet printed in English, French and German. Owing to the great promise they apparently hold forth and the interesting physical questions involved, they are receiving marked attention at the hands of terrestrial magnetists. In this country a brief description was given it and the claims of the author were set forth in the January number of the American Meteorological Journal, but no attempt whether of verification or discussion made. And on February 3d, 1892, appeared an editorial in the N. Y. Tribune under the caption: "A Scientific Mystery Unravelling." To the writer's knowledge no effort as yet has been made to refute Mr. Wilde's theory. He, having in his possession the means of instituting a comparison between fact and theory and being familiar with the comprehensive investi-

gations of the Coast and Geodetic Survey undertook an examination of Mr. Wilde's paper with the result of being forced to reach a conclusion somewhat at variance with the favorable comments already noted.

Wilde's attempt may be classified as a twofold one: (1.) He seeks to account for and reproduce those great changes in the earth's magnetism taking place with the lapse of time, termed its secular variation. Thus at London, about the year 1657, the magnetic needle pointed exactly north and south. It then marched westward until about the year 1818 when it pointed  $24^{\circ} 38'$  to the west of north. After remaining stationary for a few years, it began to turn backward on its course and march eastward, so that in 1890 it pointed but  $17^{\circ} 26'$  to the west.

(2.) He seeks to account for and reproduce the unsymmetrical distribution of terrestrial magnetism as manifested to day, by which there are at present three well-defined lines in the northern hemisphere where the needle points truly north while there are but two in the southern hemisphere.

The time allotted will only permit me to make brief mention of the second and third papers: and in regard to them it is believed that Mr. Wilde has reached most interesting and valuable results. The purpose of my paper, however, is to consider the first part, viz: the secular variation of terrestrial magnetism, and as time will not allow me to discuss all the results reached by Wilde, I will select those stations where he has actually attempted to *reproduce* the secular variation and upon which certain constants of his theory depend. These stations are: London, Cape of Good Hope, and St. Helena. I will further limit myself by discussing only the secular variation as manifested in their declinations, for only on them do the constants referred to, depend. If we succeed in overthrowing these three cases, we have overthrown Wilde's theory.

Let us see what his theory is. Perhaps we have met with the germ of it before. To avoid the danger of giving a misconception of it, I have thought it best to give his own words as far as possible.

"It is assumed that the ring of cosmical matter, from which the earth was evolved, resolved itself into a spheroid of glowing vapors, similar in constitution to those of the sun in its present condition.

From the experience we have of the cooling of bodies from a state of vapor, and by the law of continuity, the outer portions of the spheroid would, in the course of time pass from the gaseous to the liquid, and thence to the solid condition. As the specific gravity of the principal constituents of the terrestrial globe is less in the solid than in the liquid state, the

earth would then consist of a solid external crust covering a liquid shell, leaving the interior of the globe in its primitive gaseous condition.

It is not necessary for the argument to assign any particular thickness for the solid and liquid spherical shells, although there are reasons for thinking that the thickness is not very considerable, as recent investigations have shown that the elementary substances, at great depths, are of much higher specific gravity than those on which the mean density of the earth has been determined.

The remarkable relations which subsist between terrestrial magnetic disturbances and the period of sun-spot frequency, abundantly show that the solar vapors are highly electro-dynamic. It may consequently be inferred that a spherical mass of incandescent vapors of similar constitution to those in the sun, and enclosed within the solid terrestrial envelope, would also be similarly electro-dynamic.

It is also postulated that the glowing terrestrial spheroid at one period of its history revolved with its axis of rotation at right angles to the plane of its orbit, and the spheroid being symmetrically electro-dynamic, the compass needle would point due north and south on every meridian of its surface. Now, if we further assume that the polar axis of the solid and liquid globe was tilted over about its centre at a definite angle, without affecting the plane of rotation of the internal electro-dynamic sphere of vapor, and if the latter rotated with a somewhat slower motion than the solid external shell, then would all the principal phenomena of terrestrial magnetism be manifested.

It is not necessary to consider the causes which produced the present inclination of the earth's equator to the plane of its orbit, beyond suggesting that it may have been brought about by a disturbance of equilibrium through the rupture of the lunar ring on the transition of that body from the annular to the spherical form."

This is the foundation of his theory. Assuming now that the earth has passed through the following electro-dynamic and electro-magnetic stages, he attempts to reproduce them.

(1.) "The electro-dynamic condition of the terrestrial globe, at a period of its history when the crust, from its high temperature, was non-magnetic, its surface of uniform curvature, and the electro-dynamic polar foci of the internal sphere of vapors inclined at a definite angle from the poles of the earth's axis."

(2.) "The electro-dynamic and electro-magnetic condition of the earth, when its outer crust was uniform in curvature and had cooled down sufficiently to become permanently magnetic,

with dual foci of intensity coincident with the poles of the earth's axis, and separate from the dual polar foci of the internal sphere of vapors."

(3.) "The unsymmetrical distribution of the magnetic elements arising from the unequal curvature and foldings of the earth's crust during its secular cooling, as indicated by the present distribution of land and water on the terrestrial surface."

He then seeks to embody his idea in a mechanism, which he terms a Magnetarium and with it endeavors to demonstrate the correctness of his theory. A brief description of it in its final form is as follows: A plain, geographical globe, 16 inches diameter, had wound round the whole of its surface insulated copper wire, the winding beginning at the poles and ending at the equator; the terminals were then passed through the interior and brought out at the poles, where they were joined with the free ends. It was then mounted on capped axles, cemented to opposite sides of the wired surface of the globe, at an angular distance from the poles of at first  $18^{\circ}$ , but changed finally to  $23^{\circ}5'$ , the polar distance of the poles of the ecliptic. At these axles were the contrivances for establishing permanent electrical connection with the generator of electricity, when the globe was made to revolve on its axis. This represented the gaseous or electro-dynamic sphere. Then another terrestrial globe, 18 inches diameter, was cut through equatorially and the hemispheres mounted at the poles on hollow axles, made to fit over the axles of the inner globe so as to revolve separately and concentrically with it. These hemispheres, to render them permanently magnetic, were lined internally with iron wire gauze, covered with insulated copper wire wound similarly to the inner globe, and were magnetized by a branch of the current exciting the latter. These two globes were then mounted on a fixed standard in such a manner that any point up to latitude  $72^{\circ}$  could be brought directly below the contrivance bearing specially constructed magnetic needles, two inches in length. The axles were connected with an epicyclical train of wheels so that a differential motion could be imparted to the globes such that for a complete revolution of the former, the latter lost  $\frac{1}{3}$  of a revolution or  $12^{\circ}$ . The relative strength of the inner and outer fields of force was adjusted by introduction of wire resistances so that the point of vertical dip would be maintained in latitude  $72^{\circ}$ , and the known maximum west declination and inclination at London would be produced. By throwing the wheels out of gear and moving the two spheres through the same angle, the magnetic elements at all points of the globe for the same epoch could be obtained. By turning the crank

and knowing the amount in time of the retardation of the inner sphere for a complete rotation of the outer, the secular variation at any point could be ground out.

It will be seen that Wilde has presented us with a totally different idea in his mechanism from that of his theory. His *theory* would have the internal sphere differentially rotating about its axis of magnetization with the plane of rotation parallel to that of the ecliptic. Nothing whatever is said as to its transportation about the terrestrial axis, as a whole. Hence, the magnetic pole would be a transient one and be induced successively on every meridian during the diurnal rotation of the terrestrial shell, and the maximum effect would appear in the diurnal variation of the needle and not in the secular. But we know that the former is but a small percentage of the latter, hence it must be evident that Wilde has not given us his whole theory. Are we to suppose that the gaseous sphere rotates about an axis which itself rotates about the terrestrial axis and is thus continually changing its plane of rotation during every twenty-four hours? Only in this way could a permanent pole be maintained.

In his *mechanism* he has the inner sphere differentially rotating about the axis of the outer with its axis of magnetization inclined to it at an angle of  $23^{\circ}5'$  degrees. This certainly simplifies the physical conditions. But are we to suppose that when the plane of rotation of the inner sphere gradually changed its primitive direction until it coincided with the outer one, the axis of magnetization of this vaporous sphere was so rigid that it remained fixed? Is it possible that Wilde wishes us to understand that the circulation of currents of electricity round the inner sphere is equivalent to a rotation of the sphere?

The first point made in this paper, then, is that Wilde's mechanism does not coincide with his theory as he has given it to us.

But now let us set aside all discussion as to the theory and the physical conditions involved and discuss the results from the standpoint of Terrestrial Magnetism alone. Were it necessary for the support of the argument to arrive at the probable error of the magnetarium results, among others, the following points might be mentioned which would affect them and in regard to which Wilde says nothing.

(1.) The effect on the needles by the earth's magnetic force at the station where the results are ground out.

(2.) The sensible amount, his needles being in proportion to the diameter of the outer sphere as 1:9, by which they would be attracted directly or obliquely towards that globe as the

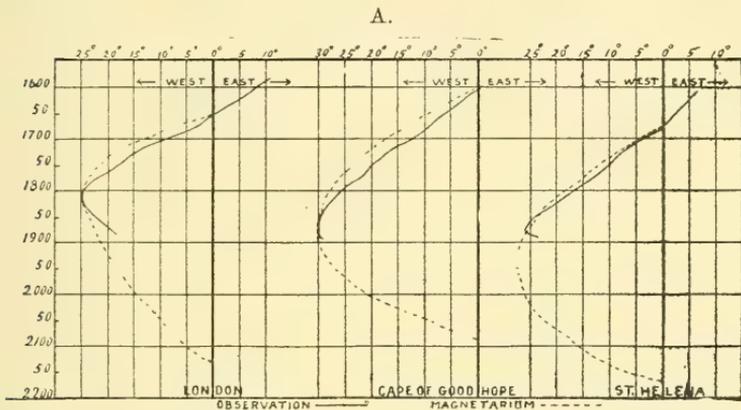
magnetic force on the two ends would be unequal and non-parallel.

(3.) The needles vibrate over about 10 degrees of terrestrial surface, so that when Wilde measures the declination at say London, he is getting it for the whole of England, over which there is a range of about five degrees.

(4.) The adjustment of the mechanism with reference to maintaining the magnetic pole in latitude  $72^\circ$  with regard to one station alone. It is well known that the magnetic meridians require considerable urging to be made to pass through one point. Besides the latitude of the north magnetic pole is uncertain by at least  $1^\circ$  and probably more, no wholly satisfactory determination of its position having ever been made. Ross made a dash at it in 1831-32 and the International Polar Commission in their comprehensive labors forgot all about this interesting point. This will introduce an uncertainty by at least  $2^\circ$  in the polar inclination of the axis of the internal sphere.

To facilitate the comparison between fact and theory, instead of the table which Wilde gives, we have before us a diagrammatic representation (Diagram A) of all the observations of magnetic declination known for the three stations, London, Cape Town, and St. Helena, and all the results as obtained with the magnetarium, the full curves representing the former, the dotted, the latter. For London our earliest observation is  $11^\circ 15'$  East in 1580. The march of the declination here has already been pointed out. For Cape Town or Cape of Good Hope, our series begins in 1605 with the needle pointing  $0.5^\circ$  to the East. Marching westward it reaches its maximum westerly elongation about 1870. After hovering here awhile it turned its course and is now diminishing its westerly declination at the rate of  $2'$  per annum. At St. Helena the observations date back to 1610, the needle pointing about  $7^\circ$  to the East. Crossing the zero line somewhere between 1680 and 1690, it has reached its maximum westerly extreme at the present time and after remaining stationary for a few years will begin to march eastward. The Magnetarium results were ground out separately, beginning in each case with zero declination and continuing until the inner sphere had accomplished one-half of a differential revolution, when the needle pointed again zero, giving thus a half period of secular change. The declination was measured for every  $6^\circ$  of differential motion. The results for London were obtained on the basis of a symmetrical distribution of terrestrial magnetism. It took  $60^\circ$  of differential motion of the globes to produce the maximum westerly elongation. Now from the observations we find that this covers a period of about 160 years, hence  $6^\circ$  of differen-

tial motion are equivalent to 16 years. As, according to Wilde, it would take one complete differential revolution of the inner sphere to produce a complete cycle of secular change, the period of the latter would be  $360 \times \frac{16}{6}$  or 960 years and the annual rate of retardation of the inner sphere  $\frac{360 \times 60}{960}$  or 22.5 minutes of arc. That is, in the time that the terrestrial or electro-magnetic shell has made  $960 \times 365\frac{1}{4}$  rotations, the vaporous sphere has made one less. Wilde carefully points out



here that the “westerly march of the needle on the magnetic globes as shown in Table II (represented by the dotted curve on diagram A), exhibits similar relations in the period and rate as those in Table I,” (represented by the full curve)! He evidently forgot that he had adjusted his mechanism in the first place, so that the maximum declination of  $24^{\circ} 38'$  at London would be obtained, hence he only got out what he put in. London, then, we shall have to put aside and count neither for nor against him.

Before grinding out the next stations, the mechanism undergoes a modification. As a first attempt to approximate to the complex magnetic condition of the earth, Wilde lines the interior of the outer globe under the land areas with sheet-iron to render them more magnetic than the ocean areas. This proves a dead failure. He next reverses his conditions and puts sheet iron below the ocean areas, when, behold, a most remarkable change takes place and most interesting correspondences with facts, as exhibited in the present distribution of terrestrial magnetism, are obtained! But as these properly refer to the distribution of terrestrial magnetism and not to

the secular variation, they cannot be entered upon here. With the apparatus in this condition he gets the secular variation at Cape of Good Hope and St. Helena. It took  $102^\circ$  of differential motion to produce the maximum west at Good Hope. As it had previously been found from the London results that the annual differential motion was  $22.5$  minutes of arc,  $102^\circ$  would be equivalent to  $\frac{102 \times 60}{22.5}$  or 272 years. From the observations we get about the same interval. Hence, here we have apparently a close correspondence between theory and fact, albeit that there is an average difference of about  $3^\circ$  between the two curves all along and but one point of correspondence actually obtained. It will also be seen from the diagram (A) that by starting about 50 years later, or in other words, if the zero at Good Hope had occurred at the same time as at London, the same maximum westerly elongation of about  $25^\circ$  would have been obtained as at London. It looks very much as though Wilde happened to strike the maximum of  $30^\circ$  instead of  $25^\circ$  because about 50 years more of secular variation had been ground out. But we will let Wilde have this point and proceed to the next station which furnishes the most satisfactory test.

Here he had no means of knowing when the maximum west would set in and what its amount would be and hence would be unbiased. The last recorded observation was in 1846, ( $23^\circ 11'$  W.) indicating that westerly declination was still increasing. In *his* table of observations, Wilde gives  $26^\circ 00'$  W. for 1880, which, I presume, was taken from the British Admiralty Chart. This is the last that he knew anything about. In 1890, Mr. E. D. Preston, while on the Solar Eclipse Expedition to St. Paul de Loanda, touched at Helena and made magnetic observations. He got an average value of  $24.3^\circ$  for the magnetic declination. Mr. Preston's observations have been published in Bulletin No. 23 of the Coast and Geodetic Survey. Even without the supposititious value of 1880 Prof. Schott, by expressing the magnetic declination in the form of a sine function, has deduced that the maximum occurred about 1890. As a further check, I have examined the excellent magnetic charts for 1885 by Neumayer in Berghaus's *Physikalischer Atlas* and find for 1885,  $25^\circ$ , showing very clearly that the maximum occurred somewhere between 1880 and 1890. Wilde, as will be seen from the diagram (A) and his table given below, gets the maximum west in 1939, or fifty years later. Hence, here he has failed, but it will be noticed that in this case there is the closest correspondence between the two curves. Let us assume now that the amount of annual retardation and period of a differential revolu-

tion of the inner sphere were unknown and proceed as we did at London to find them. It took  $96^\circ$  of differential motion to produce the maximum at St. Helena, which we have found from observation to have occurred about 1890, covering thus a period from zero of about 208 years instead of 256 as Wilde has it. Hence, instead of  $6^\circ$  being equal to 16 years as at London and Good Hope, we find  $6^\circ = 13$  years and the total period  $60 \times 13$  or 780 years instead of 960 and the annual amount of retardation  $27.8'$  instead of  $22.5'$ ! In other words, for London and Cape of Good Hope the inner electro-dynamic sphere must make one complete differential revolution in 960 years, but to accommodate St. Helena it must go at a more rapid gait and perform the complete revolution in 780 years!

The table before us is the one Wilde presents at the end of his second paper, "with the view," as he says, "that they may be of some service to science in the distant future."

*Declination periods at London, St. Helena, and the Cape of Good Hope for the cycle of secular changes of the earth's magnetism.*

Declination,		London.		St. Helena.		C. of Good Hope.	
		Epoch.	Interval.	Epoch.	Interval.	Epoch.	Interval.
$0^\circ$ outward march	W.	1657-1817	160	1683-1939	256	1609-1881	272
$0^\circ$ return	" W.	1817-2137	320	1939-2163	224	1881-2089	208
$0^\circ$ outward	" E.	2137-2457	320	2163-2387	224	2089-2297	208
$0^\circ$ return	" E.	2457-2617	160	2387-2643	256	2297-2569	272
			960		960		960

It will be seen from this table that the consequences of Wilde's theory are:

(1). That the period of a complete secular change is the same all over the globe—this period being approximately 960 years.

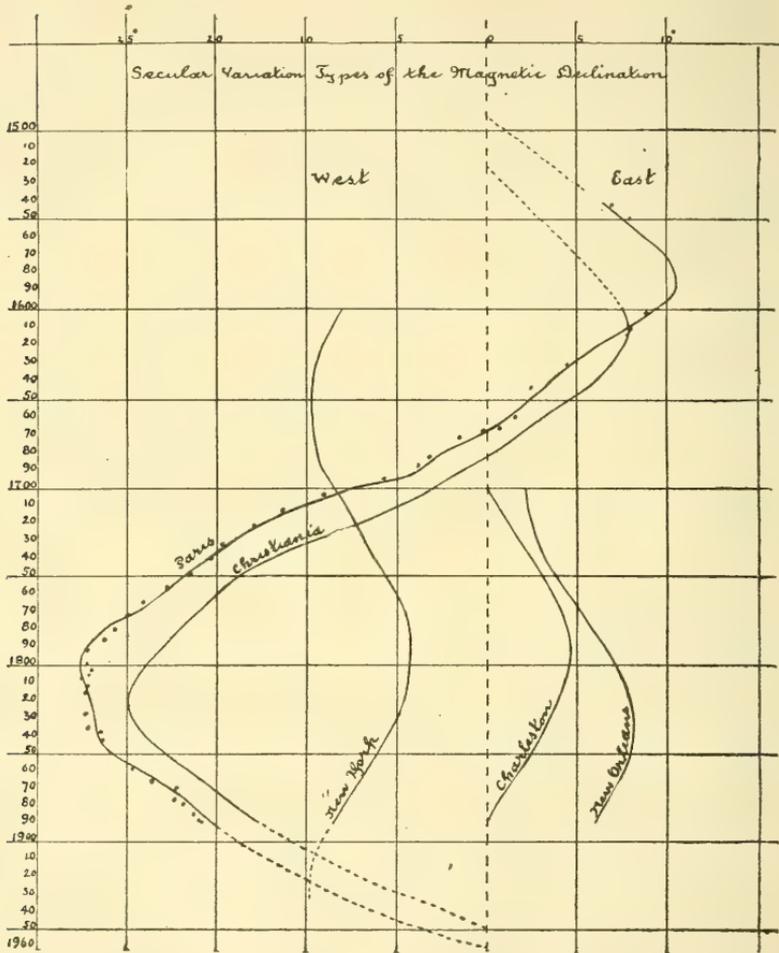
(2). That the declination at every point on the earth, at some time during the cycle, passes through zero.

(3). That the total amounts of easterly and westerly declinations are approximately equal.

How utterly contradictory these three conclusions are to facts and what little reliance can be put upon Wilde's table, will be seen from the next diagram (B) giving Secular Variation Types of the Magnetic Declination. At no station have we record of a complete period. There are a number, however, where the series of observations will warrant our foretelling the length of the period certainly within 50 years. The next half century will witness the completion of several of the American stations. The curves on the diagram, with the exception of Christiania, have all been plotted from the

secular variation expressions given in Prof. Schott's paper, App. 7, Coast and Geodetic Survey Report for 1888. Where the curve extends beyond the recorded observations, it is given in dashes. It is well known that the sine periodic function is well adapted for expressing the secular variation. Such a

B.



function enables you to deduce the period, range, times of maxima and minima, etc. How closely it can be made to agree with actual fact is indicated in the case of the Paris curve, by dots which represent the observations. Here we have the longest and best discussed series, the earliest observation dating back to 1541, over 350 years ago. The next best discussed series is for Christiania by Prof. Weyer.

I shall not be able to point out all the interesting features brought out by this diagram. Only such as will be a direct refutation of Wilde's theory will be touched upon.

(1.) *The period.*—The diagram at once shows not only how far the periods fall short of 960 years, but also, which is the important point, how greatly they differ among themselves.

In the following table I have given some of the periods and ranges. This table alone will overthrow Wilde's theory. From it will be seen that the secular variation period is not a universal one, but is different for every station. So that if

Station.	Period, years.	Range.
Paris* .....	470	32°
Christiania .....	420	27
Cape Town .....	590	30
St. Helena .....	582	31
Ft. Albany .....	300	14
St. Johns .....	347	18
Eastport .....	288	8
New York City .....	277	6
Charleston .....	257	5·5
New Orleans .....	257	6
Rio de Janeiro .....	450 (?)	20 (?)

the cause of the secular variation is the differential rotation of an electro-dynamic substance within the earth's crust, then to satisfy every point on the globe it must have every possible rate of rotation, or every station must have its own electro-dynamic sphere roll around in the inscrutable region below us! Is this not tantamount to Barlow's idea that the secular variation at every station could be explained by supposing that each had its own magnetic pole describing an orbit about the rotation pole? But, says Sir John Herschell, if that is so, haven't you renounced the idea of polarity altogether?

(2.) The diagram will show that there are stations where the declination does not cross the zero line, but remains west or east. At New York City, for example, in about 1933 we shall have a full period and there is no question but what the declination remains west. Charleston is mostly east, but crosses the zero line. New Orleans, doubtless, remains east during its whole period. Probably better illustrations of places where the declination remains east will be found with the lapse of time along the Pacific coast. And how unequal the amounts of easterly and westerly declination are about the zero line is abundantly shown by Paris and Christiania.

\* The period at London is estimated to be between 500 and 550 years, range 35°.

As this paper might be considered incomplete were no reference made to one or two things which have been brought forward as verifications, I will briefly allude to them. Wilde's next strongest argument to those given above, is a table which gives the westerly progression of the zeros of declination across the Atlantic from 1492-1880, and herein is included that very ancient observation of Columbus where his needle changed from east to west, concerning the exact location of which there has been controversy. All that will be said is that Wilde gives no means for the verification of his figures, as he did at those stations which have been discussed. Furthermore the table has been obtained on the assumption that the inner sphere retreated at the annual rate of 22.5 minutes of arc. It has already been shown that for St. Helena the sphere lagged behind 27.8 and the table of periods shows that for every point on the globe this rate is different. Again, the points mentioned affecting the accuracy of a determination of the declination on the Magnetarium and from comparisons made between fact and theory wherever possible, it is very much doubted if Wilde can get within 5°—certainly not within 3°. Now when you take into consideration that if the isogonic lines do not cut the meridians or parallels sharply, it can be seen how little reliance can be put upon the determination of geographical position by means of the magnetic declination. Nor need Wilde have gone back to the time of Columbus, where we have absolutely no data, to verify his theory. If he will reproduce in range and period, Paris, Cape of Good Hope, New York City, and St. Johns, conjointly not separately, we will ask no further verification.

The opinion of this paper then is that while Wilde's theory *has* given us a secular variation, it has *not* given us the secular variation as manifested on the earth. Nor has it given us a better representation than the old theory of a uniformly revolving magnetic pole. Furthermore, have we not taken a step backward? If we go back to Halley, two centuries ago, we find the idea embodied in Wilde's mechanism, expressed in all detail and without any difference worth mentioning. A full description of Halley's theory\* can be found in Harris' Rudimentary Magnetism. We are obliged then to characterize the Magnetarium as nothing more than an improved Barlow globe, and in conclusion we will say with Halley that the "secular period and motion are secrets as yet utterly unknown to mankind, and reserved for the industry of future ages."

\* Originally given in Philosophical Transactions of the Royal Society for 1683, p. 208 and for 1692, p. 563.

ART. LXIII.—*Josephinite, a new Nickel-Iron*; by W. H. MELVILLE.

*History.*—Several months ago Prof. F. W. Clarke submitted to me for examination a quantity of magnetic pebbles which were sent to this office by Mr. Wm. H. Hampton of Portland, Oregon, and by subsequent correspondence with this gentleman he obtained a larger amount with full liberty to publish the results arrived at in the laboratory.

In the spring of 1891 Mr. Hampton discovered these pebbles in large quantities in the placer gravel of a stream in Josephine and Jackson Counties, Oregon, which border on the south of Douglas Co. where the nickel silicate\* described by Prof. Clarke occurs. He analyzed with reference to nickel and iron an average sample of twenty pounds of the wash gravel from the placer diggings, and found that the metallic portion gave 60.3 per cent nickel and 26.7 per cent iron. From the nature of the gangue or stony portion Mr. Hampton concluded that these waterworn pebbles and boulders—for some pieces weighed over one hundred pounds—"came from an eruptive dike somewhere in the vicinity." The locality of this dike was not at that time ascertained.

*Physical Characters.*—The pebbles are irregular in shape but approximate the form of ellipsoids. Their smooth surfaces, polished by the action of water, are colored in general greenish black, interrupted by bright areas of the grayish white alloy of nickel and iron. The former portions consist of siliceous matter and when cut by a knife yield a dull and light gray powder, but broken fragments show greenish yellow and deep green colors and resinous luster resembling noble serpentine. With this is associated in some pebbles a silicate whose hardness is between 5 and 6. It is compact and on the fresh fracture exhibits a light brown color and vitreous luster, while exposed surfaces are reddened by ferric oxide.

The texture of the metallic portion as it appears on fracture is granular. The metal is gray, malleable and sectile with hardness about 5.

The specific gravity of one lot containing forty-two pebbles was taken in a pycnometer at a temperature of 22° C. These pebbles ranged in weight from 0.3159 to 1.6447 grams and were about the dimensions of a pea. The largest pebble in my possession weighed 4.2847 grams, and the specific gravity of this was made by suspending it from a silk fiber. Two determinations furnished a mean specific gravity of 6.204.

\* Bulletin No. 60, U. S. Geol. Survey, p. 21, 1887-1888.

The pebbles are strongly magnetic.

*Analyses.*—The analyses were conducted with the aim of separating the pebbles into their proximate principles and also their ultimate constituents. Two different lots of about twelve grams each were pulverized in a steel mortar, a delicate and tedious operation owing to the extreme malleability of the nickel-iron. Two complete analyses of these samples were made. The ratio between the nickel and iron in the metallic state was ascertained by deducting from the total amounts of each of these elements those quantities which were found in other combinations. The ordinary method of fusion with sodium hydrate and subsequent treatment of the residue with concentrated nitric acid failed to give the true contents of the metallic portion in the pebbles, because the nickel-iron was not passive in this acid. The ratio between the nickel and iron, however, could be obtained by this method.

The stony matter was freed as far as practicable from the magnetic parts by a fractional process, that is to say by the repeated use of an electro-magnet and by the decantation of the light particles suspended in water. The siliceous portion was then analyzed. A fresh sample was treated with diluted hydrochloric acid, and after repeated evaporations the soluble silica was separated from the insoluble residue and weighed. The insoluble residue was analyzed, and the percentage composition of soluble silicate was inferred from this analysis, the analysis of the total siliceous matter, and the total silica of the pebbles.

The mean composition of the pebbles is shown by the following numbers :

	Per cent.		Per cent.
Nickel free, Ni .....	60·45	Nickel combined .....	0·25
Cobalt, Co .....	0·55		
Iron free, Fe .....	23·22	Iron combined .....	1·79
Pyrrhotite, $\text{Fe}_7\text{S}_8$ .....	0·55	Sulphur .....	0·22
Chromite, $\text{FeO} \cdot \text{CrO}_3$ } .....	0·12	Chromium .....	0·04
Magnetite, $\text{FeO} \cdot \text{Fe}_2\text{O}_3$ }			
Copper, Cu .....	0·50		
Arsenic, As .....	0·23		
Chlorine, Cl .....	0·04		
Silicate (anhydrous) .....	12·26		
$\text{H}_2\text{O}$ below $100^\circ \text{C}$ . .....	0·81		
$\text{H}_2\text{O}$ above $100^\circ \text{C}$ . .....	1·12		
$\text{CO}_2$ .....	trace		
Volatile matter .....	0·70		
	100·55		

Per cent in pebbles.	Total silicate.	Insoluble silicate.	Soluble silicate.
SiO <sub>2</sub> .....	5.14	0.23	4.91
Al <sub>2</sub> O <sub>3</sub> .....	0.33	0.03	0.30
Fe <sub>2</sub> O <sub>3</sub> .....	2.08	0.04	2.04
(Ni <sub>2</sub> ,Co)O .....	0.32	trace	0.32
CaO .....	1.62	0.06	1.56
MgO .....	2.69	0.14	2.55
Na <sub>2</sub> O .....	0.08	---	0.08
H <sub>2</sub> O above 100° C. ..	1.12	---	1.12
	13.38	0.50	12.88

Composition.	Insoluble silicate.		Soluble silicate.		
	Per cent.	At. ratio.	Per cent.	At. ratio.	
SiO <sub>2</sub> .....	45.63	3.04	38.23	2.55	
Al <sub>2</sub> O <sub>3</sub> .....	6.58	0.39	2.34	0.14	
Fe <sub>2</sub> O <sub>3</sub> .....	8.77	0.33	15.88	0.60	} 0.74
(Ni <sub>2</sub> ,Co)O .....	undetermined		2.49	0.07	
CaO .....	11.03	0.39	12.14	0.43	} 2.47
MgO .....	28.01	1.40	19.85	0.99	
Na <sub>2</sub> O .....	---	---	0.35	0.01	
H <sub>2</sub> O above 100° C., ..	---	---	8.72	0.97	
Total .....	100.02		100.00		

*Silicates.*—There are two silicates, then, the one soluble in hydrochloric acid being undoubtedly serpentine. This serpentine surrounds the metallic portion, and on polished sections its deep green color is well brought out. It has not penetrated into the metallic mass, and it would appear that the pebbles once formed a large aggregation and that fractures took place in directions of least resistance through the serpentine. Other characters of serpentine were noted, its resinous luster, its hardness of about 3, and its infusibility. In the closed tube water was given off. The atomic ratio of the combined bases and water to silica is 3.2 : 2.55 or 5 : 4, a ratio which is identical with that of serpentine. The ratio between bases and water, 7 : 3 instead of 3 : 2, is not the true ratio for these constituents in serpentine as it exists in the pebbles, because the analysis is calculated from figures obtained from material which was dried at 100° C. Again the reddish brown coloration of this dried material indicated the presence of some impurity, probably oxides, and this could not be eliminated. The water is, therefore, too low and the iron oxide too high.

The insoluble silicate, however, cannot be so clearly made out. Its atomic ratio, SiO<sub>2</sub> : base = 6 : 5, brings it nearer an orthosilicate than a metasilicate. It is light brown, vitreous, hard, compact and not cleavable. It does not fuse before the blow-pipe. It is not so hard as olivine and its insolubility in acid

excludes this mineral. In physical and pyrognostic characters and to some extent, also, in composition it agrees fairly with bronzite (enstatite). The probable silicates to occur in this association are pyroxene, olivine, enstatite, from which serpentine is derived, while a feldspar is not to be expected. I did not determine to which silicate the sodium-oxide belonged, owing to its small quantity and the small quantity of insoluble silicate in the pebbles. A mixture of a soda-lime feldspar and enstatite (or pyroxene) would answer the requirements of the ratio, but this is purely speculative. So far as the data go it is best to regard this silicate as an impure bronzite.

During attempts to purify the silicates it was noticed that on the removal of the metallic part by a neutral concentrated solution of either cupric sulphate or mercuric chloride that the silicate was more or less attacked. Magnesia was removed, and one analysis showed that out of 2.69 per cent MgO in the pebbles only 0.43 per cent remained in the purified silicate. Curiously no iron or lime was removed. Pulverized olivine and serpentine were each digested with copper sulphate on the water bath two or three hours; a yellow copper salt was deposited and a large quantity of magnesia was taken out of both silicates. A basic copper sulphate was produced, and the liberated sulphuric acid (SO<sub>3</sub>) combined with magnesia to magnesium sulphate. In the presence of olivine or serpentine this treatment for the purification of the silicate is inadmissible.

*Chromite.*—Under the microscope a minute quantity of black metallic grains can be seen in the siliceous portion, which do not precipitate copper from a sulphate solution. These grains consist of chromite with a very few strongly magnetic particles of magnetite. 0.04 per cent of chromium was found in the pebbles, while the per cent of chromium corresponding to 0.12 per cent of chrome iron is 0.036. The presence of chromite is naturally expected in the serpentine.

*Magnetite.*—The few grains mentioned under chromite were dissolved by protracted heating in hydrochloric acid. Other particles of magnetite were not recognized with certainty.

Two magnetic pebbles were found among those which carried the large percentage of nickel, and a small amount of fibrous serpentine (not chrysotile) adhered to this magnetite. It is probable that magnetite occurs in the original deposit from which the nickel pebbles were transported. The high percentage of iron obtained by Mr. Hampton was probably due to the presence of some magnetite-pebbles in the average sample which he studied.

*Pyrrhotite (Troilite).*—The monosulphide of iron could not be separated from the other principles with sufficient purity for analysis. The amount of this mineral, formula Fe<sub>7</sub>S<sub>8</sub>, was

calculated from the total sulphur, 0.22 per cent. Hydrogen sulphide was liberated in considerable quantity when the powdered pebble was treated with diluted chlorhydric acid. Millerite does not act thus.

*Copper.*—The copper is not a constituent of the pyrrhotite, but belongs to the nickel-iron. Copper minerals were not detected under magnifying power.

*Arsenic.*—Arsenious oxide was condensed in the cool parts of a tube through which air was allowed to pass, as also in all the tubes used for the determination of volatile matter. No sulphide of arsenic dissolved by digesting in the cold with ammonium carbonate, nor could niccolite (nickel arsenide) be detected. Arsenic forms a part of the metallic portion of the pebbles.

*Chlorine.*—The chlorine was determined in a nitric acid solution of the original powder, a blank experiment with the use of the same quantity of reagents being run parallel with that. In an aqueous solution were found iron, nickel, magnesium, sodium and chlorine, and this fact together with the small available quantity of chloride caused the difficulty in determining to which element chlorine was combined. The presence of iron and nickel, since pyrrhotite carries nickel, can be accounted for in the aqueous solution by the easy oxidizability of the sulphuret with free access of air. Green ferrous chloride could not be detected in the powder, nor any soluble salt possessing that color. The permanence of the pebbles in air is also a presumption in favor of the absence of lawrencite. Nickel chloride has not before been observed, but may possibly exist in these specimens. It is more probable that the chlorine is united with sodium 0.04 per cent requiring 0.026 per cent Na or 0.035 per cent  $\text{Na}_2\text{O}$ . The magnesium is in the form of carbonate.

*Water and Volatile Matter.*—The powdered substance in a platinum boat was heated in a glass tube in a stream of dry carbonic anhydride, and the water, both hygroscopic moisture and water of constitution, was weighed in a chloride of calcium tube. Another portion was heated in hydrogen gas, and hence the oxygen in the oxides was known, although this amount might have included some, if not all, of the oxygen combined with iron in the ferric state in the silicates. After burning in a current of dry air and then reducing in hydrogen the total loss was ascertained from the difference in weight of the contents of the boat before and after the operation. In all cases except when burnt in air a brownish cloud possessing an empyreumatic odor was driven off without leaving a brown black sublimate in the tube. It was a volatile organic substance whose nature was not discovered. The pulverized pep-

bles when treated with dilute hydrochloric acid at the temperature of the water bath gave the odor characteristic of the decomposition of a carbide, so that the volatile matter given in the analysis consists of organic matter, namely combined carbon and probably a hydrocarbon. All loss arising from the volatilization of arsenic, sulphur and chlorine have not been included in the per cent given for volatile matter.

*Nickel-Iron.*—Of special interest is the metallic portion.

	(1)	(2)	At. ratio.
Two analyses gave :—Fe	23·36	23·09	0·41
Ni	60·47	60·43	1·03

From this ratio is deduced the formula  $\text{Fe}_2\text{Ni}_5$ .

The following table gives a comparison of a few examples of nickeliferous iron which form an instructive series :

	Catarinite.*	Octibbehite.†	Awaruite.‡	Josephinite.
Iron	63·69	37·69	31·02	23·22
Nickel	33·97	59·69	67·63	60·45
Atomic Ratio } F : Ni	1·14 : 0·58	0·66 : 1·02	0·55 : 1·17	0·41 : 1·03
Formula	$\text{Fe}_2\text{Ni}$	$\text{Fe}_2\text{Ni}_3$	$\frac{2(\text{FeNi}_2)}{\text{Fe}_2\text{Ni}_4}$	$\text{Fe}_2\text{Ni}_5$

The question naturally arises whether the origin of these pebbles is cosmic (meteoric) or terrestrial. Catarinite and octibbehite have been considered meteoric falls, while awaruite has been traced from the drift in the Awarua river on the western side of the middle island of New Zealand to a "mountain of peridotite, an olivine-enstatite rock more or less serpentinized," and is undoubtedly terrestrial. In the drift are found gold, platinum, cassiterite, chromite and magnetite. The placer gravel, in which josephinite is found, is like that of New Zealand with the exception of the occurrence of platinum§ and cassiterite so far as known at present.

There is one element, phosphorus, which is almost universally found in meteorites and combined with nickel and iron to form the mineral schreibersite, which has no representative among terrestrial minerals. After evaporating to dryness a nitric acid solution of a sample of the pebbles, and fusing the residue with sodium carbonate and potassium nitrate, phosphoric acid was not detected in the acid filtrate, and thus was

\* Encyclopédie chimique, Fremy, Metalloids, Tome ii, par M. Stanislas Meunier.

† This Journal, II, xxiv, p. 293, Taylor.

‡ This Journal, vol. xxxiii, p. 244, G. H. F. Ulrich; analysis by W. Skey. A. Sella described a nickel-iron from the auriferous sands of the stream Elvo, near Biella Piedmont; Fe 26·6 per cent; Ni(Co) 75·2 per cent; formula  $2(\text{FeNi}_2) = \text{Fe}_2\text{Ni}_4$ . C. R. cxii. 171; also this Journal, III, p. 252, 1891.

§ Platinum occurs in the region of Rogue river, Oregon.

proved the absence of phosphorus both as terrestrial phosphate and meteoric phosphide. In the published analysis of awaruite by W. Skey no phosphorus is given. Catarinite and octibbelite contain 0.05 per cent and 0.10 per cent respectively.

By etching with nitric acid Widmannstätten figures cannot be produced upon a polished surface of the nickel-iron. The metal seems to be homogeneous, and the little sulphide to occur in the fissures. Awaruite is passive toward an acid solution of copper sulphate, and only with difficulty and long heating is the nickel-iron from Oregon completely dissolved with replacement of the copper in a sulphate solution. This passive state is uncommon with the ordinary nickel-iron of meteorites, but the high percentage of nickel may account for this property. Concentrated nitric acid dissolves the alloy.

Daubrée\* points out that meteorites and analogous terrestrial rocks differ in that the former contain in a reduced state certain substances which appear in the latter in the state of oxides. This idea could be extended to include metamorphism in its broadest sense. Serpentine is rarely found in meteorites, although Wöhler has recognized it in some carbonaceous meteorites. In the two cases of awaruite and josephinite, serpentine is the principal silicate derived in the former from olivine and enstatite. Daubréelite is metamorphosed into chrome-iron, and this may possibly be the explanation of the origin of the latter, that the double sulphide of chromium and iron existed in the ferro-magnesian silicates before or at the time of their serpentinization, and was then oxidized to chromite.

The evidence cited in the previous paragraphs points to the terrestrial origin of the pebbles which form the subject of this paper, and here the question of origin must rest till the nickeliferous iron is found *in situ*.

The name josephinite is given in honor of the county, its locality, in accordance with the custom in use for naming analogous substances.

Laboratory, U. S. Geological Survey, March, 1892.

ART. LXIV.—*A Fibrous Intergrowth of Augite and Plagioclase, resembling a reaction rim, in a Minnesota Gabbro; by W. S. BAYLEY.*

IN the course of an investigation into the microscopical characteristics of the gabbro forming the great flow, or flows, near the base of the Keweenawan series of rocks in north-

\* Etudes Synthétiques de Géologie Expérimentale par A. Daubrée, 1879, p. 578.

eastern Minnesota,\* the attention of the writer was repeatedly attracted by a fibrous growth around olivine, that resembles very strongly the reaction rims that have been described as existing between garnet and serpentine by Schrauff† and Becke,‡ between garnet and olivine by Diller,§ and between the last named mineral and feldspar by Tornebohm,|| Julien,¶ Becke,\*\* G. H. Williams,†† Schuster,‡‡ Teall,§§ and Lacroix|||. A close study of the phenomenon, however, disclosed the fact that the growth is not due to reactionary processes between the rock's constituents, but is simply an original intergrowth of two of them. Its appearance, nevertheless, is so suggestive of a reactionary origin (see fig. 1), that it has been thought well to describe it briefly.

The rock in which the phenomena occur is a very coarse grained gabbro, composed of a perfectly fresh olivine with the composition of hyalosiderite, a pink or purple diallage and labradorite, whose analysis yielded Dr. Hillebrand the following figures :

SiO <sub>2</sub>	Al <sub>2</sub> O <sub>3</sub>	Fe <sub>2</sub> O <sub>3</sub>	FeO	CaO	MgO	K <sub>2</sub> O	Na <sub>2</sub> O	H <sub>2</sub> O	Total
51.89	29.68	0.32	0.37	12.62	0.38	0.50	3.87	0.46	100.09

Its structure is typically gabbroitic, in that the *plagioclase* is the youngest of the three components, and not the *pyroxene*, as in the case of the diabases.¶¶ It is peculiar, however, in the fact that in most sections the diallage, instead of occurring in grains and plates scattered indiscriminately among the other constituents, exhibits a fondness for the proximity of the olivine. As illustrated in figure 2 (specimen from the Falls of the Cloquet River, SE¼ Sec. 34, T. 53 N., R. 14 W.) the diallage envelops the olivine grains and so separates them from the surrounding plagioclase. It is evident that the first mineral to form from the magma was olivine. Then followed the pyroxene, which attached itself to the surfaces of the

\* R. D. Irving: Copper-Bearing Rocks of Lake Superior: Mon. v, U. S. G. S., p. 266; this Journal, III, vol. xxxiv, 1887, p. 204 and 249; and 7th Ann. Rept. U. S. G. S., 1888, p. 419.

† Neues Jahrb. f. Min., etc., 1884, ii, p. 21, and Zeitschr. f. Kryst., vi, p. 321.

‡ Min. u. Petr. Mitth., iv, pp. 189, 235, 323-6.

§ This Journal, xxxii, 1886, p. 122.

|| Neues Jahrb. f. Min., etc., 1877, pp. 267 and 384.

¶ Geology of Wisconsin, III, p. 235 and Plate XXII.

\*\* Min. u. Petrog. Mitth., 1882, iv, pp. 330, 350, 450.

†† Bull. U. S. Geol. Survey, No. 28, p. 52.

‡‡ Neues Jahrb. f. Min., etc., B. B. v, p. 451.

§§ Min. Magazine, Oct., 1888, p. 116.

||| Bull. Soc. Franc. d. Min., 1889, xii, p. 83.

¶¶ So far as the knowledge of the writer extends the rock of this flow is the only true gabbro in northeastern Minnesota. The other coarse-grained pyroxene-plagioclase rocks of this region, described by Irving and others under the name of gabbro, are either diabases or diabase-porphyrates.

olivine grains and continued to grow until it had abstracted all pyroxenic material from the still liquid mass. The residue solidified as labradorite. When the diallage is present in the rock in large amounts it completely envelopes the olivine; when it is present in small quantity only, it forms a very narrow rim that may or may not surround the older mineral. Although the association of olivine and diallage is not as described in all sections, it is sufficiently common in the rock to emphasize the tendency of the latter to arrange itself around the former.

1.

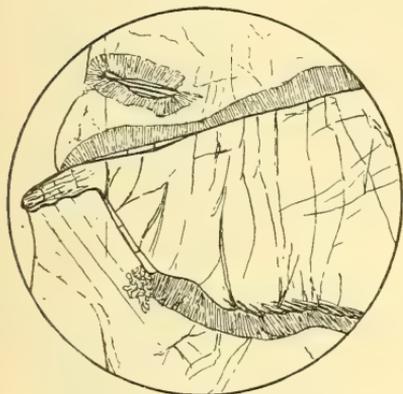


FIG. 1. Olivine and biotite surrounded by fibrous growths resembling reaction rims. Section 7025.  $\times 30$ .

2.



FIG. 2. Section of olivine-gabbro, exhibiting the tendency of the pyroxene to include olivine grains. Section 1103.  $\times 20$ .

In one-third of the sections of this rock studied, the olivine grains, where they would otherwise come in contact with plagioclase, are kept from doing so by a finely fibrous growth that polarizes in some places with bright colors, and in others with the bluish-gray tint of thin feldspar. Though in general these fibers extend perpendicularly from the bounding surfaces of the olivines, they occasionally form radial groups centering at points near the peripheries of the surrounded mineral. Nor are the fibers in all cases continuous. They often branch and fork, and frequently stop suddenly at short distances from their points of origin, while new fibers begin their courses just beyond. This fibrous envelope, moreover, is not confined exclusively to the vicinity of olivine. It is found also around decomposed biotite (see upper left hand corner of fig. 1) and around grains of magnetite (fig. 3).

A close inspection of the sections often reveals the presence of an intermediate zone between the fibrous one and the min-

eral surrounded by it. This is very narrow and consists of a highly refractive substance with strong double refraction (figs. 1 and 3). This zone is too narrow to admit of the nature of its material being discovered by its optical characteristics; but every gradation can be traced between wide enveloping mantles of diallage and thin seams with all of the characteristics of the intermediate zone. Moreover, it is frequently noticed

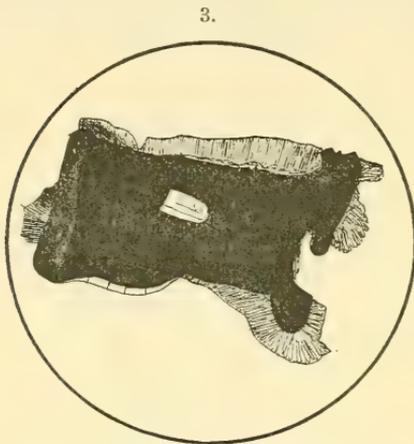


FIG. 3. Fibrous intergrowth around magnetite? Between the latter mineral and the fibrous rim can be seen a narrow zone of diallage. Section 10,439.  $\times 20$ .



FIG. 4. Olivine partly surrounded by narrow rim of augite, which is continuous with large plate of same mineral. 8803.  $\times$  ca. 18.

that the narrow rim widens out and expands into large wedge-shaped plates of whose diallagic nature there can be no doubt (fig. 4). Since the narrow zones between the fibrous envelope and the surrounded minerals are similar in every respect to these narrow rims of pyroxene, it is safe to assume that the former, like the latter, are composed of diallage. Consequently, the fibrous growth, if it be a reaction rim, is one between pyroxene and plagioclase, rather than between olivine and feldspar, as in the cases referred to in the opening paragraph of this article. But the intergrowth is rarely found around well developed diallage plates, while on the other hand it occasionally occurs around olivine, biotite and magnetite without the intervention of the seam of augite between these minerals and their envelope, and, again, it is sometimes found in the midst of feldspar as little granophyre-like bunches, not associated with any iron-bearing mineral whatsoever. It is thus quite evident that the fibrous growth is not a reaction rim between diallage and plagioclase, and, since it occurs indiscriminately around so many different minerals, that it is not a reaction rim at all.

For evidence as to the nature of the constituents of the intergrowth an appeal must be made to the fibrous growth itself. But this is not as satisfactory as it might be, for the fibers in most cases are so fine that nothing more definite can be detected in the rim than an intergrowth of two distinct substances. In instances where its fibrous structure is less well developed, and its components are coarser, the two minerals composing the rim are seen to differ in their colors between crossed nicols, as already indicated. One of these is in long narrow stringers, with club-like extremities. It appears to be continuous with the plagioclase on one side of it and to extend between similar tongues of a more highly refractive substance that spring from the opposite side. It is occasionally marked by twinning bars that are continuations of those existing in the surrounding plagioclase, and it extinguishes simultaneously with the latter. It is undoubtedly plagioclase.

The more highly refractive mineral intergrown with the feldspar is occasionally in such coarse fibers that its augitic character cannot be questioned. In the section of rock No. 8800,\* for instance, a large grain of olivine is penetrated by two lath-shaped crystals of plagioclase. Between the feldspars and the olivine is a very narrow rim of augite, while perhaps half of the material within the outlines of the crystals consists of the fibrous intergrowth. On the side of the intergrowth toward the augitic rim, its highly refractive component assumes such broad dimensions that diallagic characteristics may be traced in it, far beyond the points where it leaves the rim to form prolongations between the plagioclase fibers.

Fig. 5 illustrates a case in which augite sends out into the plagioclase in which it is imbedded, long pseudopodia-like tongues. Many other instances like the last might be cited to show the tendency of the diallage to form intergrowths with the plagioclase, but enough has already been written to emphasize the point.

It is true that there is no absolute proof that the highly refractive substance of the fine fibrous intergrowths is identical with the material of the coarse prolongations just mentioned, but the series of gradations between the mantles surrounding olivine and the fibrous intergrowth is

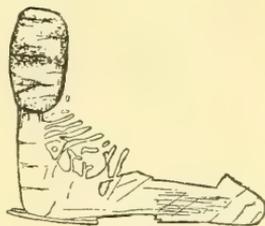


FIG. 5. Augite plate and olivine grain in plagioclase. The augite in the bend extends out into the feldspar, giving rise to an intergrowth, very like that of the fibrous rim. 8803.  $\times$  ca. 20.

\* All numbers of rocks refer to the series belonging to the Lake Superior Division of the U. S. Geological Survey.

so complete (Figs. 2, 4, 5 and 1), that the inference is justified that the highly refractive component of this intergrowth is diallage. In the coarse-grained gabbros the mantle around the olivine is certainly diallage; in those cases where a very thin seam is interposed between the fibrous growth and the mineral it envelops, the material of this seam is as surely a pyroxene. Moreover, the augite of the rock frequently sends out prolongations of its own substance into the surrounding plagioclase, and the ends of these prolongations have characteristics that are identical with those of the more highly refractive component of the intergrowths. Finally, in the coarser rims, their constituents may be traced on the one side into plagioclase and on the other side into diallage.

We may safely infer, therefore, that the fibrous intergrowth, which so closely resembles a reaction rim between olivine and plagioclase, but which is surely not such, is merely a granophyric aggregate of plagioclase and pyroxene. The major portion of the latter mineral in the rock separated before the feldspar, and taking advantage of the surfaces afforded by the already formed olivine and magnetite, fastened upon them. But in many cases, before the crystallization of the pyroxene had ceased, the feldspar began to form, and the two minerals crystallized together micropegmatitically.

So far as known to the writer, only one other description of a similar intergrowth of augite and plagioclase in a manner resembling a reaction rim is to be found in petrographical literature. In 1887 Camerlander\* mentioned the existence of such an intergrowth around garnets in a contact rock from near Prachatitz in the Bohemian Forest. The original description has not been seen, but in a review of it by Becke,† words are used that might well be applied to the phenomenon observed in the Minnesota rock: "Especially are the garnets often surrounded by the micropegmatitic intergrowth of augite and plagioclase. This varies remarkably in its appearance from that of undoubted augite imbedded in feldspar, to that of a dense radial bundle of fibres which resembles the kelyphite rims around garnets in serpentine."

United States Geological Survey,  
Lake Superior Division.

\* Jahrb. d. K. K. geol. Reichsanst., xxxvii, p. 117.

† "Besonders die Granaten sind häufig durch solche mikropegmatitische Verwachsungen von Augit und Plagioklas umrandet. Dieselbe variire ausserordentlich in ihrer Ausbildung von deutlichen in Feldspath eingewachsenen Augits bis zu radial gestellten dichter Faserbüscheln, welch an die Kelyphitränden der Pyrope von Serpentin erinnern." Ref. Neues Jahrb. f. Min., etc., 1888, ii, p. 54.

ART. LXV.—*A Method for the Determination of Barium in the presence of Calcium and Magnesium*; by F. W. MAR.

[Contributions from the Kent Chemical Laboratory of Yale College—XIV.]

THE recent investigation\* by Prof. R. Fresenius of the value of the various methods which have been proposed for the separation of barium and calcium, shows that but two of the methods tested by him are sufficiently accurate for good analytical work, and even with these it is necessary to make two treatments in order to obtain a complete separation. The method here described may therefore be of interest and by reason of its rapidity and accuracy may prove valuable, although since the publication of the work of Fresenius another method† has been published from this laboratory which, in point of accuracy, leaves little to be desired.

It has long been known that barium chloride is insoluble to a marked degree in concentrated hydrochloric acid, but the difficulty of filtering off the strong acid has in the past prevented the determination of the exact amount of this insolubility, and for the same reason the reaction has not been available for quantitative use. Since the invention of the Gooch crucible, however, the treatment of such strong acid filtrates has become a matter of the greatest ease, and it seemed worth while to investigate the limits of the insolubility of barium chloride in the strong acid and to ascertain whether the reaction might not be of use in the separation of barium from calcium and magnesium, the chlorides of which are soluble in the strong acid.

The barium chloride used in the following experiments was the pure crystallized chloride containing two molecules of water. The calcium salt was the pure fused chloride, and the magnesium salt was the pure crystallized magnesium chloride dried at 50° C. As the two latter were not determined in the experiments it was not necessary to know the composition of the salts used as regards hygroscopic moisture. Attention was first given to determining the solubility of barium chloride in hydrochloric acid.

SERIES A.

Exp.	BaCl <sub>2</sub> . 2H <sub>2</sub> O	Water.	HCl.	Total filtrate.	BaCl <sub>2</sub> .	Loss.
1	0.5024 grm.	5 cm <sup>3</sup>	20 cm <sup>3</sup>		0.4241 grm.	0.0041 grm.
2	0.5084 "	5 "	20 "		0.4304 "	0.0030 "
3	0.5099 "	2 "	25 "		0.4320 "	0.0027 "
4	0.5033 "	2 "	25 "	90 cm <sup>3</sup>	0.4251 "	0.0039 "
5	0.5047 "	2 "	25 "	52 "	0.4247 "	0.0055 "
6	0.5065 "	2 "	50 "	115 "	0.4257 "	0.0060 "
7	0.5008 "	2 "	50 "	75 "	0.4218 "	0.0051 "
8	0.5011 "	2 "	50 "	93 "	0.4220 "	0.0051 "
9	0.5024 "	2 "	75 "	123 "	0.4246 "	0.0037 "

\* *Zeitschrift für anal. Chem.*, xxx, 595.

† P. E. Browning, *this Journal*, vol. xliii, p. 314.

The experiments in Series A were made as follows:—The barium salt was weighed out, placed in a small beaker and dissolved in the amount of water indicated. The barium was then precipitated as the anhydrous chloride by adding, gradually at first, the amount of hydrochloric acid shown. After standing for five or ten minutes the precipitates were filtered off upon asbestos in Gooch crucibles, washed with concentrated hydrochloric acid, dried sometimes over a low flame (at about 150°–200° C.) and sometimes in an air bath heated to 165° C. and weighed. In several cases the total filtrate was measured and the volume is given in the tabular statement. The results show a considerable solubility amounting to about 1 part in 8000 under the conditions given.

SERIES B.						
Exp.	BaCl <sub>2</sub> . 2H <sub>2</sub> O	Water.	HCl.	Total filtrate.	BaCl <sub>2</sub> .	Loss.
10.	0·5057 gm.	2 cm <sup>3</sup>	25 cm <sup>3</sup>	75 cm <sup>3</sup>	0·4268 gm.	0·0042 gm.
11.	0·5017 “	5 “	50 “	90 “	0·4198 “	0·0078 “
12.	0·5068 “	3 “	50 “	100 “	0·4235 “	0·0085 “
13.	0·5019 “	2 “	100 “	144 “	0·4186 “	0·0082 “

The experiments in Series B were conducted similarly to those of Series A except that the precipitates were allowed to stand 24 hours before filtration. The loss due to solubility was, as is shown by the table, greater than before, due doubtless to the escape of hydrochloric acid gas from the solution.

SERIES C.						
Exp.	BaCl <sub>2</sub> . 2H <sub>2</sub> O	Water.	HCl.	Alcohol.	BaCl <sub>2</sub>	Loss.
14.	0·5011 gm.	3 cm <sup>3</sup>	25 cm <sup>3</sup>	15 cm <sup>3</sup>	0·4228 gm.	0·0043 gm.
15.	0·5096 “	2 “	25 “	10 “	0·4278 “	0·0066 “

The experiments of Series C were conducted in the same manner as those of Series A except that the amount of absolute alcohol indicated was added after the precipitation by hydrochloric acid. The results show that the alcohol neither decreased nor increased the amount of the solubility of the chloride.

SERIES D.					
Exp.	BaCl <sub>2</sub> . 2H <sub>2</sub> O	HCl.	BaCl <sub>2</sub> .	Loss.	
16.	0·5019 gm.	50 cm <sup>3</sup>	0·4249 gm.	0·0029 gm.	
17.	0·5020 “	50 “	0·4257 “	0·0022 “	
18.	0·5020 “	50 “	0·4255 “	0·0024 “	
19.	0·5016 “	50 “	0·4259 “	0·0017 “	
20.	0·5022 “	50 “	0·4267 “	0·0014 “	

In the experiments of Series D the weighed barium chloride was placed in an Erlenmeyer beaker and dissolved in four or five cubic centimeters of water. The indicated amount of acid

was then added, and a stream of hydrochloric acid gas was passed for two hours into the cooled mixture. The precipitates were then treated as in the former experiments. The results show that even in the strongest possible solution, at the ordinary temperature, of hydrochloric acid barium chloride is soluble to a considerable degree, this solubility amounting according to the first three experiments of the series to about one part in 20,000. In Exp. 18 and 19 ten cubic centimeters of absolute ether were added to the solution before passing in the hydrochloric acid gas. The results showed that the ether seemed to decrease the solubility of the barium salt, and therefore the experiments of the following series were undertaken.

SERIES E.

Exp.	BaCl <sub>2</sub> . 2H <sub>2</sub> O.	HCl.	Ether.	BaCl <sub>2</sub> .	Loss.
21.	0.5008 grm.	50 cm <sup>3</sup>	10 cm <sup>3</sup>	0.4267 grm.	0.0002 grm.
22.	0.5002 "	50 "	10 "	0.4257 "	0.0007 "
23.	0.4999 "	50 "	10 "	0.4252 "	0.0009 "
24.	0.4999 "	50 "	10 "	0.4258 "	0.0003 "
25.	0.5003 "	25 "	25 "	0.4259 "	0.0005 "
26.	0.5002 "	25 "	5 "	0.4262 "	0.0002 "
27.	0.5099 "	25 "	5 "	0.4344 "	0.0003 "
28.	0.5003 "	25 "	5 "	0.4261 "	0.0003 "

The experiments of Series E were conducted as follows. The amount of barium salt specified was dissolved in the least, convenient, amount of hot water (about 2 cm<sup>3</sup>) and precipitation was brought about by adding the indicated amount of concentrated hydrochloric acid. The beaker containing the precipitate was then placed in cold water and the amount of ether shown in the tables was added and mixed with the solution by thorough stirring. After standing for five or ten minutes the precipitate was filtered off and washed with concentrated hydrochloric acid containing about ten percentum by volume of absolute ether and dried, sometimes in an air bath at 165°–175° C. and at others over a radiator giving a temperature of 175°–200° C. A constant weight was more quickly obtained by the latter method and it was used exclusively in the experiments of the subsequent series. In using it a low heat was used at first and the temperature was not increased until the precipitate was moderately dry. The results show that barium chloride is practically insoluble in a mixture of hydrochloric acid and ether containing about one-sixth by volume of the latter. The average solubility calculated from the experiments given is one part in 122,000. The actual solubility is less than this since no account was taken of the volume of the washings which were at least equal to the original filtrates.

SERIES F.						
Exp.	BaCl <sub>2</sub> . 2H <sub>2</sub> O.	CaCl <sub>2</sub> .	HCl.	Ether.	BaCl <sub>2</sub> .	Loss.
29.	0.5001 grm.	0.5 grm.	50 cm <sup>3</sup>	10 cm <sup>3</sup>	0.4250 grm.	0.0013 grm.
30.	0.4999 "	0.5 "	50 "	10 "	0.4250 "	0.0011 "
31.	0.5005 "	0.5 "	25 "	25 "	0.4260 "	0.0006 "
32.	0.5002 "	0.42 "	25 "	5 "	0.4258 "	0.0004 "
33.	0.5001 "	0.5 "	25 "	5 "	0.4255 "	0.0008 "
34.	0.5005 "	0.5 "	25 "	5 "	0.4251 "	0.0015 "
35.	0.5001 "	0.5 "	25 "	5 "	0.4254 "	0.0009 "
36.	0.5001 "	0.5 "	25 "	5 "	0.4258 "	0.0005 "
37.	0.5003 "	0.5 "	25 "	5 "	0.4261 "	0.0004 "
38.	0.1002 "	3.0 "	25 "	5 "	0.0842 "	0.0010 "
39.	0.0107 "	3.0 "	25 "	5 "	0.0080 "	0.0005 "
40.	0.5100 "	0.5 "	25 "	---	0.4328 "	0.0020 "

Series F was undertaken to test whether the mode of precipitating barium used in the preceding series would be of use in the separation of the barium from calcium. The experiments were conducted as in Series E, except that the calcium salt was dissolved with the barium chloride. It was necessary to use more water than in Series E to effect solution, but as the barium salt was uniformly the last to dissolve the effect was practically the same as before. The results show that mixtures of barium and calcium in all proportions are perfectly separated by this method, 0.010 grm. of barium chloride being separated with accuracy from 3 grm. of calcium chloride. The calcium does not show the slightest tendency to come down with the barium, and those experiments in which separation was effected by the use of 25 cm<sup>3</sup> of hydrochloric acid and 5 cm<sup>3</sup> of ether gave rather better results than those in which double this volume was employed. It is better not to let the precipitations stand too long before filtration, even if kept cold, as the hydrochloric acid evaporates from the solutions, and experiments in which filtration was delayed for about two hours (e. g., Exps. 33, 34, 35) show a rather larger loss than the average. That there is no advantage in increasing the amount of ether over the proportions used above is shown by Exp. 31 which is comparable with Exp. 25. In the case of Exp. 40, in which no ether was used the result is comparable with the experiments of Series A. The precipitate was washed, however, with the mixture of hydrochloric acid and ether.

## SERIES G.

Exp.	BaCl <sub>2</sub> . 2H <sub>2</sub> O.	MgCl <sub>2</sub> . 6H <sub>2</sub> O.	HCl.	Ether.	BaCl <sub>2</sub> .	Loss.
41.	0.4999 grm.	0.5 grm.	25 cm <sup>3</sup>	5 cm <sup>3</sup>	0.4253 grm.	0.0007 grm.
42.	0.5000 "	0.5 "	25 "	5 "	0.4257 "	0.0005 "
43.	0.1002 "	3.0 "	25 "	5 "	0.0844 "	0.0008 "
45.	0.0100 "	3.0 "	25 "	5 "	0.0077 "	0.0008 "

The experiments of Series G were made in exactly the same manner as those of Series F, except that varying amounts of magnesium chloride were present instead of the calcium salt. The results are uniform and exact, and indicate that barium may be separated from magnesium when the two are present in any proportion. It is probable that if magnesium chloride were present in an amount larger than 3 grm. in 30 cm<sup>3</sup> it would be necessary to make two treatments, as under those circumstances it shows a slight tendency to precipitate. The amount of mixed salts present should always, therefore, be kept below this limit.

*Recapitulation.*—Barium chloride is soluble to an extent not exceeding one part in 20,000 in pure concentrated hydrochloric acid, but the solubility increases very rapidly with the diminution in the strength of the acid. In concentrated hydrochloric acid containing ether it is soluble to an amount not exceeding one part in about 120,000. To utilize this fact for the separation of barium from calcium and magnesium the chlorides of the earths are dissolved in the least possible amount of boiling water and precipitated by 25 cm<sup>3</sup> of concentrated hydrochloric acid with the addition of 5 cm<sup>3</sup> of absolute ether after cooling. The acid should be added drop by drop at first allowing the precipitate formed to redissolve as long as possible, as the precipitate is thus obtained in a coarse crystalline condition and filters very quickly and is less liable to include foreign matter. After standing a few minutes the precipitate is to be filtered in a Gooch crucible, washed with hydrochloric acid containing about 10 per cent of ether and dried at 150°–200° C. The method is accurate and rapid, and possesses the further advantage when a number of determinations are to be made that the precipitate may be dissolved off of the felt by a little water and, after ignition, the crucible and felt may be used again without re-weighing. A felt upon which half a dozen precipitates were weighed did not change its weight to the extent of one-tenth of a milligram. The fumes of the strong acid cause no inconvenience if the filtration is performed in front of a good flue. A gas flame may be used in the flue without danger from the ether which seems to be firmly held by the hydrochloric acid. A flame was used to increase the draught in all of the experiments given and with entire safety, even when the filtrate contained 50 per cent by volume of ether.

The author wishes in concluding to acknowledge his indebtedness to Prof. Gooch for many helpful suggestions freely given in the course of the investigation.

ART. LXVI.—*Note on the Absorption of Radiant Heat by Alum*; by C. C. HUTCHINS, Bowdoin College.

It seems to be the generally accepted opinion that a solution of alum acts as a particularly efficient absorber of rays of great wave length. It is certain that the alum cell is universally used and recommended wherever a transparent medium is desired for cutting off the so-called "dark" heat rays.

In the April number of this Journal Mr. F. J. Rogers states that the results of Julius Thomsen are in error because Thomsen used pure water instead of alum solution as an absorber.

Whence this idea in regard to the effect of alum solution arose it is difficult to say: I have searched in vain for any authority for it. Melloni's table, as far as it goes, shows that bodies in solution raise slightly the percentage of transmitted rays above that which passes through pure water.

I prepared a saturated solution of potash alum in distilled water and placed it in a cell  $0.6^{\text{cm}}$  thick. The sides of the cell were quartz plates  $0.15^{\text{cm}}$  thick. My heat-measuring apparatus was used to determine the transmission of the rays from a naked gas jet through this cell. The mean of ten galvanometer readings was 201 divisions.

The cell was then filled with pure water and the mean of ten readings found to be 196 divisions, showing, if anything, that water is a slightly better absorber than alum solution. When two hundred ohms resistance were added in the galvanometer circuit, the deflection produced by the unobstructed gas jet was 240 div. Through the water cell it was 21.5 div. and the per cent transmitted was 8.9. When a sheet of plate glass  $0.7^{\text{cm}}$  thick was interposed the deflection was 86 div. and the per cent transmitted was 35.8. Melloni shows that alum in its crystalline form cuts off all save nine per cent of the rays from a Locatelli lamp.

It is not easy to find perfect crystals of alum, but among a large number of ordinary crystals one was found from which a nearly flawless plate was cut. The plate was given a perfect polish on both sides by Brashear's method of working rock-salt surfaces. The plate was  $0.37^{\text{cm}}$  thick, and the deflection of the galvanometer by the gas jet through the plate was 23.4 div. and the per cent transmitted 9.7.

Hence it appears that a solution of alum is no better absorber than is water; and furthermore, that it would hardly pay to use plates of transparent alum, even if they were to be had.

ART. LXVII.—*Disruption of the Silver Haloid Molecule by Mechanical Force*; by M. CAREY LEA.

[Read before the National Academy, April, 1892, by Dr. George F. Barker.]

IN a paper published about a year ago on the subject of allotropic silver there was included an investigation into the action of the different forms of energy upon silver chloride and bromide.\* It was there shown that these substances possessed an equilibrium so singularly balanced as to be affected by the slightest action of any form of energy. Such action produced a change which though it might be wholly invisible yet caused the breaking up of the haloid when subsequently placed in contact with a reducing agent. The forms of energy with which this effect was observed are :

- 1st. Heat.
- 2d. Light.
- 3d. Mechanical force.
- 4th. Electricity (high tension spark).
- 5th. Chemism.

• It follows therefore that it is not light only that is capable of producing an invisible image *but that this power belongs alike to all forms of energy*. So that a slight impulse from any one of the forces just mentioned brings about a change in the equilibrium of such a nature that the molecule is more easily broken up by a reducing agent.

As respects four out of these five forms of energy, it was further shown that when made to act more strongly, they were able of themselves to disrupt the molecule without external aid. One form alone of energy, mechanical force, made an apparent exception to this general rule. The other four, when applied to a moderate extent, produced a latent image, applied more strongly they broke up the molecule.

The object of the present paper is to prove that this exception does not exist, and that as all forms of energy have been shown in the previous papers of this series to be capable of impressing an invisible image, so also with stronger manifestations, *any form of energy is capable of disrupting the molecule*.

I was able to show many years ago that mechanical force could produce a latent image. Lines drawn with a glass rod on a sensitive surface could be rendered visible by development in the same way as impressions of light. An embossed card pressed on a sensitive film left an invisible image which

\* This Journal, April, 1891.

could be brought out by a reducing agent. The raised portions of the embossed work exerted a stronger pressure on the sensitive film than the rest of the card and these portions darkened when acted upon by a reducing agent. In the same way, the lines traced with a glass rod blackened under a developer. In each case, it was the portions which had been subjected to pressure which yielded first to the reducer. It was therefore clear that in the molecules which had received this slight pressure the affinities of the atoms had been loosened.

To bring these phenomena fully into line with the others it is now necessary to prove that an increased pressure can take the place of a reducing agent and disrupt the molecule. And this is actually the case.

It was found that the breaking up could be produced in two ways, by simple pressure, and by shearing stress. Silver chloride and bromide formed and washed in absence of active light were subjected to these agencies.

1. *Simple Pressure.*—In the first trial made with silver chloride, it was enclosed in asbestos paper which had been first ignited with a blast lamp to remove all traces of organic matter present. This method was tried in order that the chloride should be in contact with perfectly inactive material only, but it was not found to answer. The great pressure employed forced the dry chloride into the pores of the paper cementing it together, so that the opposite sides could not be separated. Platinum foil was then substituted with satisfactory results. With a pressure of about one hundred thousand pounds to the square inch, maintained for twenty-four hours, the chloride was completely blackened except at the edges, where owing to greater thinness the pressure was less. Very bright foil was used in order to detect the slightest discoloration that might occur, but none resulted; it was impossible to distinguish the portions which had been in contact with the darkened chloride from those that had not. The chloride did not assume the usual chocolate color, but changed to a deep, greenish black.

Silver bromide gave exactly the same results. It should be mentioned that the silver chloride and bromide were each precipitated with an excess of the corresponding acid.

As silver iodide precipitated with excess of potassium iodide is not darkened by light, it seemed improbable that it should be by pressure. The experiment was however tried and it was found that the iodide darkened fully to the same extent as the others. This result surprised me so much that the experiment was repeated with every possible precaution. The result left no doubt that silver iodide, as well as the chloride and bromide is blackened by great pressure. All three silver haloids take on the same coloration, an intense greenish black. It was

found best to use the material air-dried. If at all moist the platinum foil bursts under the pressure and the experiment is invalidated. The air-dried salt retains a sufficient quantity of moisture.

2. *Shearing Stress.*—As a means of applying this form of force, the silver chloride precipitated with excess of hydrochloric acid and well washed, was put into a porcelain mortar and well triturated. The improbability that the small quantity of force that can be applied in this way would break up a stable molecule like that of silver chloride seemed so great, that at first, a substance tending to aid the reaction was added. Tannin was selected and when forcibly ground up with silver chloride the latter was soon darkened. Next a substance capable of taking up acid but having no reducing action was tried. Sodium carbonate was used. This also caused the chloride to darken. Finally it was determined to ascertain if the molecule of silver chloride could not be disrupted by stress alone. The chloride was placed in a chemically clean porcelain mortar and well triturated. For some time no effect was visible. After about ten minutes' action dark streaks began to appear and after five minutes' more work a considerable portion of the chloride was darkened. The end of the pestle was covered with a shining purple varnish. It had not become perceptibly warmer to the touch. On the violet purple substance nitric acid had no action, but aqua regia slowly whitened it. It was therefore what I have proposed to call silver photochloride, that is, a molecular combination of chloride and hemichloride. This experiment was carefully repeated with the same result. Silver bromide similarly treated gave a similar result. It was noticed that both chloride and bromide in darkening took on the familiar color between chocolate and purple, so generally seen in the darkening of these silver salts and differing strikingly from the greenish black color assumed by all three silver haloids under simple pressure.

The fact that the platinum foil remained absolutely unattacked when the silver haloid was reduced by simple pressure in actual contact with it, is interesting and would seem to show that in the reduction of the silver haloid the halogen is not at any time set free but that water, if present, is decomposed at the same moment with formation of halogen acid.

The observations recorded in this paper prove the existence of a perfect uniformity in the action of all kinds of energy on the silver haloids. The balance of the molecule is at once affected by the influence of any form of energy. A slight application produces an effect which, though invisible to the eye, is instantly made evident by the application of a reducing agent. The bonds which unite the atoms have evidently been in some

way loosened so that these molecules break up more easily than those to which energy has not been applied. Consequently, if the substance is submitted to the action of light, heat, or electricity, or if lines are drawn by a glass rod (shearing stress) or with sulphuric acid (chemism), a reducing agent blackens the parts so treated before it affects the parts not so treated. This justifies the statement made earlier in this paper that the phenomena of the latent image and of its development are not exclusively, or even especially connected with light, as hitherto supposed, but belong to all other forms of energy as well.

It is therefore true that every form of energy is not only capable of producing an invisible image, that is, of loosening the bonds which unite the atoms, but is also capable, if applied more strongly, of totally disrupting the molecule. This law, in a general form was proved in previous papers, with but a single exception, and that one exception is removed by the observations recorded in this paper.

As far as observation has gone silver compounds are the only ones that exhibit this universal sensitiveness. Of other substances, some are decomposed by heat, some by electricity or by chemical action and a few by light.

It has now been shown, as I believe for the first time, that mechanical force is competent without the aid of heat to break up a molecule that owes its existence to an exothermic reaction.

It is important to distinguish between the two treatments here described. In the case of shearing stress, force is expended in overcoming friction and in so doing produces heat. It may be questioned, however, whether the very small amount of heat thus generated has anything to do with the reaction. The heat is not perceptible, it is momentary, and it has been elsewhere shown that though moist silver chloride can be broken up by heat, the action is slow even at a temperature of 100° C.

In the case of simple pressure heat certainly plays no part. The material is small in quantity, is folded up in metal, is placed between large and heavy pieces of metal and the pressure is applied gradually by means of a screw. Even supposing a slight increase of temperature, it could not exceed one or two degrees and would be momentary. As just remarked, heat does not produce an effect except at about 100° C. and after many hours.

The powerful affinity which exists between silver and the halogens is well known. That this affinity can be counteracted and annulled by simple pressure—that the halogen can in part be forced out of the molecule by mechanical means unaided by heat, is remarkable.

It need scarcely be said that this phenomenon has nothing in common with decompositions produced by mechanical force in substances such as silver or mercury fulminate, nitrogen chloride and similar explosives. Such substances are all formed by endothermic reactions and their decompositions are exothermic. Heat does not need to be supplied, but only what Berthelot has named a "travail préliminaire," an impulse to start the reaction. But silver haloids are formed by exothermic reactions, consequently their decompositions are endothermic and require that the energy which was disengaged in their formation should be returned to effect their decomposition. The experiments described in this paper show that mechanical force may be made to supply this energy and so play the part of light, electricity or heat without previous conversion into any other form of energy.

The thermochemical reactions of the silver haloids have been studied by Berthelot and their reductions were found to be endothermic.\* There can be no doubt therefore that an endothermic reaction can be brought about by simple pressure.

Philadelphia, April, 1892.

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## SCIENTIFIC INTELLIGENCE.

### I. CHEMISTRY AND PHYSICS.

1. *On the Polarization of Platinum by Oxygen and Hydrogen.*  
—A series of measurements has been made by MARKOFSKY to ascertain the difference of potential developed between a plate of platinum entirely immersed in dilute sulphuric acid, freed from air by boiling, and a second plate partly immersed in this liquid and partly exposed to an atmosphere of pure hydrogen or pure oxygen gas. The experiments were varied by using an acid containing platinum sulphate, the strength of the solution being different in different experiments. Carbon electrodes were also employed in place of platinum. He finds that the potential-difference between a platinum plate in hydrogen and one in dilute acid free from gas, is 0.646 volt. If oxygen be substituted for the hydrogen, the polarization is reversed in direction and is equal to 0.372 volt. Moreover, this potential-difference remains the same whether the gases employed are produced electrolytically or by chemical processes. The author observed that the addition of platinum sulphate to the acid increases the potential-difference in

\* *Mécanique chimique*, vol. ii, p. 411. The reduction of silver chloride to metal involves an absorption of Cal. 29.4. That to hemichloride has not been measured, but is, according to Berthelot, also endothermic. See also, Ditte, *Les Métaux*, I, pp. 232, 233.

the case of a hydrogen cell while this addition decreases it in the case of a cell containing oxygen. His results show the potential difference to be independent of the density of the gas and of its temperature up to 70°. With carbon electrodes, however, the phenomena obtained were quite different.—*Am. Phys. Chem.* II, xlv, 457; *J. Chem. Soc.*, lxii, 393, April, 1892. G. F. B.

2. *On the Basicity of Phosphoric Acid.*—D. BERTHELOT has studied the relative conductivities of the monobasic and dibasic phosphates and has shown that while the conductivity is the same for the monobasic ammonium and potassium phosphates, the conductivity of the dibasic ammonium salt is about six per cent less than that of the potassium salt. Moreover, in the case of the tribasic phosphates the conductivities are widely different, that of the potassium salt being much the greater. It is well known that when potassium, sodium or ammonium hydroxide is continuously added to a dilute solution of phosphoric acid, the decrease in the electrical conductivity of the solution is represented by a straight line up to the point at which one of the basicities of the acid is neutralized. So that, as it would appear, these three monobasic phosphates are not dissociated even in dilute solutions. At this point the conductivity-curve shows a well-marked angular deflection, and on continuing to add the base, the resulting increase in conductivity is again represented by a straight line up to the point corresponding to the formation of a dibasic phosphate. Consequently, these dibasic phosphates must also be stable even in dilute solutions. If more base be added, another change occurs in the direction of the curve, but now the change in conductivity is no longer represented by a straight line. Moreover there is no further change in direction at the point corresponding to the formation of tribasic phosphate. Hence the tribasic alkali phosphates are almost completely dissociated in dilute solutions. If the solution be made stronger, a distinct although small angular deflection may be observed at the point corresponding to the formation of tribasic phosphate. It would seem, therefore, that phosphoric acid differs materially from the true tribasic acids, such as citric, aconitic and tricarballic, in the fact that in the case of these acids the monobasic and dibasic salts are partially dissociated in solution, while the tribasic salt is stable. Since according to Lenz the ammonium and potassium salts of strong acids show the same conductivity in dilute solution, while according to the author's experiments the conductivities of these two salts with feeble acids are distinctly different, though approximately the same, and the conductivities in the case of phenol are entirely different, he concludes that the first acid function of phosphoric acid is analogous to that of strong acids, the second to that of feeble acids and the third to that of phenols. In fact therefore phosphoric acid is not a true tribasic acid, but a monobasic acid with a complex function. Similar conclusions follow from thermochemical data.—*C. R.*, cxiii, 851, *J. Chem. Soc.*, lxii, 394, April, 1892. G. F. B.

3. *On the Occlusion of Hydrogen by Lead and other Metals.*—In order to explain certain physical phenomena of secondary battery action, NEWMANN and STREINTZ have examined the absorption of hydrogen by metals and especially lead. Two methods of charging the metal with the gas were employed: (1) charging electrolytically and (2) charging by passing the gas over or through the fused metal. Previous experimenters had used the former method; but since the plates were subsequently exposed to the air, the hydrogen was oxidized. The author therefore washed his plates in the absence of air with air-free water and dried them in pure carbon dioxide. But on igniting them only a trace of hydrogen was obtained. In using the second method, the metal was heated in pure hydrogen, the excess of hydrogen was expelled by means of nitrogen, and the metal was again heated in oxygen; whereby the occluded hydrogen was burned to water which was weighed. The following are the values obtained, the numbers representing the volumes of hydrogen absorbed by one volume of metal: Lead 0·15, 0·11; palladium 502·35 (at 450°); platinum sponge 29·95, 15·37, 12·13, 6·48; platinum black 49·30; gold 46·32, 37·31; silver 0·00; copper 4·81, 4·78; aluminum 2·72; iron 29·17, 9·38; nickel 16·85, 17·57; cobalt 153·00, 59·31. In the case of platinum sponge, of iron, of nickel and of cobalt, the successive values decrease with the same specimen of metal; the power of occluding the hydrogen diminishing with repeated use of the same sample.—*Monatsb. f. Chem.*, xii, 642; *Ber. Berl. Chem. Ges.*, xxv, (Ref.) 187, March, 1892. G. F. B.

4. *The Principles of Chemistry*; by D. MENDELÉEFF. Translated from the Russian (Fifth Edition), by George Kamensky. Edited by A. J. Greenaway. 2 vols. 8vo, pp. xvi, 611, vi, 487. London and New York, 1891. (Longmans, Green & Co.).—The first edition of this book, issued in 1870, marked an epoch in the history of chemistry, since in it was enunciated for the first time the periodic law of the elements, so inseparably connected with the name of its author. In reproducing the fifth edition in English, a great service has been done for chemical science among English-speaking people which cannot fail to produce a marked effect. The book itself is remarkable in many ways. In the first place, its treatment of the subject matter is profound and far-reaching. The author says: "The desire to direct those thirsting for truth to the pure source of the science of the forces acting throughout nature forms the first and most important aim of this book. The time has arrived when a knowledge of physics and chemistry forms as important a part of education as that of the classics did two centuries ago. In those days the nations which excelled in classical learning stood foremost just as now the most advanced are those which are superior in the knowledge of the natural sciences." The object of the book is "to acquaint the student not only with the methods of observation, the experimental facts and the laws of chemistry, but also

with the aspect of this science towards the invariable substance of varying matter." In it, "experimental and practical data occupy their place, but the philosophical principles of our science form the chief theme of the work." "In comparing the science of the past, the present and the future, in placing the particulars of its restricted experiments side by side with its aspirations for unbounded and infinite truth, and in restraining myself from yielding to a bias towards following the most attractive representation, I have endeavored to incite in the reader a spirit of inquiry, which, unsatisfied with speculative reasonings alone, should subject every idea to experiment, excite the habit of stubborn work, necessitate a knowledge of the past, and a search for fresh threads to complete the bridge over the bottomless unknown." Such a standpoint as this is unique in chemical treatises. And an examination of the book shows these claims to have been fully met. Not only is the entire work based upon the law of periodicity, but a vein of what the author calls "scientific contemplation" runs through it, which "bears the stamp of creative power and comprehends the highest branch of scientific progress." In the second place, the book exhibits an exceptional fidelity to details, not only along the main line of the subject, but along collateral lines. Perhaps the most noticeable typographical feature in it, is its wealth of foot-notes, which occupy probably one-half of the entire text. These the author suggests, should be read only after the large text has been mastered. But so seductive are they and so valuable in their bearing upon the subject in hand, that no reader will be likely to postpone them to a second reading. Thus for example, the first footnote considers in what the investigation of a substance or phenomenon of nature consists. And after enumerating seven points which go to make it up, the author says: "It is certain that it is only possible to thus study when we have taken as a basis some incontestible fact which is self-evident to our understanding; as for instance, number, time, space, movement, or mass. The determination of such primary or fundamental conceptions (categories) although not excluded from the possibility of investigation, frequently does not subject itself to our present mode of scientific generalization. Hence it follows in the investigation of anything there always remains something which is recognized without investigation or admitted as a known factor." Evidently, therefore, while Mendeléeff's book may not be the best one for a beginner to essay, it is decidedly the most desirable one for the chemical student to read at some stage of his scientific education. The knowledge which it contains is indispensable in a course of thorough chemical training.

The translation, in the main, has been faithfully performed, in spite of the difficulties inherent to such a task. We regret, however, that the original wood-cuts have not been reproduced in the English edition. The thanks of English and American chemical students are due the publishers for placing in their hands and their

own language the most philosophical work on chemistry which the nineteenth century has yet produced.

G. F. B.

5. *Manual of Chemical Technology*, by *Rudolf von Wagner*, translated and edited by WILLIAM CROOKES, F.R.S., from the thirteenth enlarged German edition as remodelled by Dr. FERDINAND FISCHER. 968 pp. large 8vo, with 596 illustrations. New York, 1892, (D. Appleton and Co.).—Wagner's Chemical Technology has so long been a standard work of reference, both in the original form and in the English translation, that it hardly seems to call for new commendation. The present edition, however, is substantially a new work and has many excellent features of matter and arrangement due to the present editors. The last edition prepared by Wagner himself was the eleventh, published shortly before his death in 1880. In the latest (13th) German issue, a new and more logical arrangement of the subject-matter has been adopted, many new subjects have been introduced and others have been thoroughly revised. Thus it is stated that, as compared with the eleventh edition, more than half the text and illustrations are new. The former English edition appeared twenty years ago; the present one is based upon the 13th German edition, and the English editor has made various minor modifications, and added many explanatory notes, bibliographical references, etc., to adapt it to home conditions.

The book is rich in valuable information in every branch of chemical technology and is indispensable to all interested in this field.

6. *Laboratory of Chemistry*, by J. E. ARMSTRONG and J. H. NORTON. 144 pp. 8vo. New York (American Book Company).—This is a useful little book detailing 164 experiments to be performed by the student in the laboratory. The experiments are well selected and described with sufficient fulness; with the aid of a competent teacher they should give good results.

7. *Untersuchungen über die Ausbreitung der elektrischen Kraft* von Dr. HEINRICH HERTZ. 294 pp. 8vo, Leipzig, 1892. (Johann Ambrosius Barth.)—It would be difficult to find, in the recent literature of the subject of Physics, contributions more distinctly "epoch-making" than those of Hertz, carried on through the last five years, on the production and propagation of electrical waves. These papers discuss, in a word, the production of electrical waves by the oscillatory electric discharge, as of an induction coil; their propagation through the ether; reflection from metallic surfaces; refraction through non-conductors; interference, polarization, and in fact all the phenomena characteristic of light waves, to which indeed they correspond although relatively of enormous length. By them Maxwell's theory in regard to the mutual connection between electrical and light phenomena has received the most signal confirmation, and new directions for experiment and theory have been opened out in which other workers also have gained, and are gaining, important results. The original papers have been for the most part published in Wiedemann's

AM. JOUR. SCI.—THIRD SERIES, VOL. XLIII, NO. 258.—JUNE, 1892.

Annalen and are hence not inaccessible, at the same time the subject is one of such unique interest that their republication in a single volume is a service on the part of the publishers for which all physicists will be grateful. Moreover, this has given the author an opportunity to present a general summary of the subject from the present standpoint with the correction of some errors, and this gives unity and completeness to the whole subject.

8. *Vorlesungen über Maxwell's Theorie der Elektrizität und des Lichtes* von Dr. LUDWIG BOLTZMANN. I Theil, Ableitung der Grundgleichungen für ruhende, homogene, isotrope Körper. 139 pp. 8vo. Leipzig, 1891.—This volume is a highly valuable contribution to the subject of Maxwell's theory. Starting from Helmholtz's theory of cyclical movements, the author has developed the theory of electrical oscillations in circuits with condensers; then the general equations of electrical movement in stationary homogeneous and isotropic conductors and semiconductors, with applications to the fundamental problems of electrodynamics, induction, electrostatics and the theory of light. The author intends to follow this contribution by other parts in which he will give the application to anisotropic bodies and those in motion, the theory of dispersion, double refraction, the rotation of the plane of polarization and finally the oscillations discovered by Hertz.

## II. GEOLOGY AND NATURAL HISTORY.

1. *A Summary Description of the Geology of Pennsylvania*, in three volumes, with a new Geological Map of the State, a map and list of Bituminous Mines and other illustrations; by J. P. LESLEY, State Geologist. Vol. I, 719 pp. 8vo. Harrisburg, Pa.—The long series of Annual Reports of the Second Geological Survey of Pennsylvania, under Prof. Lesley as Director, yield in value to none from the other State surveys. They do not comprise a full account of the animal paleontology of the State and some points are left doubtful on this account. But in other respects the geology has been well studied and described by an able corps of geologists; and, in view of the position of the area with reference to the Appalachians, and its comprising the whole Paleozoic series, the final Summary Report should be a work of great interest. The first of the three volumes of the final Report, has been recently issued. It treats of the Laurentian, Huronian, Cambrian and Lower Silurian formations. It opens with extended remarks on the nature and uncertainties of geological knowledge and reasoning. The discussion of the various views of the investigators of the Archæan and Cambrian formations occupy the next 120 pages. In the remaining part of the volume, treating of the overlying formations, and their stratigraphical relations, many sections and maps illustrate finely the flexures and positions of the rocks, and several pages of plates, made up of figures of fossils from various sources, are intro-

duced to afford information on the life of the several periods. Further, Prof. Lesley has given the volume a practical value by devoting many of its pages to the mines and ores of iron connected with the Lower Silurian and older rocks, to the limestone and slate quarries, and to unsuccessful searchings in these inferior formations for mineral oil and gas.

2. *Fossil Botany; being an Introduction to Palæophytology from the Standpoint of the Botanist.* By H. GRAF ZU SOLMS-LAUBACH. Authorized English translation, by HENRY E. F. GARNSEY; revised by ISAAC BAYLEY BALFOUR. Oxford, 1891. 401 pp., 49 illustrations.—Owing to the fact that by far the greater part of the material considered by Count Solms in the present work is Paleozoic, the remainder being taken almost exclusively from the Older Mesozoic, the student of recent plants is neither conducted back along the chain of vegetable life in geological time from present types to their remote ancestors, nor may he, after discussing the generally somewhat problematic Paleozoic plants, proceed to view, by the light of ample illustrations, the development or gradual succession of plant life up to the recent forms. The entire Angiospermic era in the history is wanting, and relatively little is given to show the connection of the fossils discussed with the living forms. The paucity of figures, without systematic descriptions, as well as its biological character, render the work of but minor value to the geologist. Its great use will be to the paleontologist; not as a handbook or manual—it is too abridged and we have other good handbooks nearly contemporaneous with the German edition—but as embodying the views of a justly distinguished structural botanist, reasoning from the botanical standpoint, in a field of troubles wherein the every-day workers are too often unfamiliar with the morphology and histology of recent plants. To the paleobotanist the work is indispensable if for nothing more than the author's opinions and conclusions which are expressed with fairness and conservatism. Its value is further increased by his criticism and verification of many originals of other workers as well as by many previously unpublished observations made from new material.

It is unfortunate that, however much a review from time to time of the existing knowledge of fossil floras may be needed, the same rapidity of progress in paleobotany which makes a résumé so necessary at a given time soon leaves that résumé, with the writer's opinions, among the historical literature of the science. There are but few fields in which discoveries more strongly affecting the ideas of ancient organic life have been made within a few years, and perhaps no science in which classificatory delimitations have shifted about more, than in Paleozoic phytology. It is, therefore, not a little disappointing to find in this authorized translation, dated four years after the German edition, no mention made of the wealth of valuable researches, some of them fundamentally modifying our ideas of the develop-

ment of certain types, recorded during the intervening four years. Surely a few of the most important of these works, such as Williamson's recent memoirs on the Organization of the Carboniferous plants, in which, among other things, the secondary growth in some Paleozoic fern stems is demonstrated, Zeiller's classical monographs on the Valenciennes and Autun floras, Renault and Zeiller's Commeny flora, Dawson's Geological History of Plants, with new additions to our knowledge of the pre-Carboniferous floras, Stur's detailed examination of the Schatzlar Calamariæ, Kidston's studies among the British collections, Weiss's Sigillariæ, and possibly Grand'Eury's flora of the Gard basin, with its correlative and synthetic discoveries, should have been given at least foot-note mention or comment.

It would have given much satisfaction to American readers, if Count Solms had included in his consideration the very interesting, and in some respects unique types described from the Lower Carboniferous of Ohio by Newberry in 1873 and Andrews in 1875, both of whose reports, published in the Ohio Paleontology, are not even mentioned. But though unrevised, and virtually unillustrated, Solms-Laubach's will for a long time be an invaluable reference work for vegetable paleontologists; and while many will wish that the systematic names were distinguished in some way in the print of the Oxford edition, most of us are obliged for the translation.

D. W.

3. *Ueber einige carbone Pflanzenreste aus der Argentinischen Republik*; von Dr. LADISLAUS SZAJNOCHA. Sitzb. k. Akad. Wiss., Wien, Math.-Nat. Cl., vol. c, Abth. 1, 1891, pp. 199-209 [1-11], Pl. I, II.—The results, which Dr. Szajnocha presents in this preliminary publication, of the examination of a few specimens of fossil plants from the Argentine Republic are of great interest from the fact that they offer the first satisfactory proof of the existence of the Carboniferous system in that great territory. Six species were found whose identities and affinities show that the horizon is in the Carboniferous system, and most probably in the Sub-carboniferous. Two, perhaps three, of the species are found in the United States. The approximate locality, Retamito, Prov. San Juan, is in about 32° S. lat., near the provincial border on the railroad from San Juan to Mendoza. The previously known South American Carboniferous plant-bearing localities, the material from which was studied by Carruthers, are in the provinces of S. Catharina and Rio Grande do Sul, Brazil, and belong to horizons probably much higher than that now recognized in the Argentine.

4. *Cambrian of Sardinia*.—A paper on the Cambrian slates of Sardinia by J. G. BORNEMANN is contained in the 56th volume of the Nova Acta Academiae L.-Car. Germ. Naturæ Curiosorum, Halle, 1891. It is illustrated by 10 plates and describes a number of new species of Trilobites and other species. Four new genera of Trilobites are introduced: *Olenopsis* (*O. Bornemanni* being *Olenus Zoppi*, var. *elongata*, of Meneghini), *Meta-*

*doxides* (*M. torosus*=*Paradoxides torosus* of Meneghini), *Meneghinella*, and *Giordanella* (*Ilænus Menghini* of Bornemann, 1883). The beds afford also two new species of *Archæocyathus* and a related species called *Dictyocyathus tenerrimus*; also among Gasteropods, a *Capulus* (?) a *Carinaropsis* (?) and a *Bellerophon* (?), also a *Confervites*.

5. *Fossils in the St. Peter's Sandstone*.—The sandstone in the railroad cuts about five miles south of St. Paul, Minnesota, has afforded Mr. F. W. SANDESON fossils of the species *Murchisonia gracilis*, and probably *M. tricarinata*, a probable *Maclurea*, *Cypricardites rectirostris* Hall, and two other species of the genus, and a doubtful *Modiolopsis*. They resemble species found in the lower part of the Trenton shales and in the Trenton limestone overlying the St. Peter's sandstone.—*Bull. Minn. Acad. Nat. Sci.*, iii, 318.

6. *Correlation Papers: The Eocene of the United States*, by WM. B. CLARK, *Bull.* 83, U. S. Geol. Survey. This makes the fourth of the valuable series of Correlation papers published by the U. S. Geological Survey.

7. *Glacier Rock-crushing*.—Mr. W. G. TIGHT has described, and illustrated by fine phototypes various examples of the crushing of the surface rocks near Newark, in Licking Co., Ohio, in the Bulletin of the Scientific Laboratories of Denison University, vol. vi, p. 12.

8. *The System of Mineralogy of James D. Dana, 1837-1868: Descriptive Mineralogy*. Sixth edition by EDWARD S. DANA.—Entirely rewritten and much enlarged, illustrated with over 1400 figures, pp. i-lxii, 1134, large 8vo. New York, 1892, (John Wiley and Sons.)—Twenty-four years have passed since the fifth edition of this work was published, and the rapid progress of the science during that time, as also the development of the plan of the work, have made the rewriting of nearly the whole necessary, with an addition of about one-half to the size. In general, the excellent and well tried plan of the former edition has been retained, especially as regards the historical lists of synonyms, the system of classification, and the concise and compact arrangement and style of description. Changes, however, of more or less importance are made at many points, and in certain directions the work has been done over again from the foundation.

Some details in regard to the work are here condensed from the Preface. On the crystallographic side it has been the attempt to trace back to the original observer the fundamental angles for each species, then the axes have been recalculated from them, and finally the important angles for all common forms have been calculated (anew, in every case), from these axes. The lists of forms have been made up as completely as possible from the original authorities, with the symbols on both the systems of Miller and Naumann, though the preference is given to the former. References to the authors are given freely; and these, with the others relating to the history of the names, and further those in connection with the lists of

analyses, present a fairly complete literature, in compact form, for each species. Where, in the case of common species, the literature is very voluminous and has been carefully worked up by some author, this source of minuter detail is also indicated. Of the figures, about 1400 in number, all but very few of those in the body of the work have been made anew and a large part, particularly those illustrating American species, have been drawn from original data. The habits of the crystals, methods of twinning, and the physical characters, especially those on the optical side, have been carefully rewritten and in general are given with much fulness. In the lists of analyses, the plan has been to give all that are useful for a complete understanding of the composition of each species. This means all reliable analyses in the case of the rare species or those of complex composition, but in the case of some common species only the most important and typical are selected; also where the old analyses have been largely superseded, in consequence of the more accurate results of new chemical methods, reference is made for them to the former edition. In this and in other directions the preceding edition must still retain its importance in the history of the science.

9. *On the supposed occurrence of Platinum in North Carolina.*—Prof. F. P. VENABLE has made a critical examination of the evidence upon which the often repeated statements rest, that platinum has been found in North Carolina. The conclusion reached is that this evidence (based chiefly upon the report of Shepard) has very slight value. Recent careful attempts to find platinum in the gold washings have failed. The only definite account of its occurrence is that of Clingman, reported by Shepard, which is far from being conclusive.—*Journ. Elisika Mitchell Sci. Soc.*, vol. viii, Pt. II.

10. *A Summary of Progress in Mineralogy and Petrography in 1891*, by W. S. BAYLEY.—Professor Bayley's notes reprinted from the pages of the monthly issues of the "American Naturalist" give a useful record of the year's work in Mineralogy and Petrography.

11. *Gay-lussite from San Bernardino Co., California.*—An account is given by H. G. HANKS in the *Mining and Scientific Press* of March 26, of a peculiar variety of Gay-lussite from the borax fields of San Bernardino Co., California. It forms a confused semi-crystalline mass without well defined crystals. It is interesting as representing the variety from which, in the opinion of the author, the thimolite of Lake Lahontan and Mono Lake has been formed.

### III. MISCELLANEOUS SCIENTIFIC INTELLIGENCE.

1. *Report of the Smithsonian Institution for 1890.*—The Smithsonian Institution, whose multifarious work for the advancement of science is of the very highest importance to the country, has recently issued its Annual Report for 1890, and the Report of the U. S. National Museum for 1889. The value of

the Annual Report is increased, as usual, by the republication of various recent scientific papers of difficult access to most interested readers besides Reports of Progress in some departments. The latter include Reports on the Progress of Astronomy for 1889, '90, by W. C. WINLOCK, and on the Progress of Anthropology by O. T. MASON : also papers On the Age of Bronze in Egypt by O. MONTÉLIUS ; the prehistoric races of Italy by Canon I. TAYLOR ; On the Antiquity of Man by JOHN EVANS ; On Temperature and life by H. DE VARIGNY ; the researches of Dr. R. KÆNIG on the physical Basis of Musical Harmony by Prof. S. P. THOMPSON ; On the Physical Structure of the Earth by H. HENNESSY ; On Color-vision and Color-blindness by R. B. CARTER, and others. The Report of the National Museum contains, besides many other papers, a full account by WM. J. THOMPSON of the U. S. Navy, of Easter Island, its people, geology, antiquities, and hieroglyphic tablets with their interpretation, illustrated by many fine plates and occupying over 100 pages ; a paper on Aboriginal Skin-dressing, with many illustrations, by O. T. MASON ; on Animals recently extinct or threatened with extermination by F. A. LUCAS, with many plates, among these a colored plate (facing p. 647) of the "Tile Fish," the most remarkable case of extinction on record, reported upon by Prof. Verrill in 1882 in this Journal, xxiv, 366, and in 1884 by J. W. Collins in the Report of the Commissioner of Fish and Fisheries for 1882, Washington, 1884.\*

The volume closes with a list of the publications of the Museum during the year ending with June 30, 1889.

2. *Boston Society of Natural History*.—A Grand Honorary Prize, placed at the disposal of the Boston Society of Natural History by the late Dr. William J. Walker "for such investigations or discovery as may seem to deserve it, provided such investigation or discovery shall have been made known or published in the United States at least one year previous to the time of award," has been unanimously awarded to Professor James D. Dana. This prize, of the maximum sum of one thousand dollars, is given "in recognition of the value of the scientific work of Professor Dana and in testimony of the Society's high appreciation of his services to science."

For the annual Walker Prizes, a first prize of one hundred dollars has been awarded to Baron Gerard de Geer, of Stockholm, for an essay entitled "On Pleistocene changes of level in eastern North America," and a second prize of fifty dollars to Prof. William M. Davis of Cambridge, for an essay on "The subglacial origin of certain eskers."

3. *Proceedings of the Colorado Scientific Society*, vol. iii, Pt. 3, 1890.—This concluding part of the third volume published by the Colorado Scientific Society contains a number of valuable

\* Prof. Verrill, in a paper in 1881 (this Journal, xxii, 295) states that a single "trawl line" in the summer of 1880 brought up 73 of these fishes, weighing 541 pounds, and varying in weight from 2½ to 31 pounds. The color which he gives is "brownish gray, more or less covered with bright yellow spots."

papers, including: On the Geology of the Rosita Hills by W. Cross; on the nature of the chemical elements by C. S. Palmer; on the columbite and tantalite of the Black Hills by W. P. Headden and others. The address of the retiring President, R. C. Hills, on the orographic and structural features of the Rocky Mountain Geology, a paper of much interest, fills the last one-hundred pages.

4. *Volcano of Kilauea, Hawaii*.—Reports from Kilauea in the Hawaiian Gazette of Feb. 23, state that the great basin of Halemaumau in the southern part of the crater of Kilauea, contains a lake of lava 1300 feet in diameter, almost the whole surface of which is in constant action.

5. *Physiography*: a class book for the Elementary Stage of the Science and Art Department by J. SPENCER, B.Sc., F.C.S. 229 pp. London, 1891 (Percival and Co.).—The many subjects embraced under the head of Physiography are treated in this little book clearly and simply but, of necessity, with great brevity.

6. *A universal English-German and German-English Dictionary* by Dr. FELIX FLÜGEL. Fourth entirely remodelled edition of Dr. J. G. Flügel's Complete Dictionary of the English and German Languages. Braunschweig, 1890-1892. (George Westermann).—This great work is now completed in three large volumes, of which the English-German part forms the first two and the German-English part the third. It has been a most laborious undertaking carried through with untiring scholarly effort and the final result is most satisfactory and reflects great honor upon the author.

7. *The Ward Collection of Meteorites*. 74 pp. 8vo. Rochester, N. Y.—This catalogue gives a descriptive price list of the meteorites in the large collection of Ward's Natural Science Establishment at Rochester; casts of a number of specimens are also included. Detailed descriptions with illustrations are given of a number of the meteorites, as La bella Roca, the Rockwood, Hamilton Co., Texas, Puquois, Chili, Washington Co., Kansas, and others.

*Cyclone Memoirs*, Part IV, Arabian Sea, pp. 301-424, large 8vo. An inquiry into the Nature and Course of Storms in the Arabian Sea, and a Catalogue and brief history of all recorded Cyclones in that sea from 1648 to 1889, by W. L. DALLAS, Esq. Published by the Meteorolog. Dept. of the Government of India, under the direction of J. ELIOT, M.A., Met. Reporter to the Gov. of India. Calcutta, 1891.

The Sextant and other Reflecting Mathematical Instruments with practical hints, suggestions and wrinkles on their errors, adjustments and use. With thirty-three illustrations by F. R. Brainard, U. S. Navy. 120 pp. 16mo. New York, 1891 (D. Van Nostrand Company).

Essentials of Physics, arranged in the form of questions and answers prepared especially for Students of Medicine, by Fred. J. Brockway, M.D. 330 pp. Philadelphia, 1892 (W. B. Saunders).

Outlines of Lessons in Botany for the use of Teachers, or Mothers studying with their children, by Jane H. Newell. Part II, Flower and Fruit. 393 pp. Boston, 1892 (Ginn and Company).

Catalogue of the Type Fossils in the Woodwardian Museum, Cambridge, by Henry Woods, with a preface by I. McKenny Hughes, Woodwardian Professor of Geology. 180 pp. 8vo, Cambridge, 1891.

## A P P E N D I X .

ART. XLVIII.—*Notes on Triassic Dinosauria*; by O. C. MARSH. (With Plates XV, XVI, and XVII.)

THE presence of Dinosaurs in the Trias is indicated by many footprints, and various bones, nearly all of which are fragmentary. The footprints were long supposed to be those of birds, while the osseous remains were most of them not sufficiently characteristic to admit of determination. Three or four specimens in this country, however, and as many more in Europe, each with characteristic parts of the skeleton, have been known for some time. These prove the Dinosaurian nature of the animals beyond question, but throw little light upon their exact affinities. Recently, the writer has obtained from the Connecticut River sandstone the greater part of three skeletons of small Dinosaurs, all of much interest. Some portions of these have already been described,\* and, in the present paper, additional remains are figured, and with them a few nearly allied fossils from European localities. The Triassic *Dinosauria* as a whole will be discussed by the writer in a later communication.

### *Anchisaurus colurus.*

The type specimen of this species, one of the most perfect Dinosaurs ever discovered, has now been worked out of the hard matrix in which it was imbedded, and the skull and limbs are represented in the accompanying plates.

The skull was somewhat crushed and distorted, but its main features are preserved, and its more important characters can be determined with certainty. In Plate XV, figure 1, a side view is given, one-half natural size. One prominent feature shown in this view is the bird-like character of the skull. The nasal aperture (*a*) is small, and well forward. There is a large antorbital opening (*b*), and a very large orbit (*c*). This is elongated oval in outline. It is bounded in front by the prefrontal, above by the same bone, and a small extent of the frontal, and further back by the postfrontal. The postorbital completes the orbit behind, and the jugal, below. The supratemporal fossa (*d*) is large, and somewhat triangular in outline. The infratemporal fossa is quite large, and is bounded below by a slender quadratojugal. The quadrate (*q*) is much inclined forward. The teeth are remarkable for the great number in

\* This Journal, vol. xxxvii, p. 331, April, 1889; and vol. xlii, p. 267, September, 1891.

use at one time. Those of the upper jaw are inclined forward, while those below are nearly vertical. The lower jaw has the same general features of this part in the *Theropoda*.

In Plate XVI, figures 1 and 2, the same skull is shown, also one-half natural size. The top of the skull, represented in figure 1, is considerably broken, and this has made it difficult to trace the sutures, but the general form and proportions of the upper surface are fairly represented. In figure 2, only the back portion of the cranium is shown. The foramen magnum is remarkably large, and the occipital condyle is small and oblique. The basiptyergoid processes are unusually short.

The neck vertebræ are long and slender, and very hollow. Their articular ends appear to be all plane or slightly concave. The trunk vertebræ are more robust, but their centra are quite long. The sacrals appear to be three in number.

The scapular arch is well preserved. The scapula, shown in Plate XV, figure 2, *s*, is very long, with its upper end obliquely truncated. The coracoid (*c*) is unusually small, and imperforate. The sternum was of cartilage, some of which is preserved. The humerus (*h*) is of the same length as the scapula, and its shaft is very hollow. The radius and ulna are also both hollow, and nearly equal in size.

There is but one carpal bone ossified in this specimen, and this is below the ulna. There were five digits in the manus, but only three of functional importance, the first, second, and third, all armed with sharp claws. The fifth (V) was quite rudimentary. The fore foot of the type species of *Anchisaurus* is shown one-half natural size, on Plate XVI, figure 3.

The pelvic bones are shown in figure 3 of Plate XV. The ilium (*il*) is small, with a slender preacetabular process. The ischia (*is*) are elongated, and their distal ends slender, and not expanded at the extremity. The pubes (*p*) are also long, imperforate, and not coössified with each other. The anterior part is a plate of moderate width. The ischia of the type species of this genus are shown on Plate XVII, figure 6.

The femur (*f*) is much curved, and longer than the tibia (*t*). The latter is nearly straight, with a narrow shaft. The fibula (*f'*) when in position was not close to the tibia, but curved outward from it. All these bones have very thin walls. The astragalus (*a*) is small, closely applied to the tibia, and has no ascending process. The calcaneum (*c*) is of moderate size, and free. There are only two tarsal bones in the second row.

The hind foot had four functional digits, all provided with claws. The fifth was represented only by a rudiment of the metatarsal (V). The first digit was so much shorter than the second, third, and fourth, that this foot would have made a three-toed track very much like the supposed Bird-tracks of the Connecticut River sandstone.

On Plate XVI, figure 4, is shown the hind foot, also one-fourth natural size, of *Ammosaurus*, a genus nearly allied to *Anchisaurus*. In this foot, the tarsus is much more complete. The astragalus has a slight ascending process, the calcaneum is closely applied to the end of the fibula, and there are three well-developed bones in the second row. The fifth digit had only a single phalanx. The sacrum and ilia of the type species of *Ammosaurus* are shown on Plate XVII, figure 3.

*Anchisaurus solus*, sp. nov.

A fortunate discovery has recently brought to light almost the entire skeleton of a diminutive Dinosaur, which may be referred to *Anchisaurus*, but clearly belongs to a distinct species. It was found in nearly the same horizon as the remains above described, and in the immediate vicinity, so there can be little doubt that it was a contemporary. The skeleton is imbedded in a very coarse matrix, so difficult to remove that the investigation is only in part completed. The portions uncovered show the animal to have been about three feet in length, and of very delicate proportions. The bones of the skeleton are almost all extremely light and hollow, but most of them are in fair preservation.

The skull, so far as it can now be observed, resembles the one just described. The teeth are numerous, and inclined forward. The orbit is very large. The quadrate is inclined forward, and the lower jaw is robust. The entire skull is about 65<sup>mm</sup> in length, and the lower jaws the same.

The neck was very long and slender, the first five cervicals measuring 80<sup>mm</sup> in extent. The dorsals are also elongated, the last six covering a space of 135<sup>mm</sup>. The number of vertebræ in the sacrum cannot yet be determined. The caudal vertebræ are short, the first ten occupying a space of 140<sup>mm</sup>.

The humerus has a very large radial crest, and is 66<sup>mm</sup> in length. The rest of the fore limb, so far as made out, is similar to those in the species described. The tibia is about 88<sup>mm</sup> in length. There were five digits in the hind foot, but the fifth is represented only by the rudimentary metatarsal. The animal when alive was about as large as a small fox.

The European Triassic Dinosaurs with which the above American forms may be compared are mainly represented by the two genera *Thecodontosaurus*, Riley and Stutchbury, from the upper Trias, or Rhætic, near Bristol, in England, and *Plateosaurus* (*Zanclodon*), von Meyer, from nearly the same horizon, in Germany. The writer has investigated with some care the type specimens, and nearly all the other known remains of these genera found at these localities.

The remains of *Thecodontosaurus* are of special interest for comparison, and a portion of the skull is given on Plate XVII, figures 1 and 2, and the fore leg on Plate XVI, figure 5. For these remains, the writer is indebted to the trustees of the Bristol museum. The base of the skull shown on Plate XVII differs in several important respects from that of *Anchisaurus*, particularly in its extended parasphenoid, and the very long basiptyergoid processes. The fore leg as a whole, especially the fore foot, is much like that of *Anchisaurus*, but in the latter, the coracoid is very small, and without a foramen. In *Thecodontosaurus*, it is much larger, has a foramen, and is coössified with the scapula.

*Plateosaurus* (*Zanclodon*) includes reptilian forms much larger than those described above. The pubis and ischia both serve to distinguish this genus from the American and British forms. The ischia have their distal ends expanded, as seen in Plate XVII, while the pubes are broad, imperforate plates.

The further discussion of these remains and of the other Dinosaurs from the Triassic will be given elsewhere.

New Haven, Conn., May 24, 1892.

#### EXPLANATION OF PLATES.

##### PLATE XV.

- FIGURE 1.—Skull of *Anchisaurus colurus*, Marsh; side view. One-half natural size. *a*, nasal opening; *b*, antorbital opening; *bp*, basiptyergoid process; *c*, lower temporal fossa; *d*, upper temporal fossa; *f*, frontal; *j*, jugal; *n*, nasal; *o*, orbit; *oc*, occipital condyle; *p*, parietal; *p'*, paroccipital process; *pf*, prefrontal; *pm*, premaxillary; *ps*, parasphenoid; *q*, quadrate; *so*, supraoccipital.
- FIGURE 2.—Bones of left fore leg of same individual; outside view. *c*, coracoid; *h*, humerus; *r*, radius; *s*, scapula; *u*, ulna; I, first digit; V, fifth digit.
- FIGURE 3.—Bones of left hind leg of same individual; outside view. Both figures are one-fourth natural size. *a*, astragalus; *c*, calcaneum; *f*, femur; *f'*, fibula; *il*, ilium; *is*, ischium; *p*, pubis; *t*, tibia.

##### PLATE XVI.

- FIGURE 1.—Skull of *Anchisaurus colurus*; top view.
- FIGURE 2.—Base of same skull; back view. Both figures one-half natural size.
- FIGURE 3.—Left fore foot of *Anchisaurus polyzelus*, Hitchcock, sp.; back view. One-half natural size. *c*, central; *r*, radial; *R*, radius; *U*, ulna.
- FIGURE 4.—Right hind foot of *Ammosaurus major*, Marsh; front view. One-fourth natural size. *F*, fibula; *T*, tibia; *t2*, *t3*, *t4*, tarsal bones.
- FIGURE 5.—Bones of left fore leg of *Thecodontosaurus platyodon*, Riley and Stutchbury; outside view. One-fourth natural size.

##### PLATE XVII.

- FIGURE 1.—Base of skull of *Thecodontosaurus platyodon*; seen from the left.
- FIGURE 2.—The same specimen; back view. Both figures are one-half natural size.
- FIGURE 3.—Sacrum and ilia of *Ammosaurus major*; seen from below. One-fourth natural size. *ac*, acetabulum; *is*, face for ischium; *pb*, face for pubis; *1*, *2*, *3*, sacral vertebrae.
- FIGURE 4.—Pubis of *Plateosaurus* (*Zanclodon*) *suevicus*, von Meyer. One-sixth natural size. *a*, front view; *b*, back view; *s*, symphysis.
- FIGURE 5.—Distal ends of ischia of same. One-sixth natural size. *p*, posterior.
- FIGURE 6.—Ischia of *Anchisaurus polyzelus*; seen from above. One-half natural size. *a*, distal ends; *il*, face for ilium; *pb*, face for pubis.

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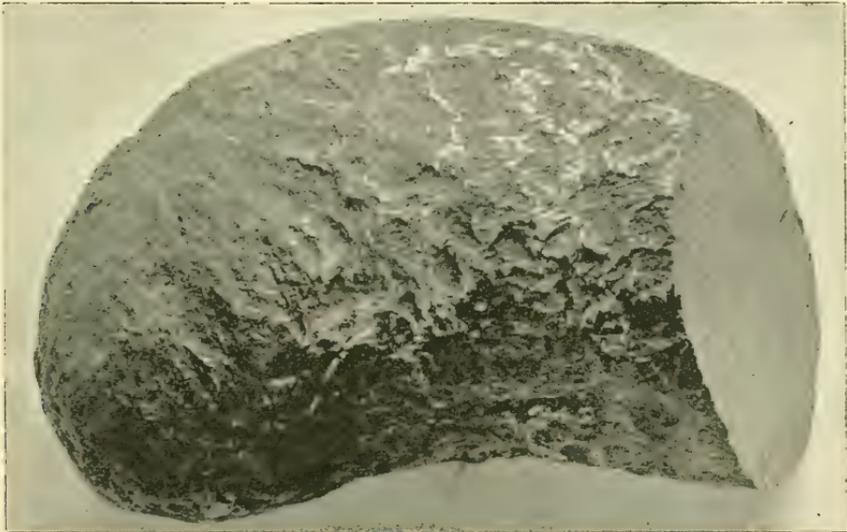
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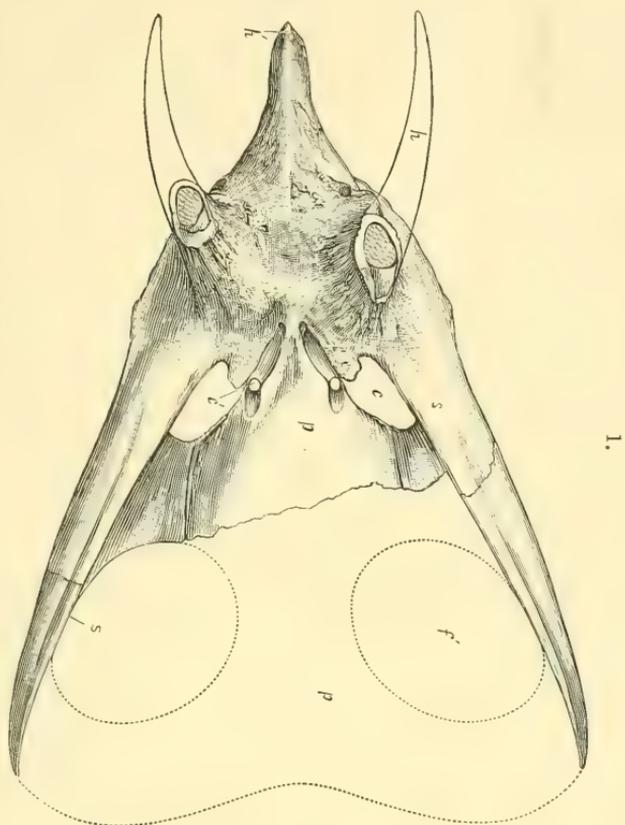


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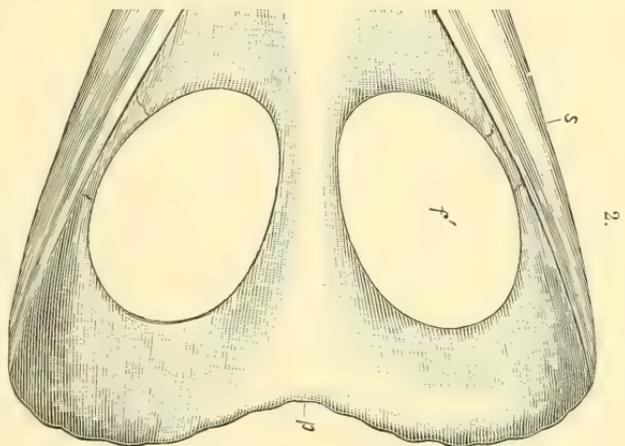


Meteoric Iron from Garrett Co., Md. Fig. 1, Etched surface. Fig. 2, Entire mass.  
Original weight, 45 oz. Present weight,  $36\frac{1}{2}$  oz.

1874



1.



2.

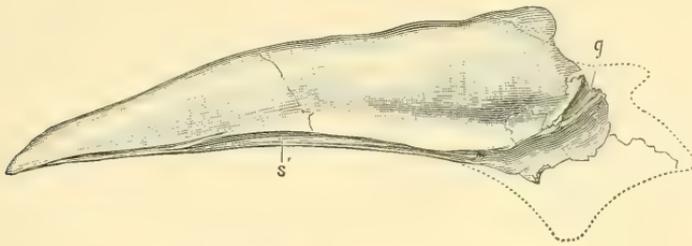
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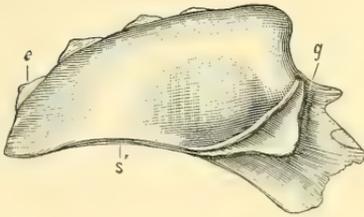
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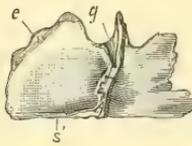
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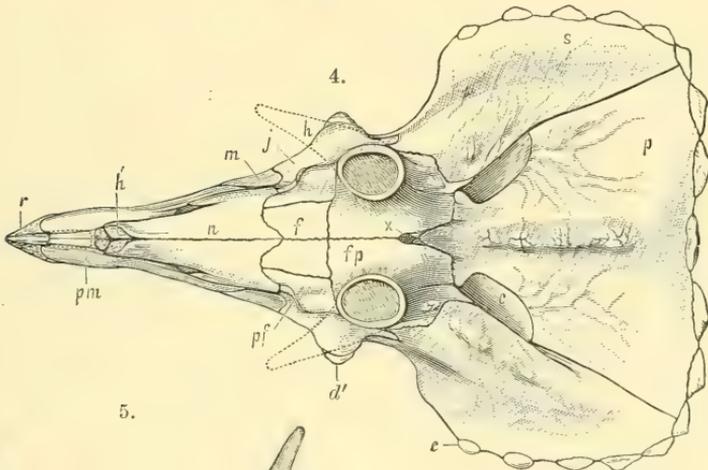
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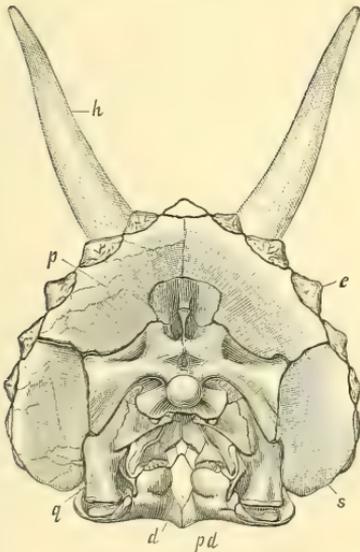
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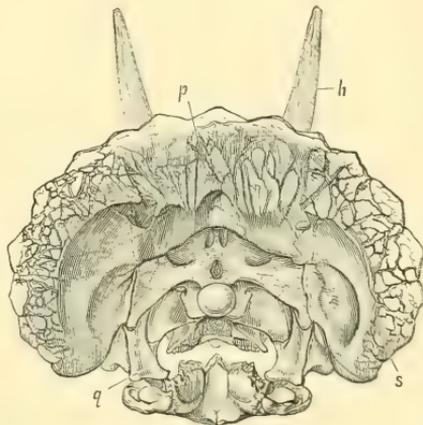
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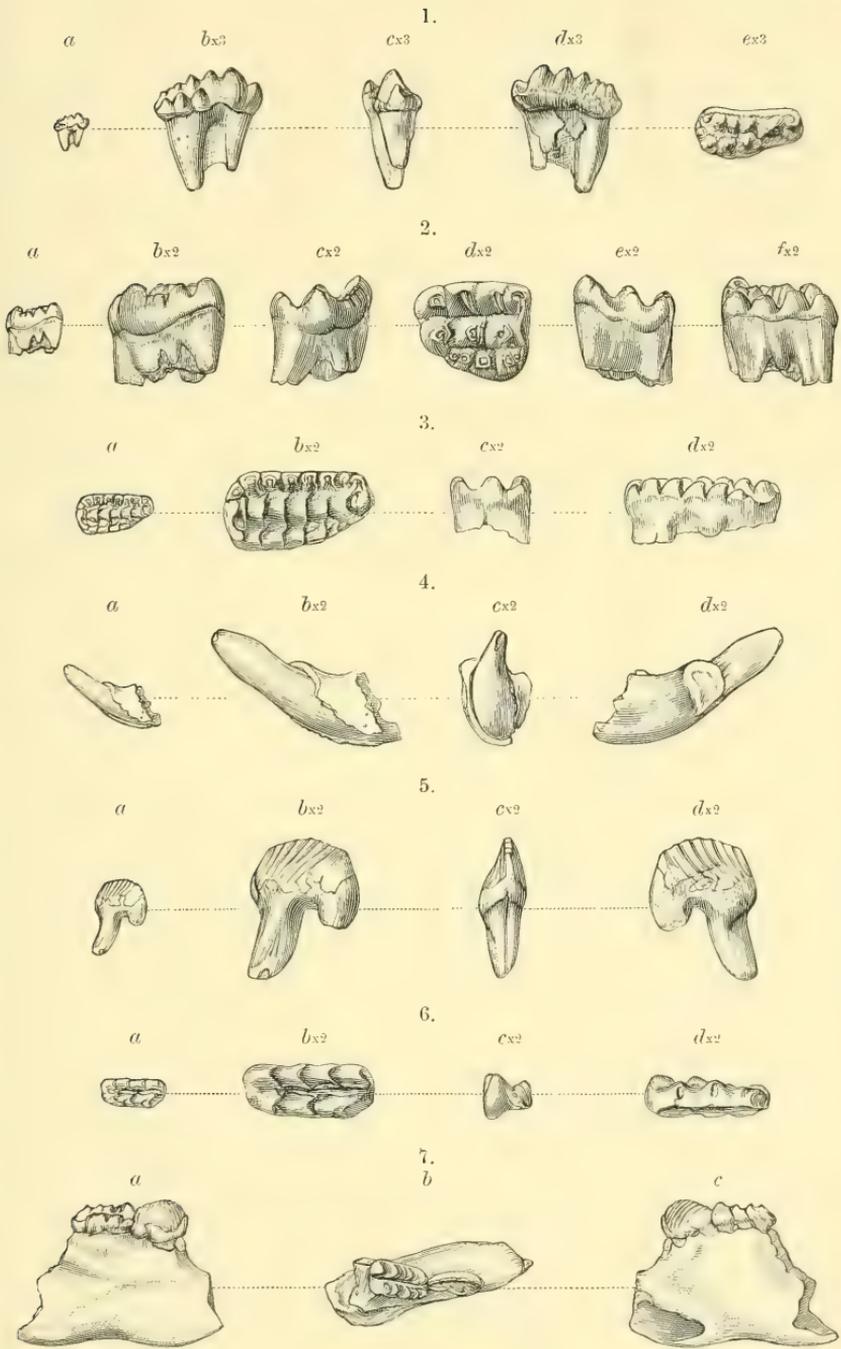


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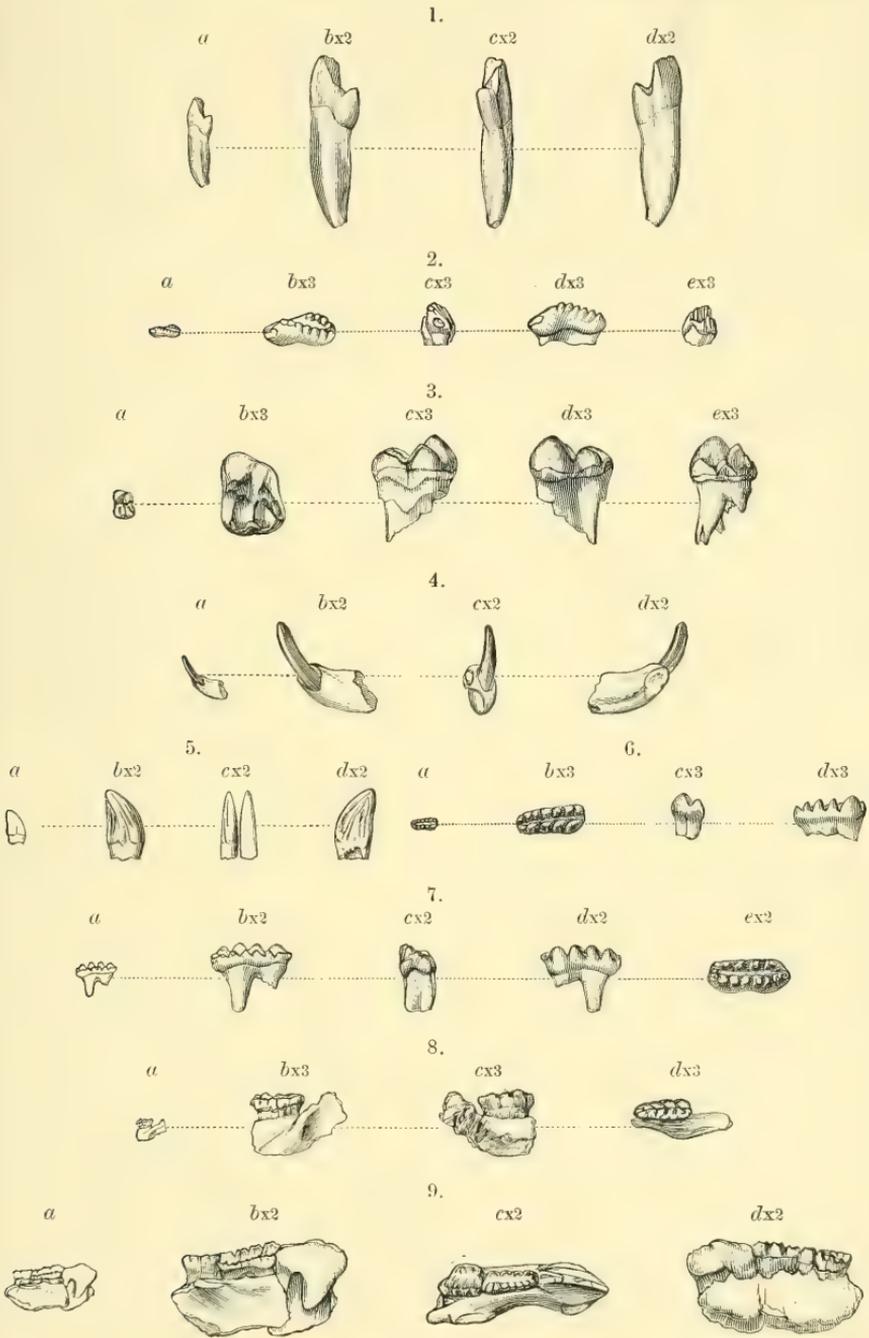






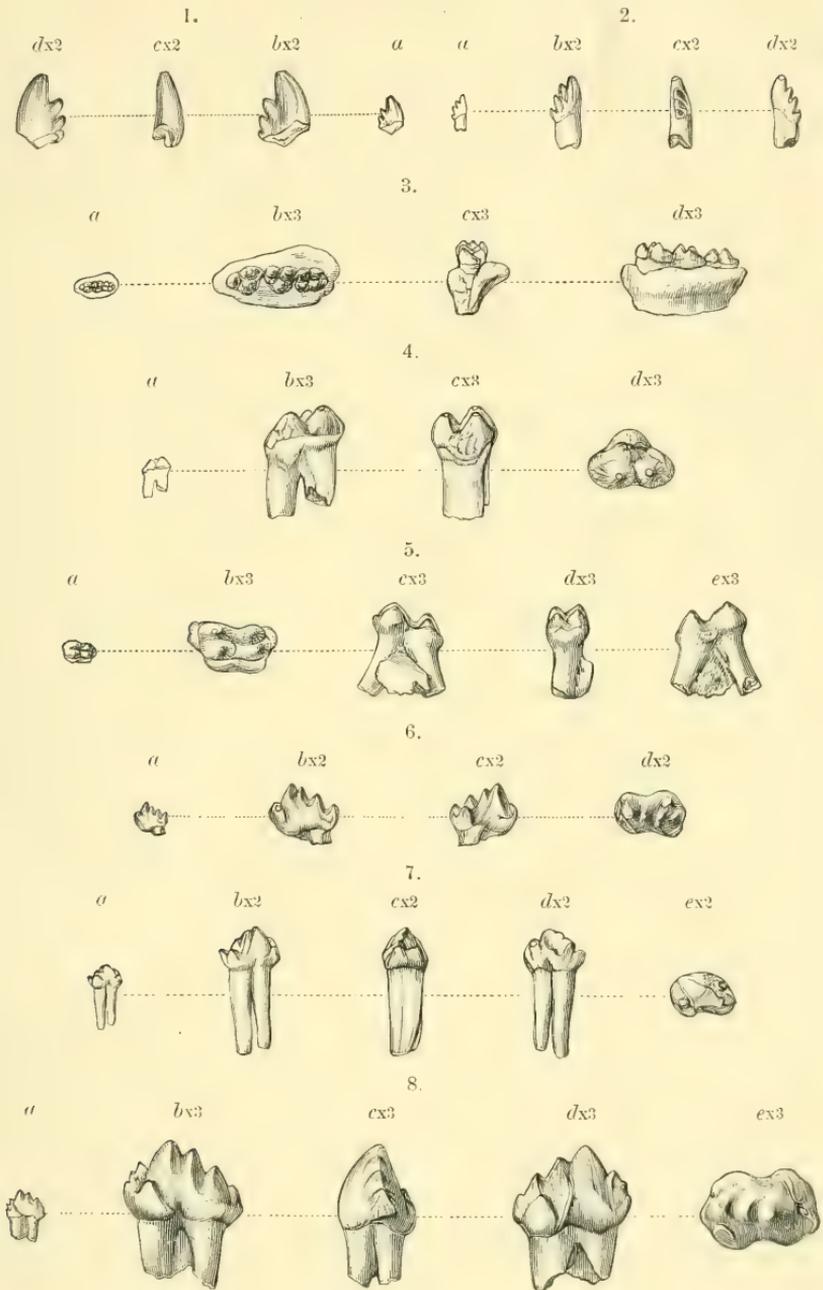
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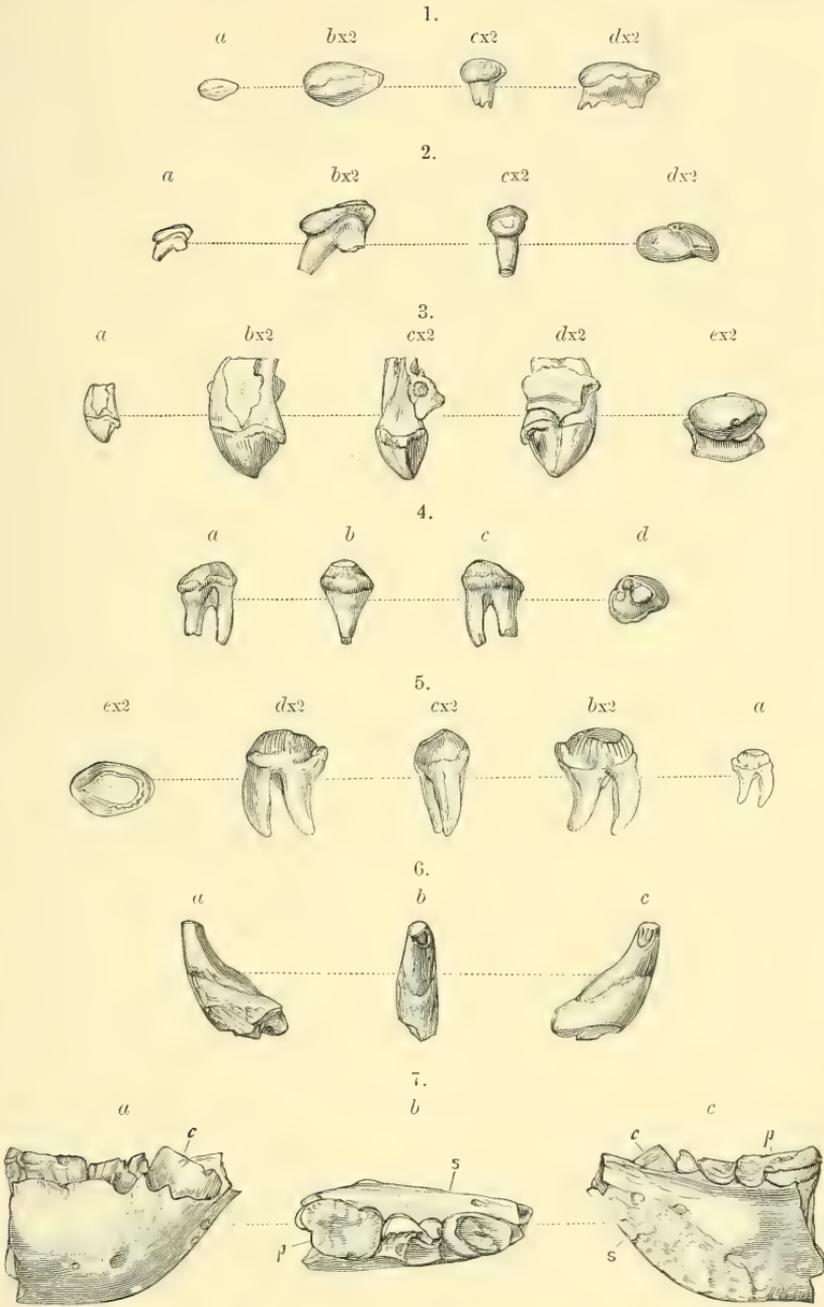
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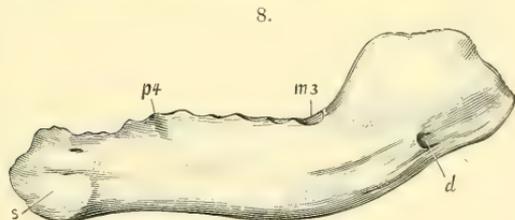
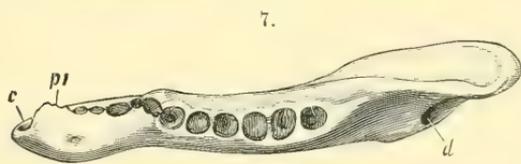
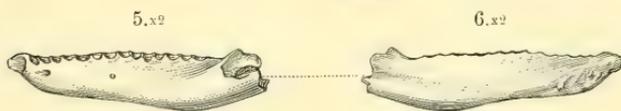
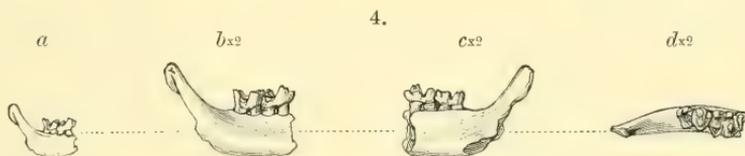
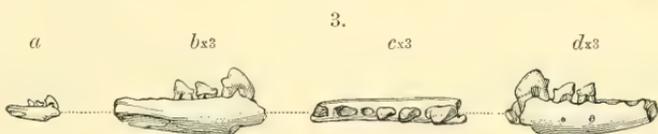
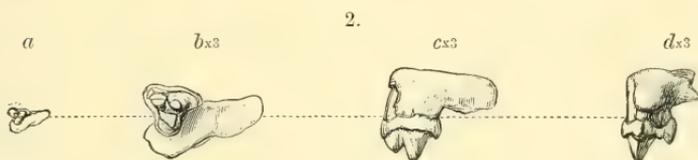
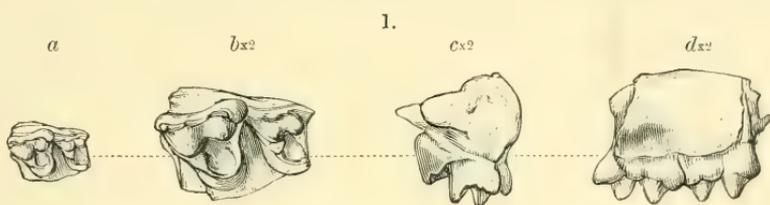
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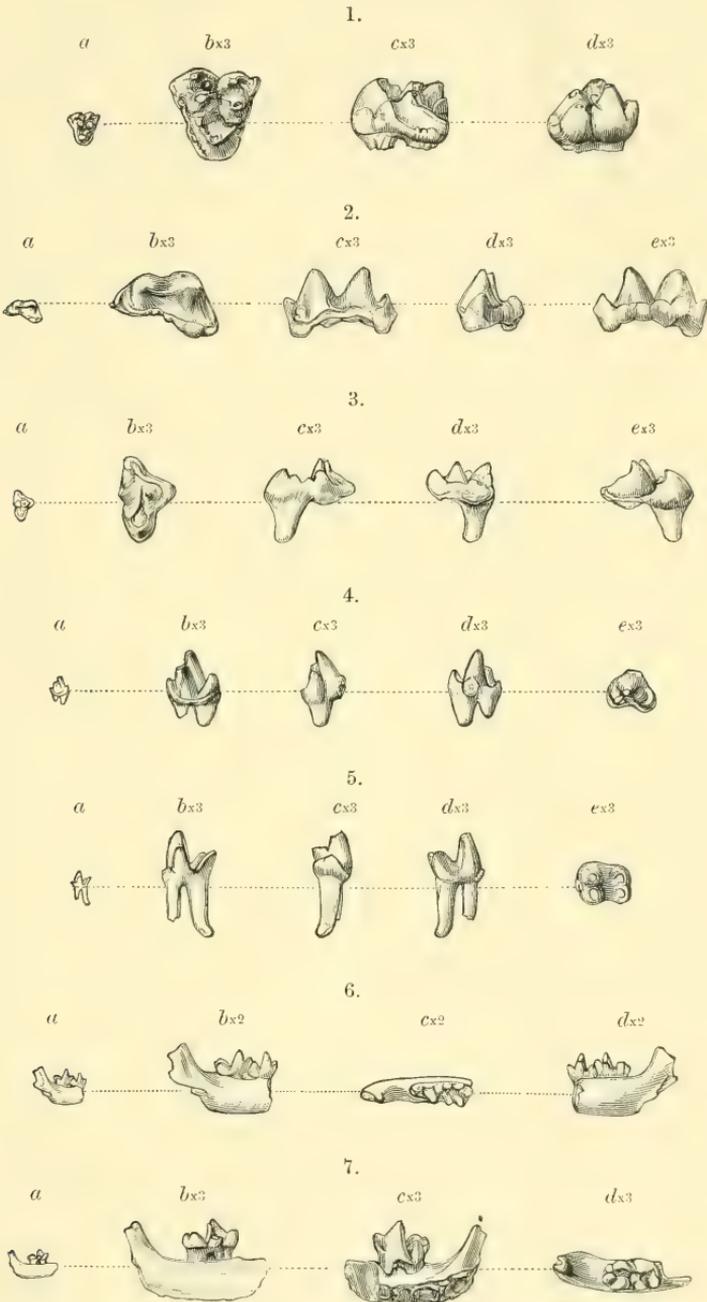
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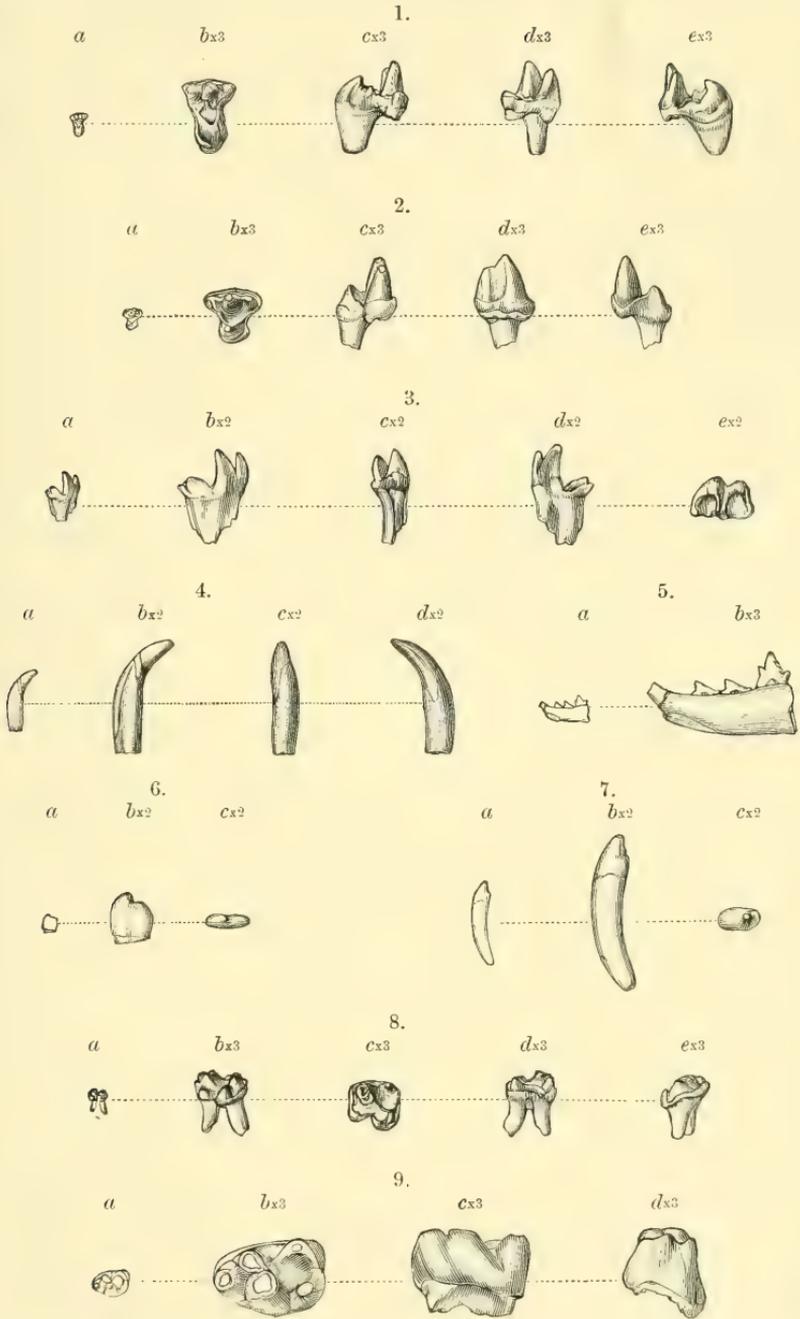
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Fig. 2

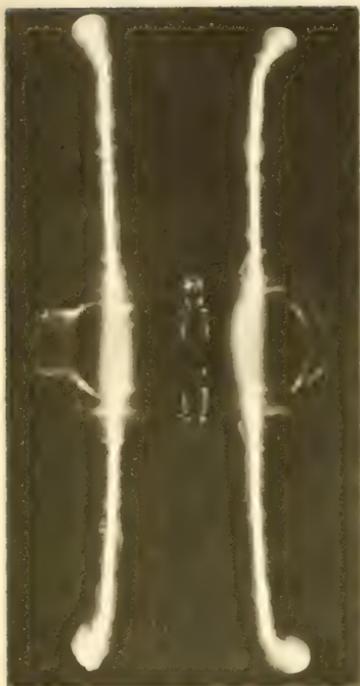


Fig. 4

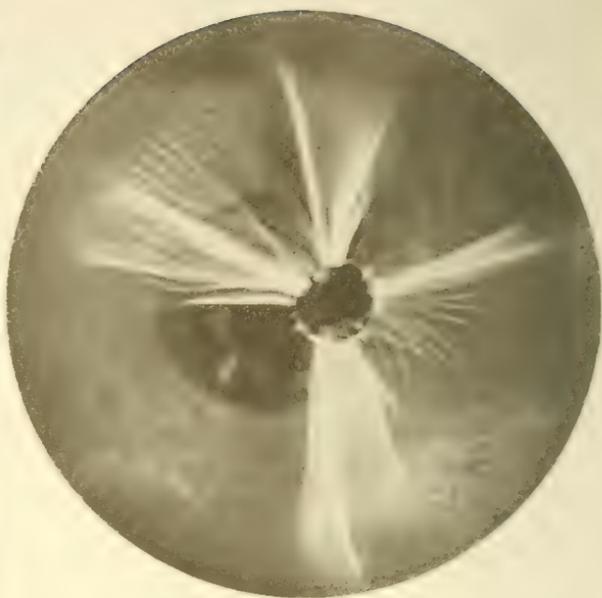


Fig. 3



Fig. 5



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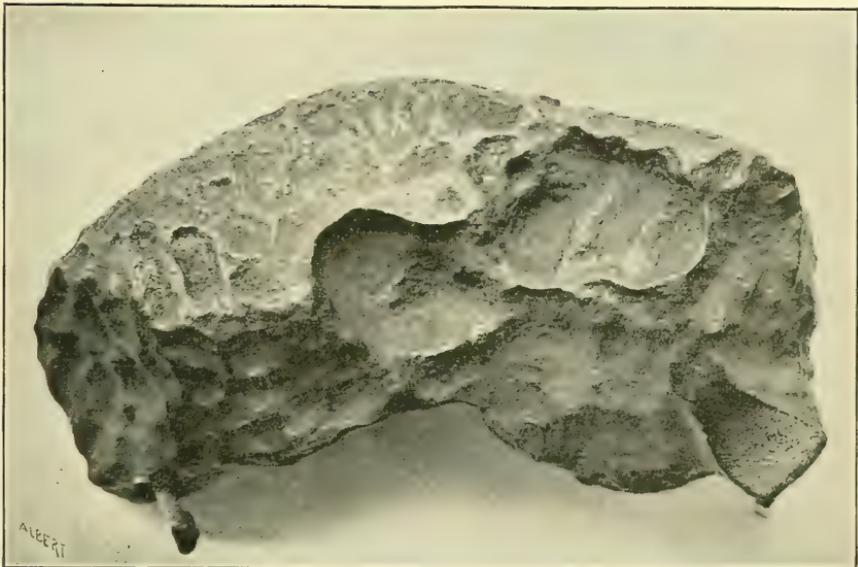


FIG. 1.—An etched section of the meteoric iron from Floyd Mountain. In this the hexahedral structure of the iron is prominent on a larger part of the surface. In a few places this is broken by the granular particles. Very prominent are the parallel markings of the elongated rhabdite crystals.

FIG. 2.—A similar etched section from nearer the interior of the mass. In this mass the granular particles are more plentiful. The sheen is more apparent in diagonal bands.

FIG. 3.—A natural sized view of the meteoric iron of Sierra de la Ternera, showing the finger-like markings and depressions with which the entire mass is covered.



Fig. 1

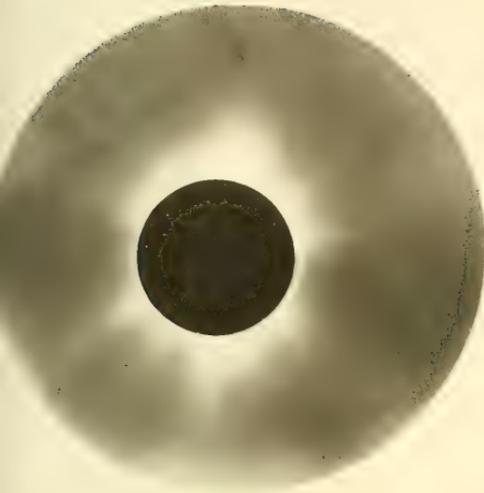


Fig. 2

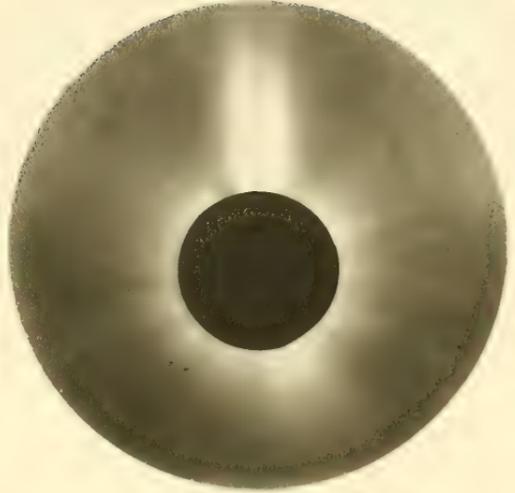


Fig. 3

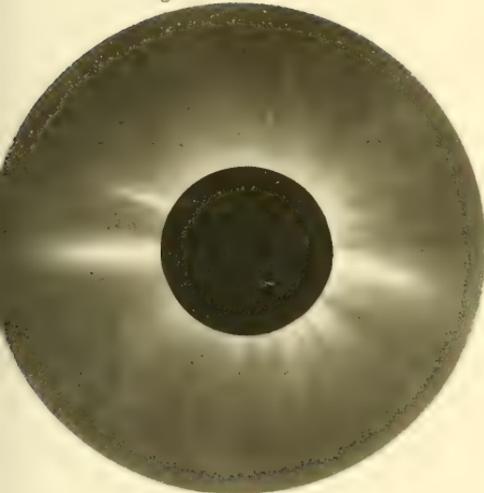


Fig. 4

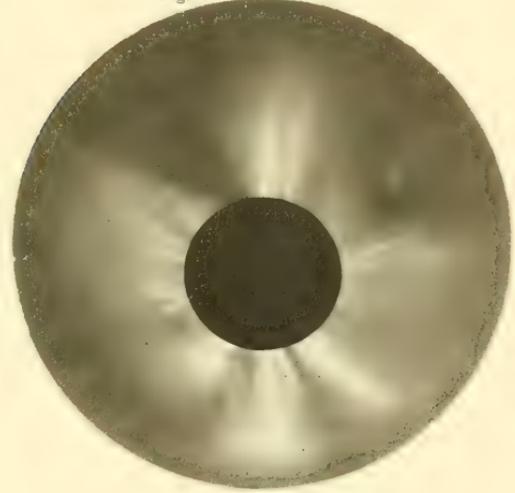
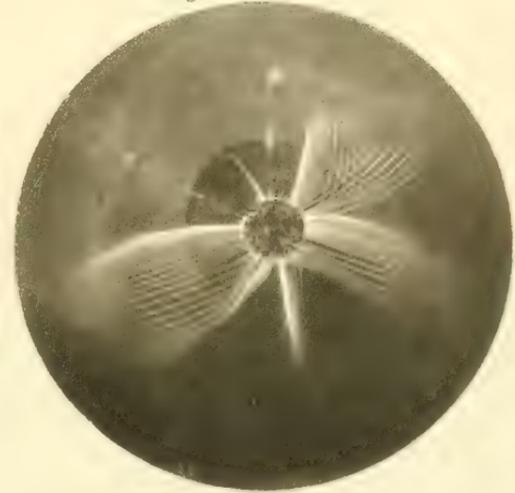


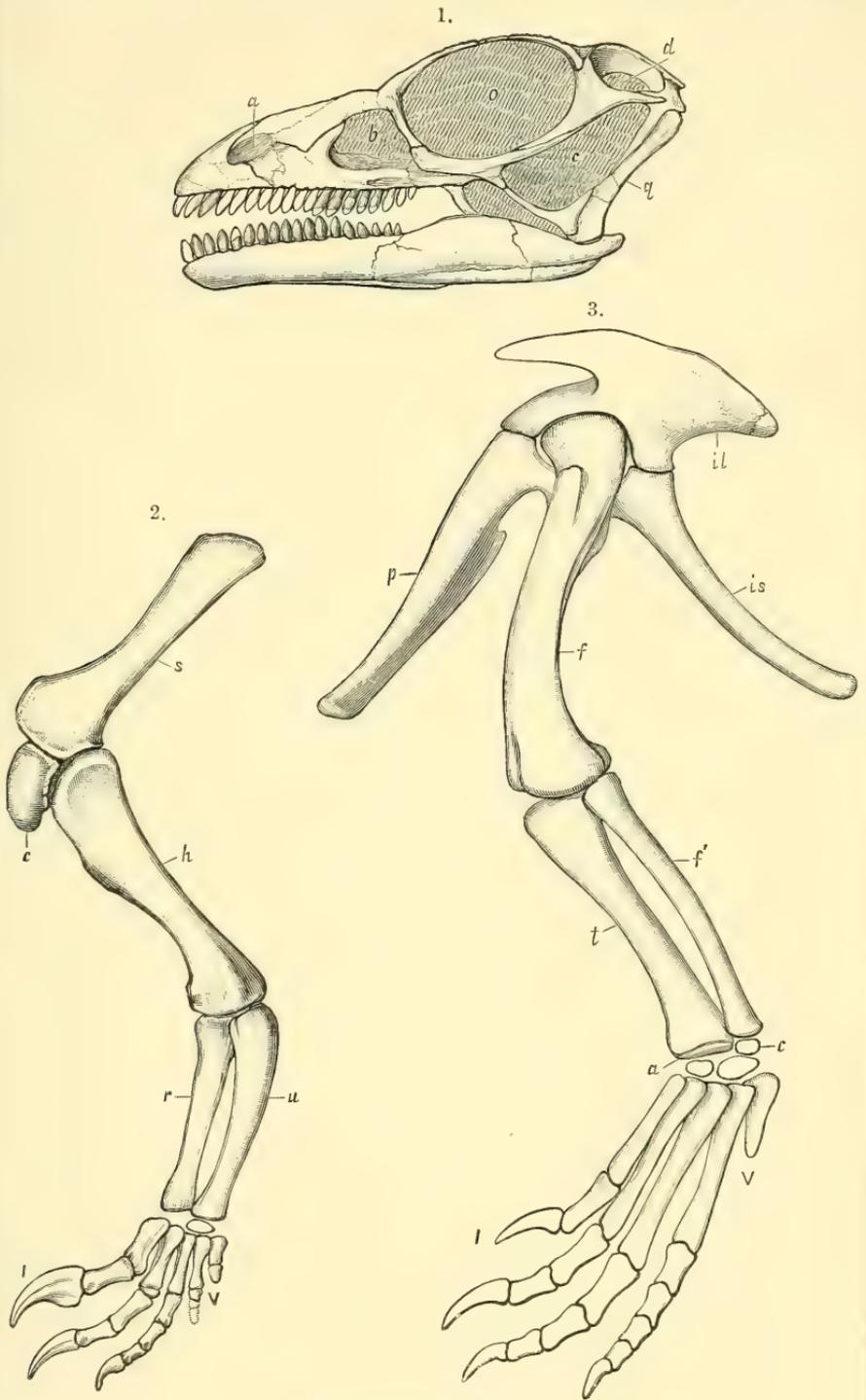
Fig. 5



Fig. 6

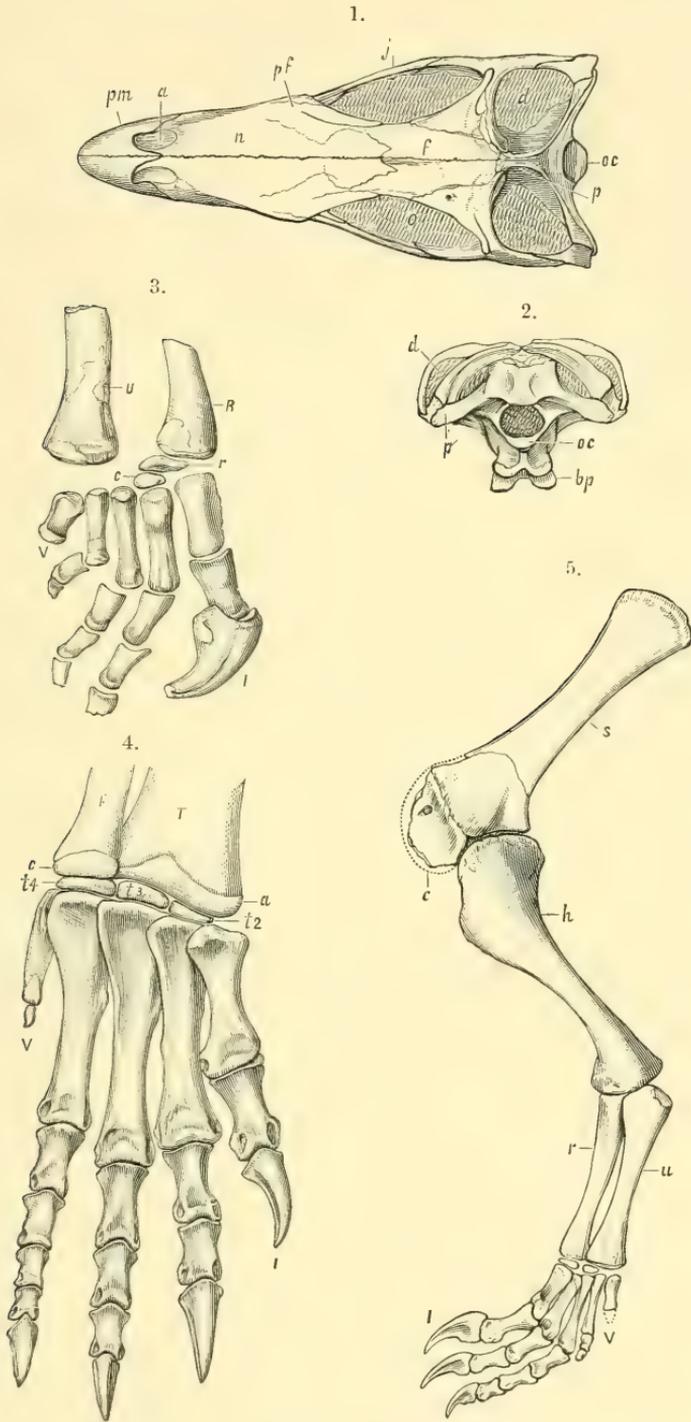






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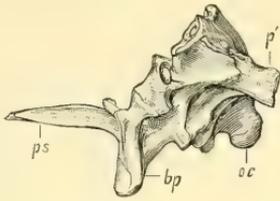




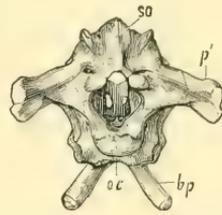
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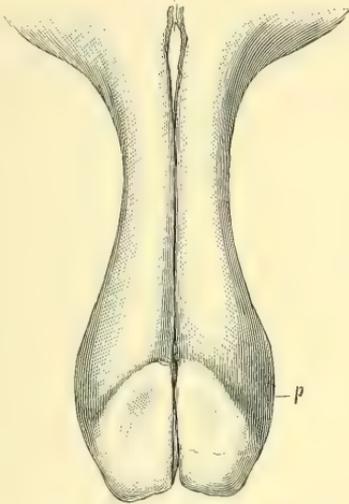
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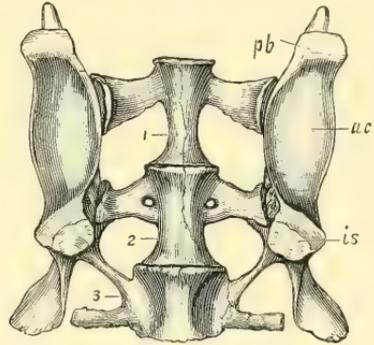
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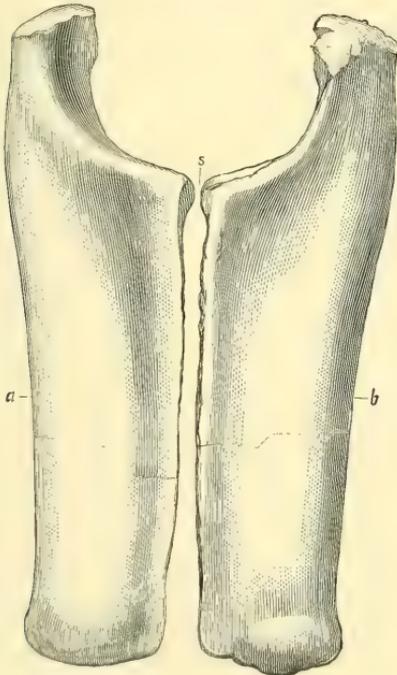
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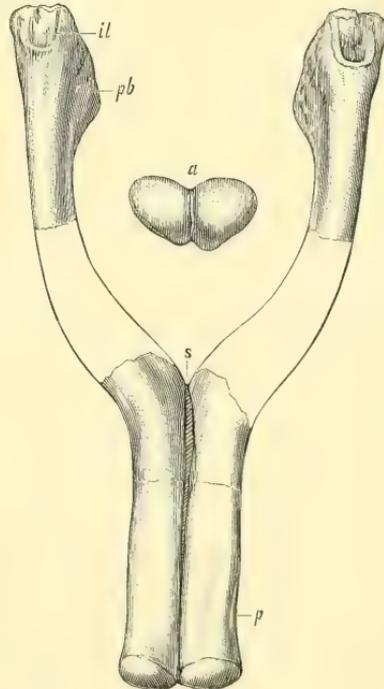
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