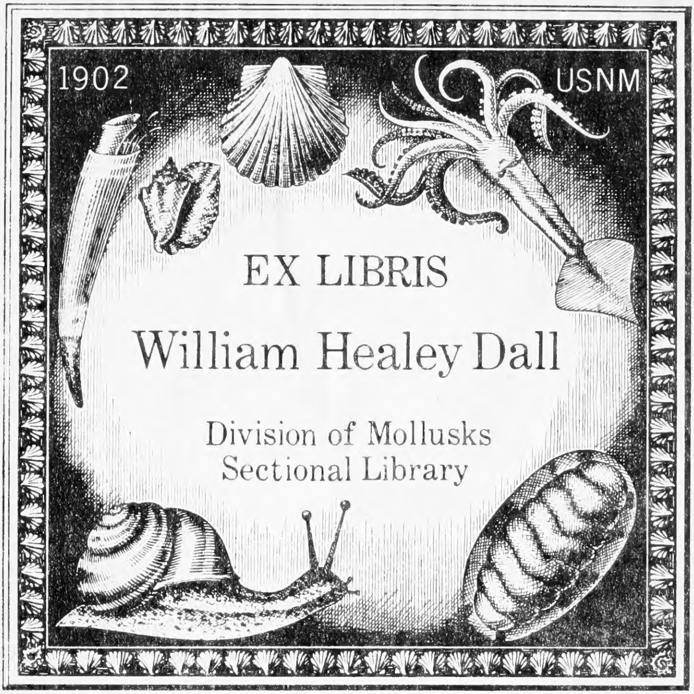

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FINAL REPORT

ON THE

GEOLOGY

OF THE

STATE OF NEW JERSEY.

BY HENRY D. ROGERS,

STATE GEOLOGIST

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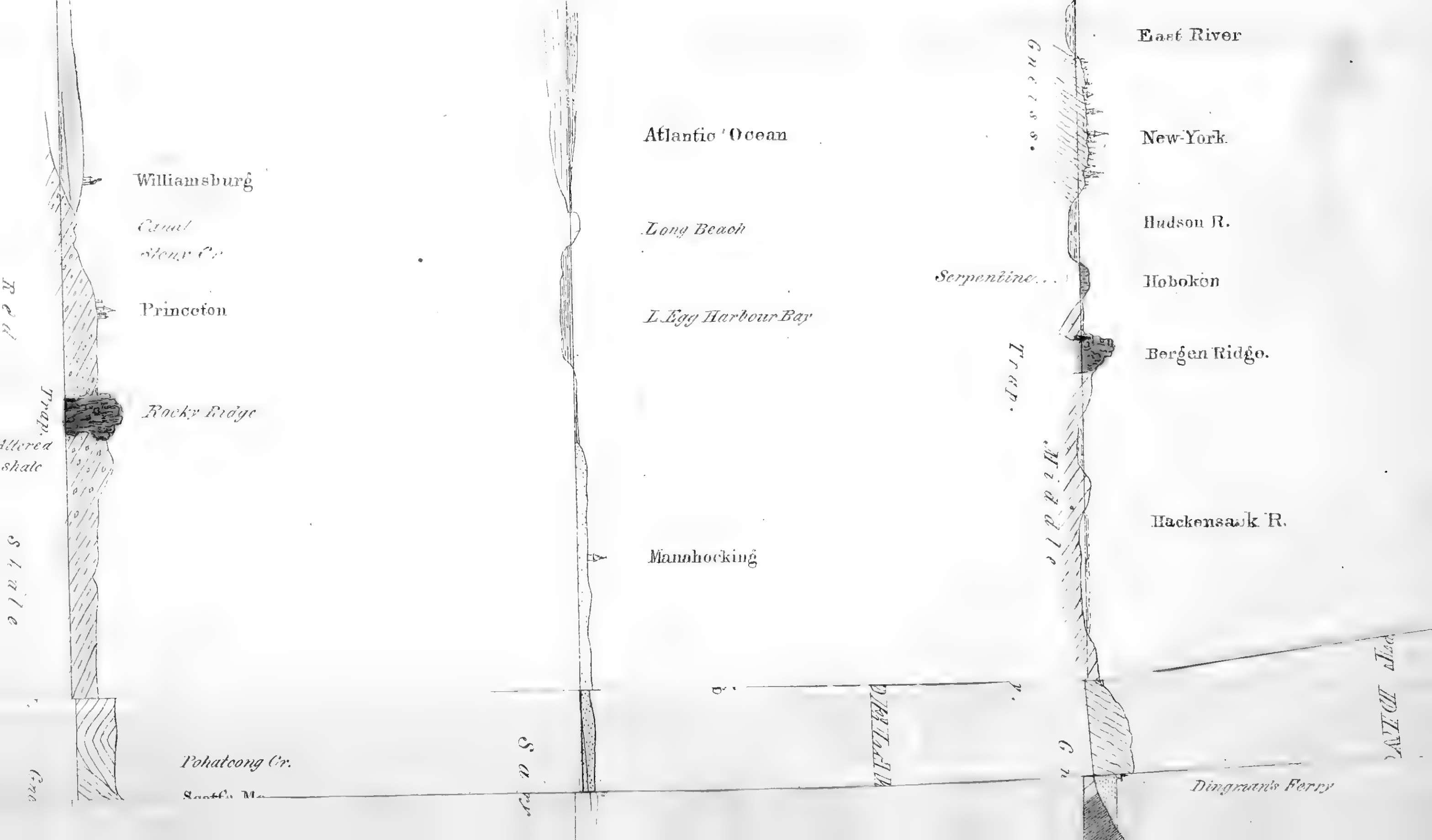
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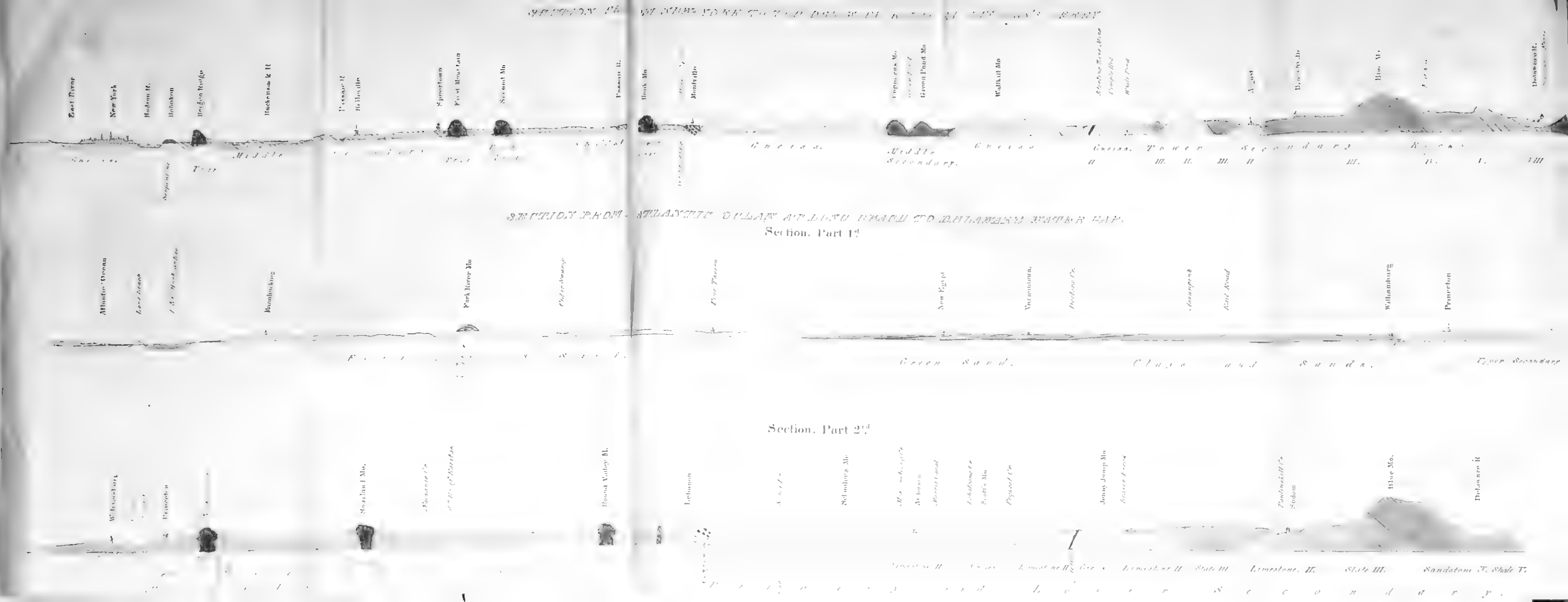
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Hook Mt.
Montville
Green Pond Mt.
Wallkill Mt.
Blue Mt.
Delaware R.
Gneiss.
Middle
Middle Secondary.
Gneiss
Lower Secondary
SECTION FROM ATLANTIC OCEAN ALONG BEACH TO DELAWARE WATER GAP.
Section, Part 1st
Atlantic Ocean
Fork River Mt.
New Egypt
Princeton
Green Sand.
Clays and Sands.
Upper Secondary
Section, Part 2nd
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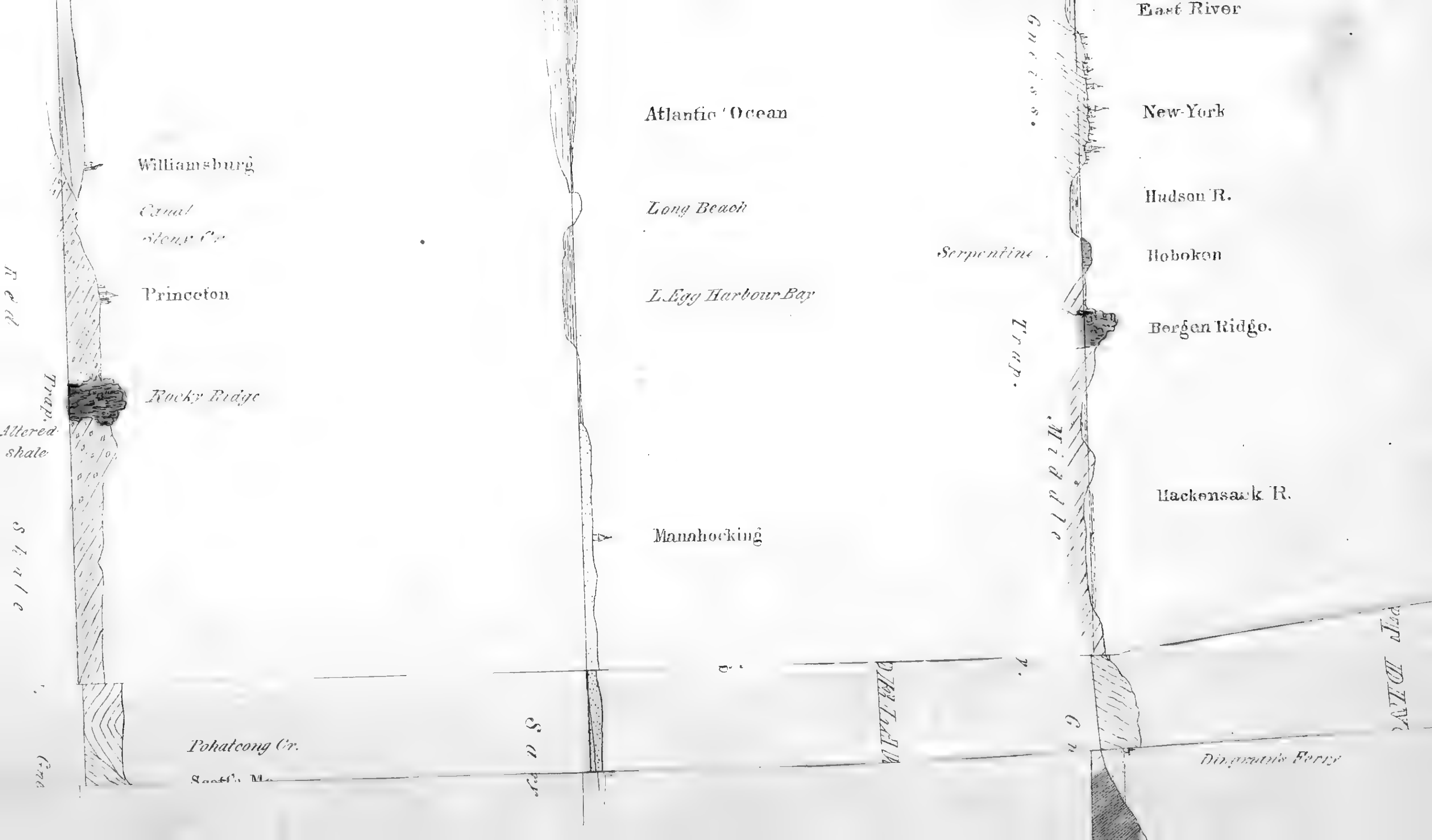
Round Valley M.
Lebanon
Blue Mt.
Delaware R.
Limestone. II.
Slate III.
Sandstone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Trap.
Altered shale
Red
Shale

DESCRIPTION

OF THE

GEOLOGY

OF THE

STATE OF NEW JERSEY,

BEING

A FINAL REPORT,

BY

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1840.

GEOLOGY OF NEW JERSEY.

INTRODUCTION.

The geological structure of a region being intimately connected with its external physical features, it will usually be found that a correct view of the latter will materially assist us in understanding a detailed description of the former. I therefore propose introducing my account of the geology of the State of New Jersey with the following brief sketch of the physical aspect which characterizes each of the several districts into which it naturally divides itself.

The State is separated on the northeast from the State of New York by an artificial boundary line, which commences at the Hudson river, very near lat. 41°, and extends in a northwest direction to the Delaware river at Carpenter's Point, or the mouth of the Macacomac river: but on every other side it is enclosed by a natural boundary, namely, by the Delaware river and its bay, on the northwest, west, and southwest, and by the waters of the Hudson river, the Raritan bay, and the Atlantic ocean on the east.

Its extreme length, measured by a line running nearly due north from Cape May to Carpenter's Point, is about one hundred and sixty-four miles,* while its shortest diameter, measuring from the Delaware river near Bordentown to the Raritan bay near South Amboy, is about thirty miles.

The area of the State, approximately estimated, is about seven thousand two hundred and seventy-six square miles. In shape it bears some resemblance to a bean—its northern half representing the one lobe, its southern half the other.

* See Gordon's Gazetteer for New Jersey.

A slightly undulating line, stretching from the Delaware river a little below Trenton to the Raritan river at the mouth of Lawrence's Brook below New Brunswick, divides the State into two regions, which are nearly equal as respects their area, but which are strongly contrasted if we regard their external physical features and scenery, their geological structure, mineral productions, and prevailing soils.

The portion of the State lying south of the Raritan bay and east of the tidewater portion of the Delaware* and the line above mentioned, is remarkable for its low, level, and uniform surface. With the exception of a few isolated hills of humble elevation, which occur at distant points, chiefly in the northern part of the region, this extended plain seldom rises higher than about sixty feet above the sea. It is extensively penetrated, however, by streams that have a very gentle descent from the summit level of the region—one half of them running east and directly into the Atlantic ocean, while the other half pursue a westward course and empty either into the Delaware river or the Raritan. The whole surface of this area is extensively undulated by a system of ravines of denudation, which furnish their drainage to the numerous streams alluded to. These, in connexion with the banks of the streams themselves, afford a ready access, to a moderate depth, to the valuable mineral deposits which expand widely beneath the surface over large tracts of this section of the State.

Throughout this entire district the strata are very nearly horizontal, excepting a brown sandstone and a thin limestone, both of which occur only in a few localities of limited range; the mineral deposits are generally soft and uncemented masses, consisting of a series of alternating sands and clays. From the evidence derived from the organic remains imbedded in the strata of the southern half of the State, these belong, with very few exceptions, to the latest period of the *secondary formations* of our continent. The exceptions referred to are a few very local and shallow deposits of a still later *tertiary date.*

The soil, throughout by far the largest part of this region, is excessively sandy, and more than three-fourths of the surface is covered by an almost continuous forest. Towards its north-

* The tide extends as high up as Trenton.

western side, however, there prevails a tolerably broad belt of much more fertile land, extending from the northern half of Monmouth county, where it is widest, regularly diminishing in breadth, in a southwest direction, to Salem. Its northwestern margin ranges parallel with the Delaware river and the railroad from Bordentown to South Amboy, keeping generally within from three to six miles of them. This highly favoured tract, which is denominated the "Marl Region," and which will be minutely described in the following pages, resembles the rest of the district very closely as to its general topographical features, but offers a striking contrast in point of agricultural productiveness. Its soil, which usually possesses a more or less proportion of the subjacent "marl" or green sand in its composition—deriving hence its superiority—belongs principally to the two varieties denominated by farmers sandy loam and loamy sand.

The northern half of the State, or all that portion of it which lies north of the line connecting the Delaware and Raritan, at points respectively a little below Trenton and New Brunswick, exhibits to the eye of the traveller a scenery wholly different from that of the more monotonous tracts of the southern division just described—possessing a surface at once diversified and picturesque. When we view the several districts included within this interesting and varied region, whether in reference to their distinctive physical features, their particular mineral productions and geological structure, or their characteristic soils, we find the whole susceptible of a natural subdivision into three well-marked tracts.

The *first* of these, or that upon the southeast, comprises nearly one half of the whole area of the northern half of the State, which it crosses in a northeast and southwest direction, from the Delaware river to the New York state line, having a length of about seventy miles. Its southeastern limit is formed in part by the line already mentioned as extending from Trenton to New Brunswick, in part by Staten Island Sound, connecting the Raritan and New York bays, and in part by the Hudson river.

Its northwestern edge coincides with the base of the range of hills denominated in New York and in this State, the Highlands. This boundary follows the foot of the chain from the New York state line in a southwest direction to the Delaware river, coinciding for several miles very nearly with the course of the Ramapo river; then pursuing, in a gently curving course, the base of the Pompton Mountain, the Trowbridge Mountain, Mine Mountain, and the Musconetcong Mountain, until it meets the Delaware in the vicinity of Durham.

The average width of the district between the two limits here traced is about twenty miles. Both as respects its geology and its topographical features, this is one of the best characterized belts of country in the State. Most of its surface is a moderately undulating plain, composed almost exclusively of a more or less *argillaceous red sandstone.* But this plain is diversified by numerous abrupt and rugged hills, and long and narrow ridges of no great elevation, but of very steep and rocky sides, consisting of *greenstone trap,* which impart to the district much pleasing scenery, and lend to its geology and mineralogy some highly curious and interesting peculiarities.

The *second* division of this part of the State includes the entire chain of the Highlands, bounded on the southeast by the line already traced along the base of the Ramapo, Pompton, Trowbridge, and Mine Mountains, Fox Hill east of German Valley, and Musconetcong Mountain, and on the northwest by the northwestern base of the ridges known as the Pochuck Mountain, Pimple Hill, Furnace Mountain, Jenny Jump Mountain, Scott's Mountain, and Marble Mountain at the Delaware.

The belt of hills embraced within the limits here delineated is widest towards New York, their breadth at the state line being about twenty-three miles; while a transverse section through Scott's and Musconetcong Mountains near the Delaware will not exceed nine miles.

Though possessing only a moderate elevation, which rarely exceeds six hundred feet, measured from the adjacent valleys, they are distinguished by their mountainous aspect, their sides being usually very rugged and steep, their outlines boldly undulating, and their surface for the most part clothed with forest. The whole group consists of a series of parallel ridges, composed, with the exception of a single range—the Green Pond Mountain—of thickly bedded stratified *primary rocks;* the prevailing direction, both of the strata and the ridges which they form, being about northeast by north and southwest by south. Included between these ridges occur several long, narrow, and parallel valleys, in which the soil, differing from that of the hills, is fertile and often highly cultivated. The subjacent rocks of these valleys is a blue limestone of the ancient secondary date.

The perfect levelness of certain tracts forms a singular and striking feature in some of these valleys, and in the parts of the red sandstone region bordering the southeastern base of the Highlands. These "plains" are in some instances extensive *natural meadows*, which are in many cases underlaid by beds of *peat.* Among them are the Pompton, Succasunny and Morris Plains. The substratum of these plains is commonly a deep deposit of *diluvial gravel.*

The *third* and remaining district, into which the northern half of the State naturally divides itself, comprising a large part of the counties of Sussex and Warren, is embraced between the northwestern base of the Highlands, already traced, and the Delaware river. A broad and fertile valley, occupying rather more than three-fourths of this district, and bounded on the southeast by the base of the Highlands, and on the northwest by the foot of the Blue and Kittatinny Mountains, extends throughout its whole length, from the New York state line southwestward to the Delaware river.

The average width of this comparatively level belt of country, the proper name of which is the *Kittatinny Valley,* is between nine and ten miles, while its length, from the New York line to the Delaware, is about forty miles. It is drained throughout two-thirds of its entire length by the Paulinskill, which flows nearly centrally along it to the Delaware. The other portion next New York is watered by the Wallkill and its sources. Its surface is moderately uneven, presenting the aspect of a gently rolling plain, intersected here and there by abrupt ravines and the valleys of the streams. It presents many knolls and low ridges, which become more numerous and elevated as we approach the base of the Blue Mountain.

Two varieties of rock, *limestone and slate,* ranging in several parallel belts, some of them throughout its entire length, compose the strata of this valley. The widest zones of the limestone occur in the southeastern half of the valley, while along the northwestern side a broad belt of the slate extends parallel with the base of the Blue Mountain. It has many tracts of highly fertile soil, especially where the limestone underlies the surface.

Bordering this valley on the northwest we have the conspicuous mountain ridge known as the Blue Mountain or Kittatinny, remarkable for the level outline of its summit, the singular straightness of its course, and its superior elevation, compared with any of the other hills of the State. The width of the mountain at its base is from one to three miles, varying at different portions of its length, but being greatest where it traverses the northern half of Sussex county. Its greatest height appears to be at the Water Gap of the Delaware river, where it has been estimated at *Fourteen Hundred and Fifty Feet.*

The materials composing this mountain are hard sandstone and conglomerate, imparting to its steep and broken sides, and to the country immediately at its base, a rough and stony soil, little congenial to the wants of agriculture. Along its northwestern base and slope this high ridge is almost every where covered with forest; but in some portions of its length, especially that part which lies in Sussex county near the New York line, large tracts of fertile farms occupy its southeastern flank. This feature, so unusual to the Kittatinny Mountain throughout its course across Pennsylvania or New Jersey, and which seems confined to this part of Sussex and to the adjacent counties of New York, arises from the circumstance that the soft and tillable slates of the southeastern base of the mountain rise to a more than usual height upon its side in these cultivated sections.

The rest of the northern region of the State lying between the northwestern base of the Blue Mountain and the Delaware river, is comprised in a narrow valley, the surface of which slopes gently to the northwest or towards the river. The soil of this confined belt of country is various, partaking partly of the nature of the several underlying strata, partly of the materials which have been swept hither by floods, from the adjoining Blue Mountain and from the more elevated lands of Pennsylvania, lying to the north and northwest. Immediately bordering upon the river we find a belt of highly fertile land, of diluvial and alluvial origin, gazing upon which the traveller on the summit of the Blue Mountain may regale his eye with a series of highly pleasing pictures, embracing a long tract of the richest farms, the meanderings of the beautiful Delaware, and the picturesque and varied slopes of the neighbouring ridges.

PART I.

GEOLOGY OF THE NORTHERN DIVISION OF THE STATE, EMBRACING THE COUNTIES OF SUSSEX, WARREN, HUNTERDON, MORRIS, BERGEN, PASSAIC, ESSEX, SOMERSET, MERCER, AND PART OF MIDDLESEX.

Of the Formations embraced within the Northern Division of the State.

THE rocks which constitute the somewhat diversified geology of the northern half of the State are to be classed in three separate groups, readily distinguishable by their different mineralogical characters, the dates of their formation, and the belts of country to which they severally belong.

Enumerating them in the order of the period of their production, they are,

First. A group of *primary rocks,* confined to the Highlands and the vicinity of Trenton.

Secondly. A group of *older secondary strata,* confined to the northwestern portions of Sussex and Warren counties, from the base of the Highlands to the Delaware river, and to most of the regular valleys between the primary ridges of the Highlands.

Thirdly. A group of *middle secondary strata,* lying in the broad belt of country between the southeastern foot of the Highlands and the boundary connecting Trenton and New Brunswick, including, also, the red shale, red sandstone, and conglomerate rocks, of the Green Pond Mountain. With the above third group are connected the *trap rocks,* which are confined almost exclusively to the region of the middle secondary formation, just referred to. We arrive at a knowledge of the relative dates of these several formations, from the order in which they severally overlap each other: thus, the lower members of the older secondary or Appalachian series, especially the blue limestone, the second from the bottom of the group, will be found to encircle very extensively the bottom of the hills, or spurs of the Highlands, and to repose at a moderate inclination *unconformably* upon the *primary* rocks of which these hills are composed. In like manner, both along the southeastern foot of the Highlands and around the Green Pond Mountain, the rocks of the middle secondary group are seen to overlie these *lower secondary* or Appalachian rocks with an unconformable inclination, which plainly establishes the subsequence of their date, by showing that the others had already been uplifted before these overlapping rocks were deposited upon them. We behold the trap rocks resting in many instances in their turn upon the middle secondary strata of their district, and with such obvious appearances at the line of contact of the two formations of a disruption and partial fusion of the latter, as to leave no doubt in the mind of the observer, that the former were poured out through fissures in the middle secondary rocks, at a period when these had been already deposited, and at least partially solidified.

The following tabular arrangement of the rocks and strata of the northern division of the State, specifies the name and nature of the several formations, and exhibits the order of their succession from the trap, which is the newest rock of the region, to the primary strata, which are the oldest.

The *Geological Map* will render intelligible the range and extent of each of these formations, while the accompanying *Sections* will point out the manner in which they are severally related in the order of superposition.

TABLE,

Showing the order of succession of the rocks forming the northern division of New Jersey.

Trap Rocks.—Generally coarsely crystalline; sometimes fine-grained and basaltic; they rest unconformably upon the middle secondary strata, through which they have been protruded.

Middle Secondary Rocks.

1. Variegated calcareous conglomerate. Generally a very heterogeneous rock, in which a large proportion of the

pebbles are limestone, the cement consisting chiefly of red argillaceous earth.

2. Red argillaceous sandstones and red shales. Towards the lower part of the formation, contains numerous beds of coarse gray arenaceous sandstone.

Lower Secondary Rocks.

1. A light blue and gray fossiliferous limestone—the lower member of formation VIII. of the Appalachian series—extends between Carpenter's Point and Wallpack Bend.
2. Red and variously coloured argillaceous shales. Passes into a heavy compact red sandstone. Occupies the northwestern base of the Blue Mountain.
3. A compact, white and gray sandstone alternating with massive layers of white quartzose conglomerate—the principal rock of the Blue Mountain.
4. A dark argillaceous shivery slate, sometimes including beds of roofing slate. Kittatinny Valley.
5. Blue limestone—presenting great diversity of aspect and composition—southeast side of the Kittatinny Valley and its branches.
6. A white quartzose sandstone, somewhat coarse and friable. Occurs only in a few isolated localities.

Primary Rocks. These are, almost exclusively, of the stratified class; consisting of *gneiss* under all its forms—the *granitoid* variety greatly predominating. Innumerable small veins of felspathic granite, sienite, &c. penetrate the gneiss.

In offering a systematic description of the geological phenomena of a region, we have our choice either to begin with the deposits of a recent date, referable to easily explained causes, passing successively to those of more remote eras and obscurer origin, or to commence our history with the earlier occurrences of our globe, and trace them in their natural order of succession.

As the latter method seems the one best adapted to our present object, which is not merely to describe the characteristic geological features of the region, but to unfold, in correct chronological order, the successive stages through which it has passed in acquiring its present complicated structure, I shall adopt it in these pages.

The formations will therefore be treated in the ascending order, as regards their superposition, or in the order of geological time, as respects the date of their production.

I shall commence with an account of the geology of the Highlands—these ridges consisting of the oldest or primary formations.

CHAPTER I.

Primary Rocks of the State.—Geology of the Highlands.

Composition and Structure.—The rocks which constitute the chain of hills to which we give the general name of the Highlands of New Jersey, are embraced, with a few exceptions, in the group denominated by geologists the *Gneiss System.* They are composed of the same assemblage of materials as the ordinary varieties of granite, viz. quartz, felspar, mica, and hornblende (and sometimes augite, magnetic oxide of iron, garnets, &c.), but differ from the true granites by possessing a *stratified* structure.

Their strata are, however, very frequently penetrated by veins and dykes of granite, sienite, greenstone, and other rocks of unequivocal igneous origin, a circumstance naturally calculated to lead the inattentive observer to infer that the granitic or unstratified primary rocks form an extensive portion of these hills. This prevailing misconception is heightened by the granitoid character of the gneiss, which is seldom comparatively of the schistose kind, being far more commonly a massive rock in thick beds, containing relatively few divisional planes. Its analogy to common granite is still further increased by the relative deficiency of its mica—the usual mixture being either felspar and quartz, with a little mica, or felspar and quartz alone; or felspar and quartz and an excess of hornblende; and, not unfrequently, felspar, quartz, hornblende and *magnetic oxide of iron,* which in many places seems to take the place of the mica, giving to the rock the speckled aspect of a micaceous gneiss. Magnetic oxide of iron is in fact an abundant, we might almost say a *characteristic constituent* in the rocks of this region, for it occurs not merely as an occasional ingredient in the gneiss, but in great dykes or veins penetrating the strata. It may be stated as a general feature in the geology of this region, that mica, talc, chlorite and other laminated minerals of the micaceous order—prominent ingredients in the more schistose primary strata—rarely prevail to any extent as regular constituents of the gneiss rocks of the Highlands. In this respect this whole primary chain, viewing it from the Delaware to the Hudson, presents a striking contrast to the other zone of primary stratified rocks, which traverses the country nearer to the seaboard with little interruption from New England to the Southern States. The gneiss rocks of that belt bordering Long Island Sound, passing through New York and Staten Island, reappearing at Trenton, and ranging through Pennsylvania and Maryland, are distinguished for the prevalence of mica and other thinly laminated minerals, imparting to them either the schistose structure or the more or less thinly-bedded character of ordinary gneiss.

A common feature in the massive gneiss of the Highlands is, a tendency to parallelism in the arrangement of its minerals, especially of the felspar and hornblende. In this case the crystals are of a flattish form, and are apt to lie in thin and somewhat separate alternate layers in the rock. This structure seems strictly in harmony with the doctrine which assumes that the so-called primary stratified rocks have been once sedimentary deposits, like the secondary strata, modified into their present crystalline texture by a heat approaching to a partial fusion of the materials. The relative absence of mica and of the more thinly laminated or schistose character, so predominant in some portions of our southeastern primary belt, has arisen, if this hypothesis, usually denominated the "metamorphic theory," be correct, simply from a relative deficiency in the original deposits of those earthy matters, such as clay, lime, magnesia, &c., which are the ingredients of mica and the minerals most nearly allied to it; or, what is the same thing, from a relative excess of silica and those other earths or oxides which are constituents of quartz, felspar, and hornblende. The influence of a difference of temperature in bringing about a difference in the mineral aggregation of the various earths, promiscuously mingled at the period of their deposition, is also possibly connected with the marked contrasts which we see prevailing in respect to their composition, between the stratified primary or metamorphic rocks of different belts of country.

Notwithstanding the innumerable granitic and other veins, which occur with all the phenomena of violent injection, penetrating at small intervals every considerable tract of the gneiss rocks of the Highlands, these strata are decidedly less contorted and folded together into those minor flexures so usual among the micaceous beds of this rock forming the southeastern belt. This probably arises from the massive character of its strata, and the absence of the more flexible mineral, the mica.

The strata are usually highly inclined, their average dip exceeding 45°. In many of the principal mountain ridges an anticlinal arrangement of the dip is plainly visible. In these instances the strata on one flank of the mountain, the northwestern, are inclined to the northwest, while on the other they dip to the southeast.

The common or rather the almost universal direction or strike of the strata, is from the northeast by north to the southwest by south. They are only occasionally found to depart from this direction, which is that of the principal mountain ridges themselves, and indeed of the entire chain of the Highlands, from the Hudson to the Delaware.

Geographical Extent of the Primary Rocks.—The general limits of the primary region of the Highlands have already been pointed out in the introductory chapter, when describing the physical aspect of the northern division of the State. The southeastern boundary of this belt was there traced as ranging along the base of the Ramapo, Pompton, Trowbridge, and Mine Mountains; thence along the base of Fox Hill east of German Valley, and the foot of Musconetcong Mountain to the Delaware: the northwestern limit was likewise stated to follow the foot of the Pochuck Mountain, Pimple Hill, Furnace Mountain, Jenny Jump Mountain, Scott's Mountain, and Marble Mountain, at the Delaware. Between these two somewhat undulating lines are comprised all the primary rocks of New Jersey, if we except the small triangular tract of gneiss which enters the State at Trenton, and which terminates in a point on the Assympink, about six miles east of that town.

It has been already mentioned, that all the rocks included between the two margins of the extensive belt above traced, do not belong to the primary class, but that most of the included valleys consist of an ancient secondary limestone, while the Green Pond Mountain is composed, throughout its whole length, of yet more recent formations of the middle secondary date.

To convey a more accurate conception of the areas occupied by the several parallel but somewhat detached belts of primary strata, which together constitute this broad chain of Highlands, we would call attention, in the first place, to the manner in which this whole range of hills is subdivided by several long, narrow longitudinal valleys.

It will be seen by inspecting the Geological Map, that these divide the whole chain into two continuous parallel mountain belts, traversing nearly the entire breadth of the State, and form also several minor interrupted ridges, skirting the former on the northwest and southeast.

Delineating severally the limits of these primary ridges, we begin on the southeast at Mine Mountain. This first tract of the gneiss rocks includes the whole of the elevated ground which commences at Morristown with the name of the Morris Mountain, and terminates under the name of Mine Mountain, in the fork of the north branch of Raritan river and Pepack Brook.

These primary strata, bounded on the northwest by the limestone and other secondary rocks of Mendham Valley, have their margin coincident very nearly with the course of the turnpike from Morristown to the village of Mendham. Thence they are traceable to the south, following the course of the north branch of the Raritan as far as its junction with Mine Brook: from this point they range to the northeastward, parallel with Mine Brook itself, as far as Vealtown, from which their margin is a somewhat undulating line, by Mount Kemble back to Morristown. Except where the short belt of limestone of the Mendham Valley comes in contact with the gneiss, its border, as here traced, is every where overlaid by the red shale and sandstone strata of the middle secondary formation. The general structure of the ridge, as respects the dip and direction of the strata, is such as strongly to imply the presence of an anticlinal axis traversing it longitudinally from northeast to southwest, to which, in all probability, its rocks owe their elevation. The next continuous zone of primary strata, is one of far more extensive area. It is included between the general northwest boundary of the middle secondary rocks, on the one hand, and on the other, the long unbroken valley, which commences at Clinton, and extends thence along the south branch of the Raritan to its source at Drakeville, and by Green Pond, Macapin Pond, and Long Pond to Dutch Hollow, in the State of New York. Between these limits its range is uninterrupted from near Clinton to the State line, or indeed to the Hudson. To trace this belt of gneiss rocks more exactly, we follow them from the point where the Ramapo river crosses the State line, along the northwestern border of the Ramapo Valley to Pompton, a little north of Ryerson's. Throughout this distance they are overlaid by the middle secondary, red shale, and sandstone group. In the neighbourhood of Ryerson's, a calcareous conglomerate, which when present is the uppermost stratum of that group, lies nearest to the gneiss; the immediate boundary of which, however, is very commonly concealed along the base of the hills, by a deep covering of diluvial gravel. From Pompton, in contact for a part of the space with the diluvial matter which composes the substratum of the Pompton Plains, the gneiss rocks take their course along the foot of the Pompton Mountain by Montville and Boonton Falls, and thence along the base of the Trowbridge Mountain to near Mendham.

As far as this latter point, the overlapping rocks are the upper beds of the middle secondary formation. In the Mendham Valley, the gneiss comes in contact, for a distance of a few miles, as far as Pepack, with the blue limestone of the Appalachian or lower secondary series. From Pepack the formation extends still to the southwest, passing about a mile to the north of New Germantown, and thence in a more westward direction to a point nearly north from Lebanon and two miles northeast of Clinton, where it meets the limestone of the valley of the South Branch. Between Pepack and a point nearly north from Lebanon, the gneiss is, with some few interruptions, in contact with the calcareous conglomerate, the uppermost stratum of the middle secondary rocks. Sweeping round to the north, and afterwards to the northeast, the margin of the gneiss thence pursues the southeastern side of the valley of the South Branch, or German Valley, in contact with the older secondary limestone, as far as a point about two miles south of Flanders. From hence, along the same side of the same topographical valley, it is marked by the overlapping diluvial matter of the Succasunny Plains. Beyond the termination of these plains, northeast of the village of Succasunny, the primary rocks, pursuing still the southeastern edge of the same valley prolonged, come in contact with the middle secondary strata of the Green Pond and Copperas Mountain, as far as the Pequannock. Northeast of this stream, for a range of several miles, they disappear beneath the older secondary limestone of the Macapin Pond. Beyond this limestone to the State line, they come again in contact with the red sandstone beds of the Copperas Mountain, here called the Long Pond Mountain. This part of the boundary is marked by the southeastern side of the valley of Belcher's creek, nearly to Long Pond.

Another axis or elevated belt of the primary rocks, still more extensive than that just described, as respects length, lies immediately to its northwest, separated only by the long line of valley already traced. The southeastern margin of this latter tract of the gneiss coincides from the State line to the Pequannock, in some places with the red sandstone strata of the Long Pond Mountain, and in some places with the slate and limestone formations of the older secondary group, while in other neighbourhoods, it is separated from these by a narrow strip of diluvium, forming the bed of the intervening valley. From the Pequannock southward to Flanders, it ranges at an average distance of half a mile from the northwestern base of the Green Pond Mountain, its immediate boundary being the diluvium of the Longwood and Berkshire Valley and their prolongation.

Thus covered, the edge of the gneiss passes Drakeville and Flanders, until, beyond the latter place, it encounters the older secondary limestone of German Valley. It thence extends down along the northwestern side of this valley to its outlet north of Clinton, the limestone every where forming the overlapping stratum. From the neighbourhood of Clinton, its course is first nearly westward to the vicinity of Vansickle's, and thence southwestward, following the base of the Musconetcong Mountain to the Delaware. Between the South Branch, north of Clinton and the head of Milford creek, the gneiss rocks dip beneath the ancient limestone; but from the latter point to where they strike the Delaware, they are overlaid, throughout the chief part of their course, by the calcareous conglomerate, which caps the middle secondary series.

The northwestern margin of this same chain of the gneiss, is marked by the edge of the Musconetcong Valley, and sometimes by the border of that stream itself, along the entire distance between its outlet at the Delaware and the head of the valley, near the old Andover Forge, the primary strata every where descending beneath the older secondary limestone. From the old Andover Forge, it follows nearly the brink of Musconetcong creek by Stanhope to Brookland, at the outlet of the Hopatcong Pond, being generally, except at Stanhope, in contact with the limestone. It there folds round the base of a hill west of the Pond, which it pursues, passing a little east of Columbia Forge and the villages of Sparta, Ogdensburg, Hamburg, and Vernon, to New Milford, at the State line. In all this part of its somewhat undulating course, the gneiss dips beneath the overlapping edge of the older secondary limestone.

The mountain belt of which the boundary has here been traced, consists essentially of a single uninterrupted belt of axes of elevation, giving to it a general anticlinal structure. It receives, nevertheless, several distinct appellations, applied to different portions of it. Between the sources of the Pequannock and the deep transverse gorge which almost intersects the chain at Drakesville, it takes the title of the Hamburg or Wallkill Mountain. From the cross valley above mentioned to that of Spruce Run, it bears the name of Schooley's Mountain, while between the latter limit and the Delaware river, it is called the Musconetcong Mountain.

To the northwest of the great continuous belt of primary hills, whose boundaries have just been traced, there rises a chain of rather less elevated scattered ridges, which occupy insulated tracts in what, if we take a comprehensive view of the topography of the region, ought to be regarded as the southeastern portion of the Kittatinny Valley. These hills are surrounded on all sides by the older secondary limestone of that valley, through which at least some of them seem to have been protruded subsequently to the period of deposition of the limestone over the gneiss. Though they do not constitute a strictly connected range of the formation, they evidently compose, like the chain to the southeast, one general belt of axes of elevation, inasmuch as they all lie within a narrow zone and nearly in the prolongation of each other. The limestone which encircles them, usually dips *from* their flanks, apparently in consequence of an upheaving action near a central line traversing each hill longitudinally.

Proceeding with our detailed delineation of the boundaries of these primary tracts, we first meet, towards the northeast, the Pochuck Mountain. This ridge, in which the gneiss has evidently an anticlinal arrangement, though a somewhat irregular one, commences in New York, about a mile northeast of the State line, and terminates near the village of Hamburg, having a length of about eight miles, and a breadth ranging between one and two miles.

At its southeastern base, the primary rocks disappear beneath the limestone of the Hamburg, or Black Creek Valley; while along the northwestern side they are overlapped by the same formation, a little east of the Meadows of the Wallkill. This ridge is interesting from its having, towards its southwest termination, a valuable deposit of *brown hematitic iron ore,* to be hereafter described.

The next ridge of importance is Pimple Hill, which, together with a spur which it throws off towards Sparta, extends from near that place to Franklin. On the southeast flank of this ridge of primary, is the much celebrated Sterling Mine, consisting of zinc ore and Franklinite.

From Sparta there extends, towards the southwest, another elongated narrow belt of the primary to within a mile and a half of Andover village, while, about a mile to the northwest of this belt, which is bounded by the limestone of a highly crystalline and altered aspect, there lies a small oval hill of the gneiss, also similarly encompassed. Next, in our progress to the southwest, we encounter two other low and detached hills of the primary, both of them lying a little east of the turnpike which joins Stanhope and Andover. Immediately west of this road, we meet with a larger tract of the primary, which extends continuously almost to the road which unites the villages of Hacketstown and Vienna. Its southeastern boundary passes Lockwood and the old Andover Forge, thence along the western side of the Hacketstown Valley to near the road last mentioned, its northwestern margin passing by Alamuche.

From the vicinity of Hacketstown to near Mount Bethel Meeting-house, there ranges another low ridge of the gneiss, having a length of about four miles and an average breadth of one. Resting upon the primary strata of this tract, is a small patch of nearly white sandstone, well adapted for purposes of architecture, for which it has been occasionally used. This is one of a few isolated patches of the lowermost rock of the older secondary or Appalachian series, in New Jersey; a formation displayed so extensively in contact with the primary rocks of the same general chain, both in New York and Pennsylvania. Another locality of the sandstone is to be found between Flanders and Succasunny, northeast of the former village; and two other exposures, are visible near Macapin Pond, where the rock is in contact with the overlying blue limestone.

Another considerable surface of the gneiss extends from near the village of Mansfield southwestward to the Easton turnpike, a little west of Bloomsburg; bounded on the northwest by the Pohatcong stream, and on the southwest by the valley of the Musconetcong.

The next important belt of primary rocks is that of the mountain called Jenny Jump. This ridge, extending from near the outlet of Bear Brook at the Great Meadows, almost to the village of Sarepta, is about seven and a half miles long, by about one in mean breadth.

Its rocks are every where overlapped around its base by the ancient secondary limestone; an interesting zone of which, in a highly crystalline and altered condition, ranges along its southeastern foot for nearly its whole length.

Two small patches of the primary rocks, which seem to have been exposed by denudation of the limestone, occur in the valley of the Pequest, between that stream and the foot of Jenny Jump.

South of the Pequest rises the conspicuous ridge of primary rocks, called Scott's Mountain. Its length is about twelve miles, while its general breadth somewhat exceeds three. Encompassed at its base by the limestone, the southeastern limit of the gneiss ranges parallel for several miles with the Pohatcong stream, and afterwards with the Morris canal; while, on the north, the valley of the Pequest is the boundary as far as Bridgeville. On the northwest, the margin is pretty nearly marked by the road uniting this place and Oxford. It extends thence through the spot called Concord to Harmony Church.

The last belt of the primary strata to be traced is that of Marble Mountain, at the Delaware: this is also surrounded by the limestone, but its western base is almost washed by the Delaware river. It terminates towards the southwest near Phillipsburg, opposite Easton; and towards the northeast almost unites with Scott's Mountain, near Harmony Meeting-house. Its length is about four miles, and its average breadth one mile.

Of the Igneous Rocks and Metalliferous Veins of the Highlands.—The metalliferous veins of the primary region of the State, though extremely numerous and widely distributed, embrace but few varieties. As regards their general structure, they are all, in fact, very nearly alike; while the only ores they comprehend in large amount belong to the two metals, iron and zinc; those of iron being by far the most abundant.

Structure of the Veins.—In their form they are unequivocally genuine lodes or veins, and often of considerable longitudinal extent coinciding with occasional slight deviations, with the direction of the strata which include them. Their position is usually between walls of the granitoid gneiss, to which they are parallel, not only in strike, but in dip. They exhibit, however, many minor irregularities, such as frequent changes in thickness, suddenly bulging to great width, and rapidly thinning out to almost imperceptible dimensions. This observation is to be received as applying with fullest force to the whole body of injected matter, regarding it as one vein, which it truly is; while the distribution of the ore within the vein is liable to even greater irregularities. Viewing these veins comprehensively, they consist not exclusively of the metalliferous ore, whatever it may be, but of the ore and other minerals, particularly hornblende and felspar, in one general injected mass. In some instances, the ore constitutes the body of the vein, resting in contact with the gneiss rock of the walls; in others, it occupies only a part of the thickness of the mass, being bounded on either one or both of its sides by the non-metalliferous minerals, usually termed the gangue; while in other cases again, the vein of ore is split by a wedge of the same gangue, which either entirely cuts it off on one side, or being of limited length, soon permits the reunion of the divided portions.

Not unfrequently this gangue comprises the chief width of the vein, and the ore included in it lies in detached elongated bodies of lenticular form, having their longer axes always in the direction of the course of the vein. These insulated masses of the ore, denominated *pots* or *pools* by the miners, are sometimes more than a hundred feet in length, their thickness varying in certain large veins from five to forty feet.

Another feature, deranging occasionally the uniformity of these veins, presents itself, when detached portions or splinters, as we may regard them, from the adjoining strata constituting the walls, are found lodged in the substance of the lode. These and other smaller wedge-shaped masses, interrupting or dividing the vein, are commonly entitled *horses* by the miners.

In addition to these irregularities in the distribution of the ore, we sometimes find the entire vein cut through by faults crossing it, commonly almost at right angles, and totally interrupting its continuity.

The several circumstances here spoken of in the structure of these metalliferous veins, seem strongly to imply that they are real veins of injection, and not true beds, contemporaneous with the adjoining gneiss, as some have supposed. A common thickness of the metalliferous veins under description is from six to twelve feet; in their inclination or pitch they are quite various, some dipping, with the strata that enclose them, at as low an angle as 50°, while many are nearly vertical. In the shallower excavations the workings are open to the sky, and the deepest shaft yet sunk, that of the Mount Pleasant Mine, near Dover, in Morris county, is only about two hundred and twelve feet below the surface.

Nature of the Ore.—The ore belongs to the species denominated by mineralogists *oxidulated iron* or *magnetic iron ore*, and is of two varieties—compact and granular. In its purest form, this mineral consists of two atomic proportions of the *peroxide* of iron, and one of the *protoxide*, which is equivalent to nearly 72 per cent. of the former, and a little more than 28 per cent. of the latter—yielding about 72 per cent. of metallic iron. In the state in which it is more usually met with, however, mingled with a greater or less proportion of extraneous mineral matter, the amount of metallic iron contained ranges between 60 and 72 per cent. It is magnetic, being endowed with the property of attracting soft iron, and affecting the magnet. Masses of it are frequently met with possessing a distinct magnetic polarity, the opposite ends manifesting a repulsive action upon the corresponding ends of the needle. Such specimens are termed loadstones.

Though the pure variety is often massive, and mingled with but little foreign mineral matter, yet this is really less productive in the manufacture of iron than the granular or imperfectly crystalline kind, in which we find a moderate proportion of small crystals of hornblende, felspar, quartz, and other minerals, interspersed with the ore. Some of the ore contains a small proportion of titanium. The veins often exhibit a tendency to cleave by numerous natural joints, extending across from one wall towards the other; a structure which suggests a strong analogy to the horizontal columnar arrangement seen in many vertical dykes of lava and basalt. This, if the proofs already cited were not enough, deserves to be regarded as an argument in behalf of the opinion that these veins of ore have been injected, while in a fused or molten state, into the gneiss, and are not in the strict sense *beds* formed contemporaneously with the surrounding rock.

This point, though at first sight unimportant, and seemingly one of mere theory, is of much practical moment to the miner, since it acquaints him with the nature of the veins in which he is operating.

Local Details.—In offering a detailed description of the veins of magnetic iron ore as far as they have been developed, we shall begin, for the sake of convenience, with those lying towards the northeast. The first which claim our attention are those of Pompton township, in Bergen county. The principal veins of this tract occur in the continuation of the Sterling Mountain of New York. In the ridges immediately west of the Ringwood Valley at least two extensive veins are known.

The most southeastern of these has been explored for much the greatest distance, several mining excavations having been made in it, throughout a length of nearly three miles. That to the northwest is distant from the former about two hundred feet, and, where it has been traced or mined, has been found to preserve a parallel direction with it. The first mentioned of these veins extends to within a quarter of a mile of the New York line. Their course is north northeast and south southwest. The rock of this region, containing these veins, is the ordinary granitoid gneiss, abounding in hornblende, and nearly destitute of mica. It has a steep dip to the southeast.

Following the most southeastern of these two veins, from the southwest to the northeast, the first considerable excavation which displays its structure is an old mine, quarried open to the day, to the depth of perhaps forty feet, and for about three hundred and fifty feet along the vein. The pitch of the vein at this point is nearly vertical. Its general regularity is somewhat disturbed by trivial slides and sudden changes of dip. Large wedge-shaped masses of the gneiss rock of the walls intrude themselves into the middle of the ore, subdividing the veins into two or more branches, which send off parallel filaments, that either dwindle out entirely in the rock, or reunite with the main body of the vein.

The mean thickness of the ore in this mine is about ten or twelve feet, exclusive of these interposed masses of rock. Though not at present used, the ore is stated to be of average purity.

About one hundred feet to the northeast of this is the mine known as the *Blue Mine*, from the bluish hue of the ore. The excavation from which the ore has been removed, is about one hundred feet in length by fifty feet in depth, while the width of the vein varies from six to fifteen feet.

At this place also the vein is divided in the middle of the ore by a vertical wedge of rock, which increases from one to five feet in thickness, and consists on the one side of red felspar, like the adjacent wall of the vein, and on the other of compact green *sahlite*. In this part of the vein are several oblique dislocations or slides, always declining to the southeast.

Within less than half a mile to the northeast of this last opening there is another point where excavations have been made, called the *Mule Mine*. The principal vein of ore here is seven or eight feet thick, swelling out at some spots to twenty feet.

Formerly it was extensively wrought, open to the sky, to a depth of seventy feet, and length of one hundred yards. Within only a few paces to the southeast of this opening, which is called the Blue Hole, is another in a more circumscribed vein, of a lenticular form, called the *Mule Ore.* This shorter vein is divided through its middle by a wedge or horse, consisting principally of massive crystallized hornblende.

Exclusive of this intruded mass, the vein, at its widest place, where it is at present worked, is twenty-five feet in thickness. At a somewhat greater distance, on the opposite or northwest side of the principal vein, occur three or more similar detached small veins, or, as we ought, perhaps, more properly to say, lenticular portions of the general vein. One of these pots or pools of ore, denominated the Henion Mine, is about fifty feet in length by ten feet in thickness. It has been wrought to a considerable extent, yielding an ore of excellent quality.

The ore of this and some of the other small subordinate veins possesses the magnetic character in a distinguishing degree.

The whole of the ore of this immediate vicinity of the Mule Mine is stated to make a good iron, which is apt, however, to be *red short,* or brittle, at a red heat.

The pitch of the principal vein of ore of the Mule Mine is parallel to the dip of the adjoining gneiss rock, which is to the southeast at an angle of about 60°.

Northwest of these several workings of the Mule Mine, and higher up the hill, we meet with another set of short, lenticular outbursts of the ore, wrought by the name of the Cannon Mine.

The greatest width of the ore in the main excavation here is forty feet, caused, however, by the coalescing at this point of two adjoining masses, which are elsewhere separated by wedges or horses of the gneiss rock. The largest of these divisions of the vein is fifteen feet across. Another somewhat oval mass, lying almost in the prolongation of the one here mentioned, and only separated from it by an intervening wall of gneiss a few feet thick, has furnished at its widest part a nearly solid body of ore, thirty feet in thickness.

These ores smelt with facility, but produce a highly brittle, or *cold short,* iron.

Beyond these excavations, to the northeast, succeeds the

Peter's Mine, formerly worked, partly in a shaft, partly in a quarry open to the sky.

At this place the dip, both of the vein and the primary strata bounding it, is at an angle of about 60° to the southeast. The rock above the ore is a mixture of felspar and mica in a state of disintegration; in other places it consists of a fine pinkish felspar rock in the same rotten condition. The form of the vein at the place where it has been worked, is that of a narrow wall of ore, six feet in thickness, which presently swells into a huge mass of an oval form, fifty feet in diameter. This pool of ore has been wrought beneath the open air to a depth of about seventy feet, the water being drained off by an adit cut through the adjoining wall of gneiss.

This ore is said to yield an iron which is brittle at a red heat, or red short.

The Spanish Hope and Good Hope mines form the next group of openings as we proceed to the northeast. They occupy the southwestern extremity of a spur of the main mountain, and occur at a distance of not more than one-third of a mile from the New York state line.

The hill in which these mines lie is very rugged, and the ordinary gneiss rock composing it much disturbed, connected with a considerable degree of irregularity in the metalliferous veins. The general width of the main body of ore is about eight feet, dipping with the strata to the southeast at an average inclination of 70°. The most northwestern of these openings, called the Good Hope Mine, exhibits the vein in considerable regularity, dipping at an angle of about 80° to the southeast, and having a pretty uniform width of nearly twelve feet. These mines were somewhat extensively worked by an English company before the revolutionary war: the Good Hope Mine now showing a large excavation, sixty feet in depth. The ore proved of superior quality, which led, about twenty years ago, to a resumption of mining operations, which have been since abandoned.

In the same prolongation, towards the north-northeast, we find a continuation of this series of mines for several miles into the State of New York, but whether these occur upon the same line of veins, seems to be not quite established.

Reviewing in their general connexion the whole line of veins of iron ore here described, we are forcibly impressed with the belief, that while they are of a moderate length, taken individually, they are to be regarded as constituting but one long and extensive belt of closely connected metalliferous injections, contemporaneously produced.

It appears from what has been detailed, that the ore in its course to the north grows more uniform and undisturbed. The general quality of the ore along much of the line here traced is excellent, answering well for the bloomery or the furnace. Much of it is coarsely granular, which is a good feature; a portion, however, is too compact—being somewhat refractory and red short—especially a particular band or subdivision of the vein.

Near the openings first mentioned, the second or northwestern vein has been penetrated throughout a length of about one hundred feet, and to a depth not exceeding thirty. Its ore makes an iron highly cold short, a circumstance which has caused the vein to be less explored than the other, though it is probable that it ranges over a considerable distance. Its position is parallel to the first. The dip is to the southeast, and its width about ten feet. The ore in these veins is highly magnetic, some of it possessing magnetic polarity. It is a coincidence which deserves at least to be alluded to, that in another even richer locality of magnetic iron ore, namely, that of Mount Pleasant and Succasunny, in Morris county, there exist two extensive veins or series of veins, the predominant character of the western vein in that neighbourhood being just as at Ringwood, that of producing a cold short iron.

About midway between Ringwood and Pompton, or six miles from each place, a vein occurs in a similar position to the above, on the west side of the Ringwood Valley, having exactly the same bearing, namely, north-northeast.

Westward of the iron range here laid down, there would appear to occur between this and the vein of Franklinite and zinc of the valley beyond the Wallkill Mountain, more than one considerable and valuable vein of magnetic ore. We may mention the veins of Charlottesburg and those of the Wallkill Mountain, four miles east of Franklin Furnace, as examples.

The next district in the primary region, remarkable for an abundance of magnetic iron ore, is a range of country extending between the Pequannock and Succasunny, running from the northeast to the southwest, parallel with the Copperas Mountain, at a distance from it of between two and three miles. The rock of this region is the usual granitoid gneiss, consisting principally of felspar and hornblende. The strike of the strata here, as almost every where else, is to the south-southwest, the usual direction of the dip being towards the south-southeast, and at high angles, commonly exceeding 60°.

A series of parallel veins, or more properly speaking, of parallel belts of closely contiguous veins, consisting of very excellent magnetic iron ore, imparts especial interest to this range.

I shall allude more particularly to three of these belts of ore, conspicuous for their length and well-developed features. Though the excavations yet made are not sufficiently numerous to establish satisfactorily either the independence or the strict continuity of the several portions of a vein or veins occupying the same line of bearing, yet the indications are, that the individual veins are of considerable length, say several furlongs, but by no means prolonged over the whole district.

I incline to view each supposed long vein as made up in fact of a string of several veins very nearly in a line, one commencing either at or a little before the termination of another.

As the question of their strict continuity is one of little practical importance, we may venture, for the sake of present convenience, to designate them as three great veins, inasmuch as they lie in three separate parallel zones. From a little to the northeast of Hibernia, where the larger exposures of the ore commence, to a point at some distance southwest of Succasunny, where they at present cease, the space over which these belts of the magnetic ore have been worked, is upwards of ten miles.

The inclination and strike of the several veins coincide, whenever they are at all regular, with that of the enclosing strata of gneiss. Their direction is from north-northeast to south-southwest.

Commencing with the southeasternmost line of ore at present developed, we find upon it the two mines, entitled Muir's Mine, and Sweed's Mine. The next parallel belt towards the northwest embraces the Hibernia Mine, Jackson's Mine, and Dickerson's Mine, near Succasunny. The third range includes the Denmark

Mine, where no large vein of pure ore has yet been discovered; the Mount Hope Blue Mine, Mount Hope Mine, Teabo Mine, Mount Pleasant Mine, Harvey's Mine, Sterling Mine, and Burwell Mine. These several mines are here designated in the order in which they occur, passing from northeast to southwest. It is not intended to convey the impression that the above classification into three belts of veins is regarded as positively accurate, for the distances between the excavations, especially along the two first ranges, are so very considerable, as to suggest a reasonable doubt whether we might not refer them to a greater number of parallel belts.

Describing the mines in the order above given, we find the most northeastern of the southeastern range, to be the excavation called Muir's Mine. This is about a mile and a half to the northwest of Rockaway. The vein at the surface of the ground, where it is occasionally exposed, is six inches thick, widening as it descends, and becoming two and a half feet thick at the depth of thirty feet. The adjoining rock is a compact gneiss, dipping parallel with the vein, which inclines at an angle of 45° or 50° to the southeast.

At a considerable distance to the southwest of the above is Sweed's Mine, situated about midway between Rockaway and Dover. Here the general features are the same, the dip being 50° to the southeast.

The thickness of the vein of solid ore varies from five to twelve feet. Next to the hanging or overlying wall, there is usually a band, of about three feet in thickness, of excellent compact ore; beneath this succeeds four feet of spar, consisting largely of vitreous felspar, and under this again occurs a very poor ore, mingled largely with the extraneous mineral matter of the foot-wall or floor, from which the vein is not clearly separable. The separation between the vein and the hanging wall, on the contrary, is well defined. The upper division of the vein is soft and of a granular structure, and yields a good iron. The impurer portion next the foot-wall affords, on the contrary, an iron characterized as *red short.* It is worthy of remark, that the adventitious matter in the red short ore, is not different from that in the ore of standard goodness. The ore in the vein is thrown into some irregularity by wedges or horses of a species of rock, composed apparently of the injected gangue of the ore, consisting of hornblende or blackjack and mica, with a variable proportion of ore in an irregular crystalline or granular form. The mine is drained by an adit which passes out through the side of the hill next the east.

Upon the second or middle range of mines, the most northeastern excavation is the *Hibernia Mine.* The situation of this mine, which is upon the top of an elevated hill, adjacent to the Hibernia Forge, renders it somewhat difficult of access. The ore here also sometimes shows itself upon the surface, though it more frequently requires an excavation of moderate depth before it can be reached.

The dimensions of the vein are quite variable, though its average thickness is perhaps about eight or nine feet. The ore, containing much foreign mineral matter, and being at the same time highly magnetic, affords an opportunity for using the magnetic separating machine, by which it is economically freed from its impurities.

About half a mile to the west of Dover is Jackson's Mine, yielding an ore similar to the last. This is inferred, by its position, to lie upon the same vein or string of veins.

The vein is here seven feet in width. There is a shaft leading down to the ore forty feet deep. The excavation is about two hundred feet in length.

The next, and by far the largest vein of the range, is half a mile further towards the southwest, at General Dickerson's, near Succasunny. Here the enclosing rock is a variety of gneiss, composed chiefly of quartz and felspar, with occasionally a little mica and oxidulated or magnetic iron ore, disseminated through it. The dip is about 60° to the southeast. The mine has been wrought to a depth of about eighty feet. In the horizontal drift, along which the vein has been chiefly worked, the quantity removed has been very great. Here the average thickness may be stated at about twelve feet, though near the entrance of the mine, in consequence of an irregularity, the mass of ore seems to have been at least thirty feet across. This being in a disturbed portion of the vein, the presumption is, that it does not continue far of this dimension.

The general structure of this ore is highly granular, showing a frequent approach to the octohedron, the regular crystalline form of this species of iron ore. It is also sometimes of the compact variety. It is considered equal to any in the State for the quality of the iron which it produces. The same vein is said to have been opened still further to the southwest, but the remotest point in that direction to which it may be traced has not been ascertained.

Three varieties of the ore occur at the Succasunny Mine—a blue ore, a reddish ore, and a sparry ore. The first lies next to the foot-wall, the red ore occurring adjacent to the hanging wall, while the sparry ore runs generally in separate veins between the rest of the vein and the hanging wall. One vein of this variety, measuring twenty-two inches in thickness, is divided from the other part of the ore by only about three or four inches of rocky matter.

The price of the *blue* and *red* ores at the mine is $3.50 per ton; that of the sparry ore, somewhat less rich in iron, is $2.50. The mine is not very actively worked; about fifteen hundred tons per annum having been mined during the last five years.

Entering in the next place upon the third or northwestern belt of veins, we commence, towards the northeast, with the unimportant excavations near the old Denmark Forge, which are to be regarded as openings in search of ore rather than a regular mine. The first mine of consequence in this series is the *Mount Hope Blue Mine*, now no longer wrought, occurring at a distance of nearly four miles to the southwest of the Denmark openings. The vein seems to average from twelve to fourteen feet in thickness. At the surface of the ground the vein was from eighteen to twenty feet thick. It has been worked to a depth of one hundred feet, being, at the deeper portions, as much as twenty-four feet in thickness.

The excavations consist of a series of inclined galleries, at a slope of about 25°, in descending zigzag arrangement. The ore has been removed throughout a length of several hundred feet. The mine has been abandoned in consequence of the too rapid accumulation of water. An adit, carried into the mine from near the base of the hill, would seem to be all that is required to give access once more to this large mass of ore.

The next mine, in our progress to the southwest, is the

Mount Hope Mine, about a quarter of a mile from the former, and upon the same line of metalliferous injections. Its position is upon the northeastern brow of a hill, about three hundred feet in elevation, overlooking the old *Mount Hope Furnace.* The quality of the ore appears to be analogous to that of the Mount Hope Blue Mine. The thickness of the vein varies, being only one foot at the south end of the mine, and six feet at the north end. A shaft has been sunk here between seventy and eighty feet in depth. This mine is now in operation.

About one-fourth of a mile to the southwest of the last occurs the *Teabo Mine,* on the southwestern declivity of the same hill. Here the vein of ore is almost ten feet in thickness, holding a nearly vertical position, its inclination being towards the southeast. The walls are regular and unbroken, consisting of a rather micaceous gneiss. This is one of the veins in which the *horizontal columnar structure* of the ore is very obviously displayed. A wedge of rock separates the vein in one or two places, but only for a short distance. The ore is of excellent quality, though compact, the foreign matter mingled with the magnetic oxide of iron consisting of a green hornblende and some quartz. The mine is about one hundred feet in depth, the length of the excavation exceeding one hundred and fifty feet.

Upon the same supposed northwestern vein or belt of ore, and one mile further to the southwest, is the Mount Pleasant Mine. The average thickness of the vein may be given at about eight feet, though it is very variable, changing from eighteen inches to twelve feet, and sometimes thinning away, for a short space, almost to nothing. These fluctuations of width take place as well in the vertical as in the horizontal direction. The rock immediately adjacent to the ore, from all appearance protruded contemporaneously with it, is an almost pure hornblende, having an extremely beautiful massive crystallization. The material of the regular wall, on the one side, is a hard, light-coloured felspathic rock, while that of the other, or hanging wall, is chloritic and often micaceous. In driving to the southwest in one of the galleries of this mine, the progress of the vein was suddenly arrested by a cross dike of quartz rock, fourteen feet in thickness. After many fruitless borings for the recovery of the vein, it was discovered, heaved to the southeast, many feet out of its original line. Beyond the dike the vein is tossed about in very considerable confusion, the masses of ore occurring rather in detached pools than in one continuous lode.

The dip of the regular portion of the vein is to the southeast. The depth to which the mine has been wrought is two hundred and twelve feet. Lying below the surrounding streams, its drainage is effected by machinery; a series of well-contrived pumps, driven by a small brook acting on a water-wheel, being employed for the purpose.

Nearly a mile and a half west of Dover we find the *Harvey Mine*, once extensively wrought by a shaft, but now no longer in operation. The ore here resembles that of the Mount Hope Mine, lying in a vein which varies from four to nine feet in thickness.

About three-fourths of a mile west of Dover occurs the Sterling Mine, not at present wrought. The vein of ore was found to vary from two to thirteen feet in thickness. At one spot, at twenty feet from the surface, it was only eighteen inches wide, but grew larger lower down. The walls consist of a hard dark-coloured granitoid gneiss. Several shafts were sunk upon this vein; the deepest, however, did not exceed thirty-five feet.

The last in this series of mines lies about half a mile southwestward from the Sterling Mine, and is known as the *Burwell Mine.* The vein of ore is about eight feet wide. Two shafts have been sunk upon it.

Not far from Mount Pleasant, there is a small mine upon a vein which is supposed to lie to the southeast of those above traced. But little is known of the length or course of this vein, any further than that its direction and dip are parallel with those of the others.

A similar vein is known, and has been mined to a considerable extent, near Powerville; and no doubt many more exist in the district, though nothing has been done to develope them, and no useful facts concerning them have come to light. It should be mentioned that the long range of ore veins above traced, lies almost exactly in the bearing of the vein near the old Charlottesburg Furnace, on the Pequannock.

But few indications of iron ore have been hitherto discovered in the southwestern prolongation of this first or southeastern chain of the Highlands, in that part of it which is called the Chester Mountain.

Adverting in the next place to the metalliferous veins of the other great parallel range of primary hills, which includes in one continuous chain the Wallkill, Schooley's, and Musconetcong Mountains, we are forcibly struck with the fact of their relative fewness, when compared with the numerous and extensive injections which traverse the more southeastern belt, above described.

Upon the Walkill or Hamburg Mountain magnetic iron ore may be occasionally met with in the soil, while excavations made at various spots have also brought to light small bodies of the ore, but no veins of considerable magnitude.

Advancing along this chain towards the southwest, we meet with similar indications of ore in the neighbourhood of Stanhope, and also south of this, in the vicinity of Flanders, where many loose fragments of it occur in the soil, especially in the neighbourhood of Bartley's Forge. About three-fourths of a mile north of the forge a small excavation for ore may be seen, which, it is said, yielded a mineral of good quality. An opening has also been made about a mile from Mount Olive, but it did not develope a vein of any magnitude.

Nearly a mile and a half northeast of Drakestown, on Schooley's Mountain, a digging was lately made (summer of 1838), which produced some ten or twelve tons of ore, of a highly magnetic character, pronounced to be of good quality: but it did not lead to the developement of a regular and solid vein.

Upon the same mountain, and about a mile and a half east of Hacketstown, some ore is visible in the soil, but of too quartzose a nature to produce a good iron. The diggings which were made at this spot did not succeed in disclosing a regular vein.

Upon the mountain, a few furlongs to the west and northwest of the Heath House, ore in considerable abundance strews the surface of the fields. A portion of the mineral here is pretty largely contaminated with hornblende, augite, and other foreign substances, which do not, however, materially interfere with the reduction of this species of ore into iron, except where their quantity is considerable. Much of the ore of the same locality, is distinguished by having the magnetic property, sometimes in a high degree, many masses being found endowed with magnetic polarity in unusual strength.

Numerous small openings have been made here, at various times, in quest of a regular and solid vein, but, until recently, none promising to be of useful quality and dimensions have been explored. From some excavations lately made the indications seem to be more encouraging.

In the Musconetcong Mountain, the appearances of the surface do not justify the hope of there being any considerable veins of the magnetic ore.

The next and last tract of the primary hills, towards the west, abounding in this valuable mineral is Scott's Mountain, in Warren county.

A brief account of the veins in the vicinity of Oxford Furnace, the locality of chief importance in that district, will complete the details which we have to offer upon the subject of the magnetic iron ore of the region.

Here, as elsewhere, the direction of the veins is parallel with the bearing of the strata of granitoid gneiss which include them. There appear to be at least two principal veins, but the precise thickness of either it is difficult to ascertain, owing to their varying constantly in their dimensions. The quantity of ore, however, is enormously great. The veins are divided here and there, by thin beds of the rock, into several parallel branches, so that the aggregate width of the ore has not been wrought in many places. The adjoining strata are, moreover, considerably disordered, and the veins are, in consequence, thrown out of direction by two or three pretty large faults. These are connected with detached or broken off portions of the lodes, two of which are known to sweep round a curve of almost semicircular form.

Some portions of the adjacent strata contain the oxidulated magnetic iron in a crystalline state, disseminated in sensible proportions through the rock, or rather through certain layers, either associated with the hornblende or replacing it.

The greater part of the ore resembles in quality that of the ranges before described, being the magnetic oxide of iron, either compact and massive, or in granular crystallization. It has the defect common to nearly all the veins in the primary region; that is to say, it is apt to be *too compact* for easy reduction in the furnace. It yields an excellent iron, and seems especially well suited for making castings.

Let me here be permitted to express the hope that this favoured region of New Jersey, so eminently enriched by nature with that most valuable of mineral treasures, iron, is destined to behold, at no very distant day, a brighter era as a manufacturing district. Two important new methods, recently introduced into the smelting of iron, namely, that of the hot blast and the substitution of anthracite coal for charcoal—now become in many districts of the State too scarce to be employed—seem peculiarly well adapted to remove some of the difficulties which attend the use of these compact magnetic ores. These obviously require a more elevated temperature for their profitable reduction than can be given them by the aid of charcoal and the ordinary blast, and seem particularly to call for the application of the modern improvements referred to. The success which has lately attended the use of anthracite in the smelting of iron in Pennsylvania, suggests that New Jersey need no longer be prevented from availing herself of the advantages, arising from her superabundant treasures in ore, by the absence of wood upon her hills.

Conclusions deducible from the previous facts.—The first theoretical inference, naturally suggested by the remarkable manner in which all the veins, without any exception, occur is, that the primary strata existed in all probability at a rather steep inclination before the intrusion of the veins; for it is inconceivable how a forcible injection of fluid ore could enter a series of beds, lying in a nearly horizontal position, without in some cases causing and occupying fissures transverse to the strike of the strata. The fact that other similar veins—those of the altered white limestone of Sussex—occupy a corresponding position in reference to the neighbouring strata, and appear to have been produced after the formation of the limestone, is another argument lending probability to the notion that their origin was subsequent to the formation and upheaving of the gneiss.

Moreover, it is not difficult to conceive, that if the strata were previously nearly vertical, or at a high angle, the molten ore would easily insinuate itself in the plane of the stratification of the rock, this being the direction in which the strata would most readily give way. If the rule be a general one, that these veins range and dip parallel to the strata, we are led to some important general hints for seeking and opening mines in this region. One is, that the veins of ore may be expected to follow the same layer or bed of rock for a considerable distance; and that the nature, therefore, of the *adjoining rock*, will often prove a clue for finding a previously known vein in the direction towards which it is prolonged. Another suggestion is, that when levels are cut, or shafts sunk to reach a vein, the indications of which are witnessed upon the surface, the excavations should be made on that side of the presumed *outcrop* of the vein which is towards the *underlie*, or dip of the gneiss, because the vein, keeping parallel with the rock, will descend in that direction.

Respecting the geological date of these veins of magnetic iron ore, it seems difficult, from the imperfect nature of the data afforded by the region, to arrive at positive conclusions. The views which we here venture to suggest in the light of the hypothesis on the subject, are offered as merely conjectural. They are deemed at the same time worthy of a place in our account of the geology of the Highlands, as assisting to throw light upon other questions hereafter to arise, and as opening a train of inquiry interesting to future investigators—some of whom, let us hope, may hereafter find an inviting field for research in the structure and former physical history of this mountain belt.

In examining the question of the date of the veins of magnetic iron ore, our attention is at once called to the interesting general fact, that these veins lie exclusively in the primary rocks. I think we must conclude, that most, if not all of these veins of ore, were etruded from their deep source beneath the surface, during the epochs which preceded the deposition of the first widely dispersed secondary strata.

CHEMICAL COMPOSITION OF THE MAGNETIC IRON ORES OF THE HIGHLANDS.

Suggestions concerning the treatment of these ores, can be of service to the manufacturer only in proportion as they are the results of numerous and precise chemical investigations into their composition.

The following analyses will exhibit their average richness in iron; and display, moreover, the amount and nature of the extraneous substances, which occasionally interfere with their reduction.

Analyses.

Peters' Mine, Ringwood, Bergen county.

Description.—Ore, magnetic, perfectly granular and crystalline; the grains uncommonly large and distinct. Contains a few spots of yellowish decomposed mineral. It is extremely friable.

Specific gravity.—5·112 at a temperature of 65·5° Fahr.

Composition.—Iron,	- -	71·9 per cent.
Insoluble matter,		0·3 do.
Alumina,	-	a trace.
Lime,	- -	none.

Good Hope Mine, Ringwood.

Description.—Ore, magnetic, beautifully crystalline; the grains exhibiting nearly regular facets. Contains a little interspersed yellowish clayey matter.

Specific gravity.—5·019 at temperature 50° Fahr.

Composition.—Iron,	- -	71·88 per cent.
Insoluble matter,		1·5 do.
Lime and alumina,		a trace.

"Cannon Ore," Ringwood.

Description.—Ore, magnetic, highly crystalline; the grains distinctly angular and rather small. Contains much white and greenish mineral matter.

Specific gravity.—4·685 at temperature 69° Fahr.

Composition.—Metallic iron, 63·2 per cent.

Mount Hope Blue Mine, Morris county.

Description.—Ore, magnetic, compact and massive; having but little of the granular structure. Fracture nearly flat, but not smooth; somewhat mottled with white and greenish specks.

Specific gravity.—4·918 at temperature 65° Fahr.

Composition.—Metallic iron,	-	69.6 per cent.
Insoluble matter,	-	2·8 do.

Teabo Mine, near Dover.

Description.—Ore, magnetic, compact, slightly granular, fracture irregular; lustre, brilliant, metallic. Contains dispersed grains of hornblende and vitreous felspar.

Specific gravity.—44·82 at a temperature of 69° Fahr.

Composition.—Metallic iron,	-	64·9 per cent.
Insoluble matter,	-	6·2 do.
Lime and alumina,		a trace.

Mount Pleasant Mine, near Dover.

Description.—Ore, magnetic, compact and massive; somewhat granular; grains less than the average size; contains greenish and white specks of extraneous matter.

Specific gravity.—4·697 at a temperature of 70° Fahr.

Composition.—Metallic iron,	-	65·99 per cent.
Insoluble matter,	-	7·2 do.
Lime and alumina,		slight traces.

Sterling Mine, near the Mount Pleasant Mine.

Description.—Ore, magnetic, massive and granular; grains distinct, interspersed with specks of a whitish decomposed mineral, amounting to almost one-half the whole bulk.

Specific gravity.—4·691 at a temperature of 66° Fahr.

Composition.—Metallic iron,	-	66·4 per cent.
Insoluble matter,	-	4·4 do.
Alumina,		rather more than a trace.

Succasunny Mine.

Description.—Ore, magnetic, highly crystalline; grains large and distinct.

Composition.—Peroxide of iron,	-	70·00 per cent.
Protoxide of iron,	-	28·25 do.
Oxide of titanium,	-	a trace.
Oxide of manganese,	-	a trace.

Oxford Furnace Ore, Scott's Mountain, Warren county.

Description.—Ore, magnetic, and somewhat granular and friable. Contains numerous grains of felspar, hornblende, and other extraneous minerals.

Composition.—Peroxide of iron,	-	67·25 per cent.
Protoxide of iron,	-	26·50 do.
Oxide of manganese,	-	0·50 do.
Oxide of titanium,	-	a trace.
Silica, - -	-	2·10
Alumina, &c. -	-	3·00

The analyses of these ores being undertaken with a view to ascertain more particularly the quantity of metallic iron, the process adopted was to dissolve the powdered ore in nitro-muriatic acid, precipitate the iron by potash, to redissolve it in excess of acid, and subsequently precipitate it by ammonia.

A portion, considered as representing the average composition of the specimen, was selected for examination. In each instance the specific gravity has been taken by Nicholson's hydrometer.

Five or six times the amount which was employed for analysis being finely pulverized, from ten to twelve grains were generally used, this being found the most convenient quantity for accuracy.

It deserves the attention of those engaged in manufacturing iron from these ores, that very frequently the portion of the vein lying immediately beneath the surface, and the fragments and grains of the ore, which often fill the soil in very considerable abundance, are much softer than the ore in the main body of the vein. The action of atmospheric agents upon it appears to have rendered it more yielding, and it consequently mingles more readily in the furnace with the other materials, greatly facilitating the smelting of the mass. The clay and earthy matters, which remain attached to the surface ore, even after it is washed free from the loose soil, account, in part, for its beneficial effects; for, the highly silicious nature of the foreign minerals in the ore, seem to counteract, in part, the fluxing agency of the limestone, and render it less efficient than when other ores are smelted. Some trials have been made at the Oxford Furnace, which consisted in mixing a loamy clay with the ore, in addition to the limestone, and were decidedly encouraging. The loose surface ore, therefore, merits the attention of the smelter. At Oxford Furnace, the soil containing it is washed in a stream of water, running through troughs; after which it is sifted, and the increase in the product proves that the extra labour spent in preparing it is economically bestowed.

In two or three places, in the iron region, *magnetic separating machines* are used to clear the ore of the foreign mineral matter with which it there is mixed. They are applied, of course, only when the quantity of non-metallic matter is so large as to constitute a motive for removing it; nor are they admissible except where the ore is highly magnetic. One has been used at Ringwood, and another at Hibernia.

It is a curious circumstance, that the igneous injections, penetrating the older secondary limestone of the chain of valleys, north of the main range of the Highlands, from Amity, in New York, to Scott's Mountain, producing a striking change in its structure, though sometimes wholly metalliferous in their nature, rarely embrace veins of magnetic iron ore such as belong to the gneiss of the Highlands.

Some of the veins of magnetic iron ore, penetrating the gneiss, may, therefore, claim an earlier date than those metalliferous and non-metalliferous veins which traverse only the subsequently formed blue limestone.

The highly singular phenomena, connected with the intrusion of these last named veins in the limestone rocks of the valleys, will demand a particular description, which it is deemed proper, however, to defer, until the general geology of the older secondary strata shall have been previously discussed.

Gneiss Formation of Trenton.—The very extensive belt of stratified primary rocks, which ranges nearly parallel with the Atlantic coast, and forms the western limit of the tide in the rivers of Virginia, Maryland, Delaware, and Pennsylvania, after gradually contracting in width, crosses the Delaware at Trenton, and soon entirely vanishes, dwindling to a point about six miles to the northeast of the state metropolis. Its further course through the State is concealed by the overlying horizontal deposits of clay and sand, referable to the greensand series. The formation again comes into view in Staten Island, Long Island, and New York.

Where it crosses the Delaware, this belt of gneiss is about three and a half miles broad, narrowing in its course to the north-northeast, until, by the overlapping of the newer beds upon it, the visible portion of the formation fines away almost to a point, about the sixth mile-post upon the Delaware and Raritan canal. The triangular area which it forms has the valley of the Assunpink very nearly for its southeastern boundary, while its northwestern margin is formed by the lower members of the overlying middle secondary sandstones. Throughout the whole included space, the mineralogical character of the rock is extremely well marked. It is usually a triple mixture of quartz, felspar, and hornblende, the latter being frequently replaced by mica. Like the rock of the other primary zone of the State, the Highands, it goes very frequently under an improper name, being called a granite, and sometimes a sienite. Its well-marked dip and stratification, its occasionally schistose structure, and the decisive fact of its running in strict continuity with the acknowledged gneiss rock of the Schuylkill above Philadelphia, are sufficient to establish its claim to be considered a portion of the great Atlantic belt of gneiss.

A little north of Trenton, and near its border, there is a quartzose variety of the rock, containing a little mica, giving it the laminated form, but the mass of the rock is a close-grained stratified mixture of felspar and quartz. This band consists of an intimate mixture of quartzose and felspathic matter fused together. It seems to be continuous with the felspathic rock of Barrel Hill, in Montgomery county, Pennsylvania. Splitting into rather well-formed large slates, and having a smooth surface, it furnishes a very good flag stone for the walks and steps in Trenton.

Wherever the stratification of the gneiss can be seen, it is found to dip at a steep angle, nearly 70°, to the southeast. And there can be no doubt that it underlies unconformably both the upper secondary, or greensand deposits on its southeast, and the middle secondary, or argillaceous red sandstone formation, on its northwest. One variety of the rock possesses the general aspect of a sienite, and another often contains such an excess of hornblende as to cause it to resemble closely a greenstone or basalt, for which it might be taken were it not for the stratified structure evident in almost every mass. In some portions the quartz is blue, semi-transparent, and opalescent, and the hornblende and felspar show a tendency to decomposition. It is met with of this variety upon the canal about two miles from Trenton, and in several places further to the northeast, as far as the spot where the rock ceases to show itself in place, which is about three and a half miles from the town. It may be traced about two miles further, by observing the character of the diluvium above it.

Its economical importance consists chiefly in its including several valuable varieties of building stone, well adapted to structures demanding solidity and strength. Some of it would make a very fine road-stone. To the scientific world it is interesting, as presenting one of our few localities of *zircon*, which occurs about fifty yards above the bridge at Trenton. The soil over this formation is a very heterogeneous mass of diluvium, derived from the gneiss and the formations to the northwest. It is generally gravelly. In the valley of the Assunpink it is often a greenish sand and gravel, derived from the quartz and hornblende, and is then rather sterile.

CHAPTER II.

OF THE OLDER SECONDARY OR APPALACHIAN ROCKS.—GEOLOGY OF THE KITTATINNY VALLEY, WITH ITS BRANCHES, AND OF THE REGION OF THE KITTATINNY MOUNTAIN.

Nature and Composition of the Strata.—Having in the last chapter described the general and local geology of the primary districts of the State in as much detail as the limits of the present work would permit, I propose, in the present place, to offer a similar account of the geological features and structure of the region occupied by that extensive group of formations of exclusively sedimentary origin, which I conceive to have been deposited during the period that next succeeded the first elevation of the primary strata.

As these sedimentary rocks repose in immediate contact with the gneiss, presenting, from the attitude of their beds, abundant evidence that they were precipitated upon it while it was yet only in part elevated above the waters, and, as the same strata, moreover, hold a similar relation to our primary rocks throughout their entire range, from Vermont to Alabama, separated from them by no other group of strata yet discovered, claiming an earlier origin, I have deemed it expedient, for the sake of classification, to confer upon them the title of the *Older Secondary Strata* of the United States. Constituting almost the entire chain of the Appalachian or Alleghany system of mountains, in which the whole series is not only much more complete but better developed than in an any other region of the continent, I have thought it judicious elsewhere in my geological descriptions to propose for these rocks the synonyme of the *Appalachian System of Strata.**

Comparing them with the older secondary rocks of Europe, they are evidently related, as respects their date, more nearly to the English silurian strata than to any other known system. The probable extent of their *affinity* to these will be touched upon under another more suitable head.

Confining our attention in this place to those members of the older secondary series which enter the territory of the State, they will be found to comprise the *five lowermost* formations of that extensive group, together with the lower division of the *eighth* (the sixth and seventh being absent), counting always in the ascending order.

The *first*, or *lowest* of these, seen only in two or three localities, is a white sandstone, Formation I. of the general Appalachian series; the second in the order of superposition, is the blue limestone of the Kittatinny Valley and its branches, and is Formation II. of that group; the third great stratum is the slate of the same wide valley, and in the general series is Formation III.; the fourth is the rock of the Kittatinny, or Blue Mountain, a gray sandstone, passing into conglomerate, and is designated as Formation IV.; the fifth is the red sandstone, Formation V., occupying the northwestern flank and base of the Kittatinny Mountain; while the *sixth*, and uppermost, is the blue fossiliferous *limestone*, skirting the valley of the Delaware, from Wallpack Bend to Carpenter's Point, being the lower division of Formation VIII. of the same Appalachian system.

* See Annual Reports on the Geological Survey of Pennsylvania.

The following table will serve to explain more clearly the order of stratification, and the prevailing composition of these several rocks.

TABLE,

Of the Lower Secondary or Appalachian Rocks, as they occur in New Jersey.

FORMATIONS IN THE ASCENDING ORDER.	PREVAILING COMPOSITION OF THE STRATUM.	MAXIMUM THICKNESS.
* VIII.	A light blue and gray limestone; some of the beds argillaceous; others, more or less magnesian; many layers abounding in fossils. Lies at the bottom of Formation VIII.	Probably 200 feet.
V.	A group of alternating red sandstones, and red, argillaceous shales; the lower layers, a very compact and ponderous sandstone, of a claret red colour. These contain *fossil fucoides.*	About 2000 feet.
IV.	A set of compact white and gray sandstones, with layers of quartzose conglomerate. Contains several species of fucoides.	About 2000 feet at Delaware Water Gap.
III.	A thick mass of dark, argillaceous slates—bluish, black, gray, greenish-gray, or olive, yellowish, and red. Affords good roofing slate; contains, also, beds of dark gray sandstone, and a few layers of conglomerate. Occasionally exhibits marine fossils.	Not positively known, but thought to be at least 3000 feet.
II.	A blue limestone, occasionally magnesian. Contains thin beds of chert.	Not positively known; probably upwards of 2000 feet.
I.	A compact and very quartzose sandstone, of light bluish-gray colour, approaching to white.	Whole thickness not ascertained, owing to denudation.

SECTION I.

Of the White Sandstone—Formation 1.

Geographical Extent.—This formation, so largely developed in Pennsylvania, in the flanks and even summits of the hills, which constitute the same chain as the Highlands, I have hitherto discovered in only three or four small isolated tracts in New Jersey. The first locality, commencing towards the northeast, is north of the Pequannock, between Long Pond and Macapin Pond. Its position is in a narrow belt of the ancient secondary rocks, which extends for several miles along the confined valley included between the eastern base of the Green Pond Mountain and the primary hills directly east. The first visible mass of the sandstone occurs about two miles north of the farm of Richard Gould, Esq., or about four miles south of Long Pond. The rock here lies near the base of the primary hills. It probably extends southward in a continued belt for several miles beneath the limestone (Formation II.) of the same valley, though it does not show itself again until we reach the farm of Mr. Gould, where it is displayed near the head of Macapin Pond, in an interesting exposure, at the base of a ridge of the limestone, dipping beneath that rock at an angle of 60°.

The next spot at which this stratum reveals itself at the surface, is, in the prolongation of the same valley, and about midway between Flanders and Succasunny Plains. The rock occupies a small low hill, nearly but not exactly in a line with the low ridges which constitute the denuded extremity of the Copperas Mountain at Succasunny. The stratum has evidently sustained extensive denudation, only a patch, not more than a mile in length, of the lower portions of the formations being left in the middle of the valley. The rock is nearly white, very quartzose, and somewhat friable in texture to a considerable depth below the soil, yielding, therefore, a very pure white sand.

The only remaining locality at present known occurs on the northwestern side of the small ridge of primary strata, which commences a little to the west of Hacketstown, and extends thence southward about four miles. The range of the sandstone, occupying a confined area upon this ridge, is very limited. The rock is of a grayish white, has an even texture, dresses readily under the hammer of the mason, and is, in many respects, entitled to attention as a material well adapted for architectural uses. It has been occasionally employed with that view at Hacketstown.

Almost every where else along the boundary which separates the limestone from the primary rocks, where this formation should be found, we find either no traces of it whatever, or else here and there a *debris*, consisting of a white sand and gravel, derived from the destruction of the rock at its outcrop. The frequent accumulation of the large deposits of diluvial matter at the bases of so many of the primary hills, together with the easy destructibility of the rock itself, which can nowhere within the State have attained to a great thickness, will serve to explain the very limited extent to which it is exposed.

SECTION II.

Of the Blue Limestone (Formation II.) of the Kittatinny Valley and its Branches.

The second rock of the Appalachian series which we meet with in the ascending order, is the great *blue limestone* formation of the southeastern half of the Kittatinny Valley, and of most of the valleys included between the several ranges of the primary hills, or Highlands.

Geological range of the Formation.—Omitting, for the present, the task of tracing the lesser belts of the blue limestone, which occupy the narrow longitudinal valleys of the primary chain and the valley of the Paulinskill, and restricting our attention to the principal tract of this formation in the State, we may define it in general terms, as occupying the southeastern half of the Kittatinny Valley, understanding this name in its most comprehensive sense as extending to the base of the long *continuous* mountain range, known as the Wallkill, Schooley's, and Musconetcong Mountains. Within this broad belt rise up a number of the detached primary ridges of the general chain of the Highlands, whose exact position and boundaries we have already traced.

The continuity of its surface is still further interrupted near its northeastern margin, by a succession of long and narrow synclinal belts, consisting of the slate of the overlying formation.

The general southeastern border of this large limestone district has been already traced in sufficient detail, when describing in another chapter, the northwestern limit of the main continuous range of the primary, above referred to. It was stated as keeping a little to the southeast of the Musconetcong creek from its mouth nearly to Stanhope, towards its source, and thence to extend in a more wavering line along the base of the Wallkill Mountain to New York.

Its northwestern margin, separating it from the main continuous slate belt of the Kittatinny Valley, may be given as extending longitudinally in a somewhat undulating course, through the middle of that valley, from a little above Belvidere, on the Delaware, to near the intersection of the Wallkill and the state line of New York.

Tracing this boundary more minutely, it will be found, beginning at the Delaware, to run in a northeast direction for about four miles, to the little village of Sarepta, to deflect thence north for several miles, to the Free Church, on the road from Hope to Columbia; passing which, it sweeps again towards the east, until it reaches the vicinity of Johnsonburg. From this point to the New York line, it preserves a nearly straight course, skirting the town of Newton on the northwest, passing a little west of the village of Harmonyvale and a corresponding distance east of Deckertown, and meeting the meadows of the Wallkill about three miles to the southwest of the line bounding the State.

The large zone of limestone now delineated, offers many curious features to the geologist. Conspicuous among these are its numerous anticlinal axes and the striking phenomena of an induced crystallization, effected along certain belts of the stratum by the heating agency of the numerous igneous dikes and veins which traverse it. These will be systematically described and traced in their own more appropriate places. In the mean while, we proceed to give the boundaries of the other lesser bands of the limestone formation.

Next in extent of surface to the broad area already traced, is the smaller parallel tract of the valley of the Paulinskill, lying to the northwest. Commencing at Coursinville in a wedge-shaped point, in the midst of the wide tract of the slate of Sussex county, it ranges southwestward, following nearly the valley of the Paulinskill creek to its mouth, and terminating in another wedge-shaped point on Cobus creek, in Pennsylvania, about a mile and a half beyond the Delaware. It has the form of a long, continuous, and nearly straight belt; varying between one and two and a half miles in breadth. The only conspicuous irregularity in its margin, is where a long narrow tongue of the overlying slate intrudes itself into this tract northwest of Newton, following the immediate valley of the Paulinskill for several miles.

The physical features of this extensive range of the limestone, are those of a valley deriving its outlines from an active denudation of the rocks along an axis of elevation which traverses it nearly centrally from one extremity to the other.

On the opposite or southeastern side of the main zone of primary rocks which crosses the State, we meet with the limestone extending at somewhat interrupted intervals in a long narrow band, in the bed of that great continuous valley which separates the main chain of the Highlands longitudinally into two nearly equal wide belts of hills.

Taking up this range of the limestone at its northeastern extremity, the first narrow band which we encounter, is between the outlet of Long Pond, and the outlet of Macapin Pond, along the eastern base of the Long Pond Mountain. This exposure of the rock is about three and a half miles in length, commencing about two and a half miles north of Macapin Pond. Another very small patch of the limestone presents itself about one mile to the northeast of the head of Green Pond. Both this and the former locality, exhibit a considerable quantity of fossil marine shells in the rock, belonging, however, to but a limited number of species. Elsewhere, throughout the State, this limestone formation is singularly deficient in organic remains; and consequently, these isolated tracts derive considerable interest to the geologist from their fossiliferous character.

Extending our researches through the same general valley, we again come upon the limestone, about two miles to the southwest of Flanders, from whence we may trace it in an interrupted belt down German Valley to Clinton, and thence along the southeastern base of the Musconetcong Mountain, past Vansickle's to Pattensburg, reappearing again within a few miles of the Delaware, and extending to the river.

The small isolated range of this limestone in Mendham Valley, forms the only remaining tract of the formation in the State. It occupies the bottom of the valley, lying between the base of the Mine Mountain and the Trowbridge Mountain, and first shows itself about a mile east of Mendham, from whence it extends to near the mill, which is a short distance below the village. There it disappears beneath the overlying beds of the middle secondary red sandstone series, which repose unconformably upon it. It soon emerges again from beneath this covering, and may be traced nearly from Ralston's to the Pepack Brook.

Composition and Structure of the Rock.—This rock possesses a remarkable diversity of aspect and composition. It assumes almost every variey of tint, from a deep blue, almost approaching to black, to the lightest shades of gray; but its prevailing colour is a soft grayish blue. It is equally multifarious as to texture, presenting every possible gradation, from an almost crystalline character, to the closest and finest earthy aggregation of the particles. When the latter character is associated with a clear tint of blue, and with a sharp, smooth, well-defined and conchoidal fracture, the rock usually consists of pure *carbonate of lime;* while, on the other hand, a rougher texture, a duller tint, and a more irregular surface of fracture, indicate the presence of other materials.

The extraneous ingredients which most abound, are *carbonate of magnesia*, *alumina*, and *silica;* while *oxide of iron* and *carbon* also frequently enter into its composition, but in less proportion. The rock is sometimes sandy, especially in the lower part of the formation; and it is frequently in other portions more or less argillaceous, in which case it is apt to present a partially slaty structure. It is also thin-bedded or flaggy, but oftener occurs in layers of from several inches to a foot or more in thickness.

Throughout a large portion of the geographical range of this rock, it exhibits in a greater or less degree, the *oblique cleavage planes*, so conspicuous in many belts of the slate, which adjoins it. As this interesting subject of the cleavage of rocks will be considered more in detail when discussing the geological features of the slate, it is passed by for the present, with the remark that the general direction of the cleavage planes in the limestone follows strictly that which prevails almost universally in the slate, the dip and strike of these planes of cleavage being in both formations entire, independent of the direction of the dip of the strata.

Axes of elevation affecting the Formation.—Seeking by the study of the external phenomena of a formation, to understand either the revolutions in the past physical condition of its district, or the present structure of that portion of the earth which it constitutes, we shall find it essentially important to examine in an early stage of the inquiry, the nature, extent, and relative situation or direction of all the *axes of elevation*, which may disturb its beds from their original nearly horizontal position. These axes of elevation, marking the lines along which the subterranean forces have exerted themselves in their greatest energy, are the surest guides we can possess, not merely to the changes which the strata may have undergone, both of displacement and of alteration of structure; but to the existing position of every thing they may regularly include, whether it may interest science only, or prove particularly useful to the wants of man. They show us what portions of the formation have become deeply buried beneath the surface, and often at what depths, whether accessible or inaccessible, and they inform us what portions of the formation have been removed from the surface, by the crushing and washing away of the strata along the lines where they were most uplifted. They constitute, in fact, an indispensable clue to the operations of the miner, the quarryman, and even the road-maker, in every much convulsed district where they may abound.

As, therefore, the primary chain of the State, and the whole of the great valley which borders it upon the northwest, are traversed longitudinally by a most extensive system of such axes, lying mutually parallel and closely contiguous, and connected intimately with nearly every point in their geological structure, both general and local, I deem it important to introduce here a systematic enumeration of all such as are of much note, intending, as I proceed, to exhibit their relations to the disturbances and changes of structure, caused in the adjoining strata.

Pursuing our usual course, from the northeast towards the southwest, and examining first the southeastern belts of the formation in the Kittatinny Valley, we commence with that axis, or rather, probably, that chain of axes, which we find ranging in the prolongation of the Pochuck Mountain.

That the oval-shaped primary hill, called the Pochuck Mountain, owes a part at least of its present altitude, to an axis of elevation passing through it longitudinally from north-northeast, to south-southwest, is rendered sufficiently apparent by the anticlinal posture of the limestone reposing at its base; that which flanks it on the southeast dipping towards the Pochuck Valley; while that at its northwest foot has an inclination towards the valley of the Wallkill, in the opposite direction. The valley of Black and Warwick creeks, which I here call the Pochuck Valley, contains the limestone in a trough, considerably disturbed, however, from a symmetrical synclinal structure by a series of igneous dikes of mineral matter, ranging at broken intervals, at a nearly straight line from Amity, in New York, to a point a little south of Hamburg, which either locally derange, or altogether obliterate the dip of the limestone by fusion and recrystallization. The prolongation past Hamburg of this synclinal axis, is not clearly traceable, in consequence, most probably, of the close approach of the uptilting primary rocks of the Hamburg Mountain to those of the Pochuck Mountain; at this vicinity the upheaving influence of the former countervailing, for a limited space, the anticlinal axis of the Pochuck Mountain, causing all in the tract immediately southwest of Hamburg to dip along a certain distance towards the northwest. But tracing what ought to be the line of the Pochuck axis, a little further towards the southwest, we find distinct evidence throughout a belt having a somewhat confused anticlinal dip, of its prolongation under the limestone between Hamburg and Munroe. It would seem not to extend as far as the turnpike, south of the village of Lafayette; for though the limestone displays a northwestern dip along the margin of the slate, both at Munroe and on the turnpike, we cannot find in the proper places any corresponding dip to the southeast, which might give proof of a continuation of the axis so far towards the southwest.

Another axis of elevation is traceable in Pimple Hill, for the limestone at its southeastern base is seen dipping from the hill, or towards the southeast; and we have already recorded the northwestern dip of its beds on the western side, or between Munroe and the turnpike. Though the stratification is locally much contorted and disturbed in the valley between Pimple Hill and Hamburg Mountain, by the violent disrupting igneous agencies, which have so extensively altered the texture of the limestone, yet the general structure of this belt is that of a somewhat irregular synclinal trough, which may be traced past Sparta into the valley of Lubber run, though with many interruptions to the regularity of the synclinal axis. The portion of this valley between Sparta and Lockwood owes the uplifting of its beds, along the northwestern side, to an axis occupying longitudinally the narrow primary ridge which stretches from Sparta to Andover village.

The dip of the limestone becomes, however, very irregular as we approach the several insulated primary knobs in the vicinity of Lion Pond and Panther Pond, and between these and Stanhope. Just north of Panther Pond, the little limestone which is visible is seen to dip towards the northwest, evidently thrown off into that position from an axis in one of these knobs. Whether the axis of the Sparta ridge, that of the knob south of the pond, and that traversing the ridge which passes Alamuche, belong to one line of elevation, or whether, more probably, they are discontinuous, is a point not readily settled, owing to the obscure exposure of the limestone and gneiss, which are here much covered by diluvium, and to the remarkable intricacy of the country between Lockwood and Andover village.

Between Panther Pond and Lockwood, though there are probably several contiguous short anticlinal axes in the primary knobs, including, no doubt, intervening troughs of the limestone, yet this rock has been subsequently so affected by extensive igneous agency in this quarter, as to show an almost total loss of regularity in its dip.

Prolonging our observations southwestward, we find in the comparatively broad tract of primary rocks, which lies between Lockwood and Vienna, indications of more than one axis of elevation in the gneiss. The most southeastern of these has upheaved the limestone rocks of the northwestern side of the Hacketstown Valley, imparting to them their present dip to the southeast. This axis has probably brought to the surface, the narrow tract of gneiss, extending from Hacketstown towards the Mount Bethel Church, pursuing the same line of elevation, namely, that immediately west of Musconetcong Valley, we trace the same anticlinal line, or more probably, one parallel and nearly continuous with it, through what is termed the Mansfield Valley. This is properly the axis of the upheaved belt of gneiss which lies between the Musconetcong and Pohatcong streams. We have proofs that the elevatory force extended southwestward, nearly to the Delaware, inclining the beds of limestone, on the one hand, towards the Musconetcong; and on the other, towards the Pohatcong.

That this axis of elevation is not strictly coincident with that which comes in to meet it from the northeast, is rendered likely by the variable undulating dip of the rocks along the centre of the Mansfield Valley, where these axes should pass. It is a phenomenon which the geologist may often have occasion to remark when detecting the near juxtaposition of two anticlinal axes which overlap or pass each other, that the strata immediately within its range are almost invariably thrown in a succession of opposite or undulating dips.

To the southeast of the general axis of elevation, viewing it as one, thus traceable from near Lockwood to the Delaware, we have the singularly uniform straight and narrow synclinal valley of the Musconetcong, along nearly the whole length of which the limestone will be found dipping away from the hills which bound it towards a synclinal axis, which ranges not exactly along its centre, however, but lies nearest to its southeastern margin, approaching the stream itself. This departure from a central position in the synclinal axis of the valley, is a very usual feature in the axes of the Appalachian chain. It results as a necessary consequence from the northwestern dips belonging to the anticlinal axes lying next to the southeast, or that of the Schooley's Mountain chain, being steeper than the southeastern dips from the axis of elevation northwest of it. This want of symmetry in the dip of the strata would not claim a special mention in this place, but for the truly remarkable circumstance, that throughout nearly the whole length of the Appalachian chain, embracing many hundred anticlinal axes, the same rule prevails with scarcely an exception, the northwestern dips being steeper than the opposite southeastern ones.

Resuming our delineation of the anticlinal axes which affect the limestone formation of the Kittatinny Valley, the next in order which plainly manifests itself to the northwest of the general line of elevation already described, belongs to the small ridge of primary rocks which runs very nearly in the prolongation of Pimple Hill, southwestward from the turnpike towards Long Pond. South of the pond, this axis is distinctly traceable in the limestone nearly to the next turnpike, which passes through Andover. If this and the axis of Pimple Hill are not identical, they are most probably the joint results of one elevatory force, exerted along a nearly continuous line. West of Andover, this line of elevation in the limestone is no longer traceable, the dips of the rock on the northern side of the Pequest being referable to the more influential axis which is prolonged from the violently uplifted ridge of Jenny Jump.

Between the short axis now described and that of the Sparta ridge southeast of it, we meet with a narrow belt of limestone, coming to a point towards Pimple Hill. In this belt, which opens out towards the southwest in the more expanded synclinal basin, southeast of the Jenny Jump axes, the limestone is much disturbed, and along its eastern side is in some places entirely crystallized by igneous agency.

The axis of elevation which passes longitudinally through Jenny Jump, is plainly exposed in the limestone for several miles in both directions. At the southwestern extremity of the ridge it passes to the south of the little village of Sarepta, and parallel with the base of Scott's Mountain towards Belvidere, forming a small synclinal basin in the secondary rocks, between Bridgeville and Belvidere. Along this anticlinal axis, especially near the mountain, the beds of the limestone are highly uplifted, and in many places, greatly crushed.

The movement which elevated Jenny Jump, seems to have been every where one of excessive suddenness and violence, as the strata along its anticlinal axis are not only there frequently much dislocated and broken, but those lying immediately along its northwestern base, are in several places thrown into an inverted posture, dipping, not to the northwest, but in towards the base of the hill.

Tracing this anticlinal axis towards the northeast, we find it exhibited in very steep, and somewhat disturbed dips in the limestone, for a short distance beyond the termination of the mountain. It afterwards becomes more regular, and may be discovered running for many miles in a nearly straight course, passing a little to the east of Greenville. Between this point and the turnpike, we fail to follow it in consequence of the difficulty of procuring distinct exposures of the strata; but about a mile northeast of the turnpike, we perceive an anticlinal axis, ranging somewhat parallel with and northwest of Long Pond, and coinciding so nearly in direction and position with this of Jenny Jump, as to warrant us in regarding it as a portion of the same line of elevation near its northeastern termination. Were this axis prolonged yet further to the northeast, it would constitute one long and nearly straight axis with that which approaches it from the northeast, through the centre of Pochuck Mountain; but as we have already shown that the latter subsides near Munroe, we have a space of several miles along which their continuity is interrupted.

Adverting now to the synclinal basins, included between this main axis of Jenny Jump and the chain of axes previously traced, lying to the southeast of it, we discover the limestone to form one general trough, in the valley of the Pequest, between Greenville and the Alamuche belt of the primary. But passing the Andover turnpike, this trough runs into two, on account of the interposed short anticlinal axis, prolonged from Pimple Hill. Between the anticlinal axis and Alamuche, the southeastern dips are observed to occupy, as they frequently do, a much *wider* belt than the northwestern one, the latter being by far the *steepest.* Whether farther towards the southwest, between Jenny Jump and the ridges east and south of the little village of Vienna, the limestone of this tract may not be disturbed from the simple synclinal arrangement which it has near Alamuche, in consequence of one or more short axes of elevation extending into it from the spurs of Scott's Mountain, is a question not readily answered, owing to so large a portion of the surface of the limestone being hid from view, first by the Great Meadow, and southwest of this, by the large accumulations of diluvium in that quarter.

That such short axes do disturb the limestone near Scott's Mountain, is, however, highly probable, even from the few dips disclosed.

Though it is difficult to trace the axes of elevation as they traverse the primary ridges, on account of the frequency of the igneous injections in the gneiss producing much contortion in the strata, yet viewing the topography of Scott's Mountain in connexion with the more regular dips which it discloses, we cannot resist the impression, that it owes its elevation to at least two considerable anticlinal axes.

One of these would seem to range along its southeastern ridges, passing not far from Oxford Furnace, and southwestward between the Lopatcong and Merrill's brook, affecting the limestone north of the former stream. The other observes a more northwestern line, and is probably connected with the elevation of the primary ridge, called the Marble Mountain, at the Delaware. At the southeastern base of Scott's Mountain, we find the limestone assuming the synclinal structure in the valley of the Pohatcong; but not every where symmetrically, as it gives evidence, especially as we approach the Delaware, of being in some places actually *inverted* along its southwestern border.

It is difficult, indeed, to find the rocks any where dipping to the northwest, throughout the whole distance from the Pohatcong, across their strike, to the base of Marble Mountain. This indicates, in the Kittatinny Valley, that those belts of the stratum lying to the northwest of each anticlinal axis, instead of assuming, as we would expect, a northwestern dip, have been so forcibly upheaved in that direction as to have been tilted in many cases *beyond* the vertical plane, and made to fold over, with a southeast dip, upon the southeastern dipping beds belonging to the next northwestern axis. Connected, most probably, with some early movement of elevation in the strata around Jenny Jump, there occurs an interesting and rather unusual phenomenon, in the narrow belt of limestone at the base of the mountain, immediately to the southeast of the little village of Hope. We allude here to the uncommon structure of the rock, which is at this place a true conglomerate, made up entirely of pebbles and rotted fragments, some of them being many inches in diameter, which, like the paste imbedding and cementing them, consist exclusively of the same materials as the rest of the blue limestone formation, in which this conglomerate occurs as one of the interposed beds.

The same formation embraces, in Pennsylvania, a similar included stratum, occupying, to all appearances, a corresponding position in the general mass of the limestone. This occurs on the Northkill, a little above the village of Bernville, in Berks county: these are the two principal localities at which I have hitherto discovered this coarse, calcareous conglomerate. But I am authorized by my brother, Professor William B. Rogers, the state geologist of Virginia, to mention, that an equivalent rock prevails in the same relative place in the geological series, at several points along the Kittatinny Valley in that State.

This conglomerate imparts interest to all inquiries respecting the *date* of the disturbances which have elevated our great series of Appalachian rocks, throughout their prodigious range, from Vermont to Alabama: it distinctly implies that the shores of the Appalachian ocean were agitated at the early epoch at which the limestone was produced, by a movement sufficiently violent to shatter and convert into pebbles some of that rock already deposited.

The facts above adduced, prove, also, that, though apparently sudden and of short duration, this convulsion of the limestone ranged, if not uninterruptedly at least at intervals, far to the south-west, along the same line of ancient shore: for it is indisputable, that the general belt of the Highlands, and their prolongation southward, formed the general southeastern coast of the great ancient secondary or Appalachian sea, if not every where at the *commencement* of these deposits, certainly after the first two or three formations were accumulated.

The next main axis of elevation beyond that of Jenny Jump, is traceable from near Deckertown southward, passing the villages of Harmonyvale, Lafayette, Newton, and Johnsonburg. Strict continuity of the anticlinal axis between these several points is not, however, clearly established; and, very possibly, it is rather a succession of two or three coincident axes than one of unbroken regularity: the upheaved belt of limestone containing this chain of axes is itself uninterrupted from the Wallkill, near Deckertown, to Johnsonburg, its northwestern margin; and that of the belts on its southwestern prolongation, at Hope and Belvidere, have been delineated in detail when describing the geographical range of the formation. On the southeast, between this anticlinal belt of the limestone and that which contains the axes of the

Pochuck and Jenny Jump Mountains, there is a long and narrow zone of the overlying slate, Formation III. This starts from the Wallkill, about three miles northeast of Deckertown, and ranges in an attenuated ridge, until opposite Newton, passing about half a mile east of Harmonyvale and Lafayette. It presents throughout its whole length a regular synclinal structure, lying in the middle of the trough of limestone, formed by the two parallel anticlinal axes above referred to. About four miles southwest of the termination of this narrow range of slate, another commences, beginning between Reading's Pond and the turnpike, and passing a little west of Greenville. Between this belt, which is very narrow, and Grass Pond, near the anticlinal axis, occurs another similar small range of the slate. The two parallel little ridges of this rock lie in the prolongation of the general synclinal trough, between the two main anticlinal axes, separated, however, by a short interposed axis of elevation, traceable between them from Reading's Pond, southwestward. Each belt of the slate has, therefore, the structure of a narrow synclinal ridge.

Lying a little further to the northwest than the principal axis, which passes Johnsonburg, there commences an axis which elevates the limestone of the oval tract, extending from near Johnsonburg nearly to Sarepta.

The axis to which we now allude passes a little northwest of the village of Hope, dying out beneath the slate towards Sarepta. Between it and the northwestern dipping limestone, uptilted by the axis of Jenny Jump, we may trace another long, narrow, and nearly straight belt of the slate. This small ridge of the slate, like those previously mentioned, contains a synclinal axis running centrally along it.

Besides the anticlinal axis which ranges a little northwest of Hope, we have indications of another shorter one, lying between it and the western margin of the limestone. But this lesser axis, the presence of which explains the sweep towards the westward at this place, at the edge of the upheaved rocks, has not been accurately traced, owing to the fewness of distinct exposures.

The last of the main anticlinal axis of the Kittatinny Valley towards the northwest, is that of the limestone belt of the valley of the Paulinskill.

This axis may be pursued for nearly the whole length of this limestone valley, from northeast of Augusta to the Delaware river. Its usual position is somewhat to the southeast of the middle of the valley. Like many of the others, upon its southeast it is not always symmetrical, the strata on its two sides dipping at different degrees of inclination, and being, besides, often separated by either a crush of the rocks near their turn, or by a partial dislocation immediately at the axis.

West of Newtown the general belt of limestone is traversed, for a space of several miles, by a narrow tract of the slate, causing its northeastern termination to be in the form of two wedge-shaped prongs, one ending near Courserville, the other about three miles north of Newtown.

This southeastern branch, from the main tract of the limestone, contains, we have reason to believe, a lesser parallel anticlinal axis, the cause, indeed, of the elevation of the limestone along this line. Between it and the main axis, a little southeast of Swartwout's Pond, all the rocks have a synclinal arrangement, the belt of slate lying in the middle of the trough of the limestone.

Tracing the principal axis of the Paulinskill Valley beyond the termination of the limestone near Courserville, we find it running for several miles further towards the northeast, until it passes a little west of Deckertown, elevating the beds of the slate.

The limestone valley of the Paulinskill corresponds accurately in its general physical features with what is termed a valley of elevation.

Its strata having been upheaved along a central anticlinal axis, the surface of the valley is somewhat raised in the centre, and depressed along both margins, while the overlying and surrounding strata of slate, less broken and denuded than the limestone, encompasses it in a regular escarpment, giving to the whole the true structure of a valley of elevation.

A much broader zone of slate is interposed between the Paulinskill axis and that of the Newtown Valley, than between this latter and the axis of the Jenny Jump and Pochuck range. This is obviously the result of a twofold cause, the greater interval which separates the two northwestern axes, and the less amount of vertical elevation in the strata adjoining them: leaving, therefore, both a broader and deeper synclinal trough in the slate to resist the denuding agency of the currents, which have swept off so large a portion of the upper strata from the Kittatinny Valley. Between Belvidere and Columbia, on the Delaware, the tract of slate, which is here several miles in breadth, exhibits numerous local changes of dip, the result probably of a series of lesser anticlinal axes, which may traverse this end of the belt. The oblique cleavage planes are so conspicuously displayed in this part of its range, as to efface, very generally, all distinct traces of the true stratification, rendering the determination of its axes a work of extreme uncertainty. The simple synclinal structure of this belt opposite Newton and Augusta may, however, be readily established by a close attention to the true dip of the rocks.

Only two other ranges of the lower Appalachian limestone, besides those already referred to, occur within the State. These are, the belt traversing German Valley and its extension, and the small patch in the valley of Mendham. Both of these have been previously adverted to, as occurring in the form of narrow synclinal basins, included between the adjacent ridges of the primary rocks. The upheaving of these latter, by a series of axes of elevation difficult to trace in detail, has manifestly given to the limestone its synclinal posture in the intervening valleys, where this rock obviously once spread itself over much wider tracts than at present.

Igneous Rocks connected with Formation II.

Of the changes induced upon the limestone by igneous action.— The blue limestone of the Kittatinny Valley exhibits, in certain localities, some highly impressive and remarkable phenomena of alteration of structure, induced by the heating agency of a series of igneous injections. The altered bands of the rock may be correctly grouped into two distinct belts, ranging from northeast to southwest, parallel to the general strike of all the strata in this quarter of the State. The more northeastern of these belts occupies, at intervals, the valley which lies immediately at the foot of the Hamburg or Wallkill Mountain, throughout nearly its whole length, keeping usually towards its northwestern margin, or near the base of the Pochuck Mountain, and the belt of hills in its prolongation to the southwest, namely, the hills north of

Franklin, Pimple Hill, and the hills north and west of Sparta and Lockwood.

That further to the southwest commences at the northeastern extremity of Jenny Jump, and follows the southeastern base of this mountain throughout nearly its whole length, beyond which, after an interruption of about two miles, it again occurs near Oxford; and further still, at intervals, near Concord and Davidson, where it is within two miles of the Delaware. Traced longitudinally, the altered rock shows itself not so much in one continuous line, as in a succession of long, narrow, and somewhat detached belts, several of which sometimes lie parallel to each other and closely contiguous.

The northeastern tract first shows itself at Mounts Adam and Eve, in New York, about five miles beyond the state line, and has its southwestern termination in the neighbourhood of Lockwood. Over this whole distance, though the altered material exhibits considerable diversity in regard to the imbedded minerals which it contains, yet the main mass of the rock, or the calcareous paste investing them, retains to a great extent, a uniform character as to colour and structure.

When destitute, or nearly so, of the extraneous minerals often diffused through it, the prevailing condition of the rock is that of a white, perfectly crystalline limestone. An extreme degree of developement of the crystalline structure, is when the mass had assumed the condition of rhombic calcareous spar. It is then often semitranslucent, but more frequently it is of an opaque white, and occasionally of a pink hue, resembling somewhat reddish felspar. These varieties may be regarded as the altered rock under its most characteristic features, and are to be viewed as exhibiting the *limit of alteration* of which the limestone has been susceptible by igneous action, where it has been *pure,* or consisted of little else than carbonate of lime. When of such aspect and structure, the mineral most usually disseminated through it is *plumbago,* in small brilliant plates, often perfectly hexagonal. Besides this highly developed crystallization, it presents every gradation of crystalline structure down to a finely granular one, and even to what may be termed the subcrystalline condition, when it often partakes of the colour and texture of the blue limestone, out of which all these varieties have originated. Clouded, veined, and spotted, by various mineral matters mingled through it, and frequently susceptible of an excellent polish, it promises to furnish, if attainable in masses of sufficient size, a material of superior beauty for ornamental purposes in architecture. Various foreign minerals blend themselves occasionally through the substance of the calcareous rock in every possible proportion, from a few sparse crystals to such an abundance as almost to replace the calcareous matter, which then merely fulfils the part of a cement.

These minerals, several of which are rare in the cabinets of the mineralogist, constitute a list, when all are enumerated, of considerable extent. Those which chiefly predominate, and which tend by their prevalence to impart a certain uniform mineral character to the altered limestone, are: *Condrodite*, or Brucite, in orange-yellow crystals; *augite*, common and crystallized; *plumbago*, foliated usually in six-sided scales; *spinelle*, often in octohedral crystals; *sahlite*, and *mica*.

The following catalogue, by Dr. Fowler, of Franklin, who has zealously contributed to draw the attention of mineralogists to this interesting region, exhibits a sufficiently detailed list of the minerals hitherto discovered in association with the altered limestone:

"*Franklinite.*—A new metalliferous combination, containing, according to Berthier, of oxide of zinc 17, of iron 66, and manganese 16 parts, is very abundant, indeed it appears inexhaustible. It commences about half a mile northeast of Franklin Furnace, and extends two miles southwest of Sparta, a distance of nine miles. It is accompanied in this whole distance by the red oxide of zinc, mutually enveloping each other. The greatest quantity appears to be at Franklin Furnace. The bed here is about one hundred feet high above the adjoining land, on the west side of it, and from ten to forty feet wide. Various attempts have been made to work this ore in a blast furnace, but without success. It frequently congeals in the hearth before time is allowed to get it out in a liquid state, in consequence of a combination of the iron with manganese. All this difficulty, I apprehend, might be overcome, if a method could be discovered of smelting iron ore in a blast furnace with anthracite coal; as the Franklinite requires a greater degree of heat to cause it to retain its liquid state, than can be obtained by the use of charcoal. It occurs in grains, imbedded in the white carbonate of lime, and detached in concretions of various sizes, from that of a pin's head to a hickory nut; also in regular octohedral crystals emarginated on the angles, small at Franklin, but very perfect, with brilliant faces. At Sterling, the crystals are large and perfect. I have one from that place that measures sixteen inches around the base.

" *Red Oxide of Zinc.*—At Sterling, three miles from Franklin, a mountain mass of this formation presents itself about two hundred feet high. Here, as Mr. Nuttall truly observes, the red oxide of zinc forms, as it were, a paste, in which the crystals of Franklinite are thickly imbedded; in fact a metalliferous porphyry. This appears to be best adapted for manufacturing purposes. The Franklinite imbedded in the zinc ore here, is highly magnetic, and may be all separated by magnetic cylinders, recently brought into use to separate the earthy portion of magnetic iron ore. It was long since observed, that this ore is well adapted for the manufacture of the best brass, and may be employed without any previous preparation. It is reduced without any difficulty to a metallic state, and may be made to furnish the sulphate of zinc (white vitriol.) Berthier found it to contain oxide of zinc 88, red oxide of manganese 12.

" *Magnetic Iron Ore.*—On the west side of the Franklinite, and often within a few feet of it, appears an abundance of magnetic iron ore, usually accompanied by hornblende rock. In some places it soon runs into the Franklinite, which destroys its usefulness; and the largest beds are combined with plumbago, which renders it unprofitable to work in a blooming forge, but valuable in a blast furnace.

" The other minerals found in this district are numerous, rare, interesting, and several of them new, and not found in any other place, but better calculated to instruct the naturalist and adorn his cabinet, than for any particular uses to which they have as yet been applied. A catalogue which I have subjoined, designates the minerals as they occur in each township.

" In *Byram Township,* considered the southwestern extremity of the white carbonate of lime, occur: Spinelle, colour reddish-brown, green, and black, in octohedral crystals, associated with orange-coloured Brucite. Brucite of various shades, from that of a straw-colour, to dark-orange, and nearly black. Gray hornblende, in six-sided prisms, with dihedral summits.

" In the *Township of Hardiston.—At Sparta:* Brucite of a beautiful honey-colour: the finest we have is found here. Augite, in six-sided prisms; colour brownish-green.

" *At Sterling.*—Spinelle, black, green, and gray, in octohedral crystals. Brucite of various shades. Rutile; colour steel-gray; lustre metallic, in acicular prisms, with longitudinal striæ. Blende, black and white; the white sometimes in octohedral crystals, the lustre brilliant. Dysluite, in octohedral crystals; colour brown externally; internally yellowish-brown; lustre metallic (a new mineral). Ferruginous silicate of manganese, in six-sided prisms, colour pale-yellow; associated with Franklinite. Tourmaline, imbedded in white felspar, in six-sided prisms; longitudinally striated; colour reddish-brown. Green and blue carbonate of copper. A number of large excavations were made at the Sterling Mine for copper, during the revolutionary war, under an erroneous impression, that the red oxide of zinc was the red copper ore. It was the property of Lord Sterling; hence the name of the Sterling Mine. Of copper, we only find there a trace of the green and blue carbonate.

" *At Franklin.*—Spinelle, black and red crystallized. Ceylonite, green and bluish-green, in perfect octohedrons, truncated on the angles; lustre of the brilliance of polished steel. Garnets, black, brown, yellow, red, and green, crystallized in dodecahedrons. Silicate of manganese, light brownish-red. Ferro-silicate of manganese, of Professor Thompson, and the Fowlerite of Nuttall, light red or pink, foliated and splendent; has much the appearance of felspar; is also in rectangular prisms. Sesquisilicate of manganese, lamellar in scales or small plates; colour brownish-black. Hornblende, crystallized. Actynolite, crystallized. Tremolite, crystallized. Augite, common variety, crystallized. Jeffersonite, common variety, crystallized. Plumbago, foliated and crystallized in six-sided scales. Brucite of various shades. Scapolite, white, crystallized. Wernerite, yellow, crystallized. Tourmaline, black, crystallized. Fluate of lime, earthy and crystallized. Galena. Oolite, in small grains about the size of a mustard-seed, disseminated in blue secondary carbonate of lime. Asbestus, connected with hornblende rock. Green beryl. Felspar, green and white, crystallized. Epidote and pink carbonate of lime. Arsenical pyrites. Serpentine. Sahlite. Cocolite, green and black. Sphene, honey-colour, crystallized. Quartz. Jasper. Chalcedony. Amethyst crystallized. Agate. Mica, black and orange-coloured, crystallized. Zircon, crystallized. Sulphate of Molybdena. Phosphate of iron. Carbonate of iron. Steatite, foliated, with yellow garnet. Phosphate of lime crystallized. Pale yellow blende, of a foliated structure, lustre, vitreous.

"*Near Hamburgh.*—An ore of manganese and iron, of a light reddish-brown, very compact and heavy. Augite and Brucite.

"*In the Township of Vernon.*—Green spinelle and Brucite, in octohedral crystals.

"*In Newton Township.*—Sulphate of barytes in lamellar masses, and tabular crystals, in a vein traversing secondary limestone. Sapphire, blue and white, in rhombs and six-sided prisms. Red oxide of titanium. Gray spinelle in large octohedral crystals. Mica, copper-coloured, in hexahedral crystals. Idocrase, crystallized, yellowish-brown. Steatite, presenting the pseudomorphous form of quartz, scapolite, and spinelle. Scapolite, in four-sided prisms.

"For a more particular account of the Newton minerals, see Silliman's Journal, vol. xxi. page 319.

"*In Frankford Township.*—Serpentine, of a light yellowish-green, bears a fine polish, has a glistening lustre, and is quite abundant."

On the Franklin or Warwick mountain, about four miles east of the furnace, are numerous beds of iron ore, from which many thousand tons have been taken; and which still contain a large quantity of the best quality of ore, either for a blooming forge or blast furnace. Iron pyrites occurs here, both in the valley and on the mountain, of a proper quality to manufacture sulphate of iron (copperas). It also occurs crystallized, in cubes, in octahedrons, and dodecahedrons, frequently perfect and highly splendid.

Following the range of the crystalline limestone somewhat more in detail, we shall commence our description of its geological features where it first conspicuously shows itself, in the neighbourhood of Amity, in New York. Here, and for several miles to the southwest, the belts of altered rock occupy a very considerable width, in the valley ranging from Mounts Adam and Eve towards Hamburg, forming a zone averaging, at first, half a mile in breadth, but contracting to two or three hundred yards. The crystalline material in its most perfect form, does not, however, fill the whole space, but occupies rather a series of closely adjacent parallel bands, most numerous towards the middle and northwestern side of the valley, where a chain of low irregular ridges usually contain the limestone in the highest state of crystallization. These evidently mark the existence of a series of parallel veins of igneous origin, the intrusion of which into the limestone, have obviously caused its alteration. Between the base of the Wallkill Mountain and the crystalline rock towards the middle of the valley, we usually meet with beds of the formation which evince but a partial amount of change from the igneous action; the limestone retaining more or less of its bluish tint, and presenting only a subcrystalline, or even the ordinary earthy, texture. These less altered beds, reposing upon the gneiss of the Wallkill Mountain, dip towards the northwest. Towards the base of the Pochuck Hill, on the other side of the valley, the limestone would seem to have undergone a more extensive alteration. Approaching Hamburg, the crystalline belt contracts considerably in width. About two and a half miles northeast of that village, we find it occupying a broken chain of long, narrow, irregular ridges of considerable elevation. These range parallel with the base of the Pochuck Mountain, separated from it by a tract of low meadow ground, about three hundred yards in breadth. In this belt the altered limestone is in great confusion; the calcareous crystalline matter being mingled largely, in many places, with a white friable sandstone, referable, obviously, to Formation I., the position of which, when it occurs at all, is immediately beneath the limestone. The fused calcareous matter seems in some cases to have penetrated the substance of the sandstone. The height of this ridge or chain of ridges may be stated to average about two hnndred feet;

the width at the base being not less than a fourth of a mile, and the length rather more than one mile. Besides the mass of altered limestone, these ridges comprise portions of Formation I., together with beds of the gneiss, both in a highly disordered and shattered condition, with more than one extensive dike of igneous matter, the immediate cause, most probably, of these disturbances.

From the confusion which accompanies all these rocks, none of them can be found, even for a short distance, possessing any regularity of dip.

The gneiss rocks of the Pochuck Mountain, on the contrary, are distinctly seen dipping steeply towards the valley to the southeast.

The most conspicuous display of the crystalline limestone is at the two extremities of the ridge which lie nearest Hamburg. Between these points, towards its central portion, the same ridge contains a large well-known deposit of brown or hematitic *iron ore*, occupying its summit and sides, and penetrating deeply into the body of the hill; details regarding this valuable iron mine will be given under another head.

Separated from the Hamburg belt of altered limestone, by a spur of the Wallkill Mountain, there exists another band of the crystalline rock on the Sand Pond creek, about one mile and three quarters southeast of Hamburg. This commences near the southwestern termination of a small knob of gneiss.

Though highly crystalline, the limestone still retains considerable regularity of stratification, dipping towards the west-northwest, at an angle of 20°, being well exposed in a quarry, (the property of Wm. Edsall,) where it is used for making pure lime. It is white, and highly crystalline, and contains disseminated scales of graphite. This line of altered rock ranges south-westward nearly to the turnpike, and is met with again on the road to Sparta, about half a mile beyond the turnpike.

Between the small knob of gneiss, above spoken of, and the Wallkill Mountain, to the southeast, we meet with another deposit of brown or hematitic iron ore, a little beyond the termination of the crystalline limestone, none of which, however, is discovered near it. This ore will be more minutely described in another place.

To the northeast of this altered belt we trace another, occupying the northwestern side of the Mine Hill, east of the Wallkill stream, a long narrow point of primary rocks, extending from Pimple Hill to within about three miles of Hamburg. Not far from the northeast termination of Pimple Hill, and near the old Franklin furnace, we encounter, in the northwestern side of the Mine Hill, next the valley of the Wallkill, a narrow belt of common gneiss rock, dipping, as usual, to the southeast. Reposing upon this, with a conformable dip, is seen a highly interesting mineral vein composed of impure *magnetic iron ore*, *Franklinite*, *Garnet*, *Jeffersonite*, and several other crystalline minerals, blended, especially near the borders of the mass, with the crystalline limestone, much darkened and changed from its ordinary appearance, by the amount of combined mineral matter; much of this calcareous portion of the vein is pervaded by small granular crystals of the *Franklinite.* The whole vein has a thickness of several feet.

Immediately east of this metalliferous vein, there rests, in the main body of the hill, a broad belt of the white crystalline limestone, preserving its original, rather steep, southeastern dip. The position of the vein here, is therefore, as in the majority of instances in the region, intermediate between the primary strata and the beds of altered limestone, which, notwithstanding the partial fusion and intense heat to which it has been subjected, still furnishes distinct traces of its lines of deposition.

Towards the eastern declivity of the hill, the crystalline rock prevails in considerable purity, though it is often very free from foreign admixtures, even adjacent to the metalliferous vein. In this latter position, however, it is more frequently mixed with *quartz*, *felspar*, *sahlite*, *augite*, *hornblende*, and a great variety of minerals, some of which are common ingredients in the primary strata of the country. In the quartz, and near its contact with the limestone, *green spinelle* occurs.

The occurrence of so many of the minerals which are constituents of the adjoining *primary* rocks, both in the intrusive vein itself, and in the neighbouring portions of the altered limestone, is a fact of no little theoretical interest, as it leads us directly to views tending to explain satisfactorily the several sources of the numerous and varied crystalline minerals found connected with the changes effected in the limestone.

At the summit of the ridge there is a seam of quartz rock, presenting some indications of its occurring as a vein in the white limestone. Its nature and origin cannot be proved, for it may be a vein of mineral matter strictly intrusive, or one of the beds of *chert*, so common in the limestone, or a portion of Formation I., completely fused by contact with the intensely heated metalliferous vein. The confused arrangement and varied aggregation of the altering and altered materials at this place, render it next to impossible to trace the true relationship subsisting between some of the parts comprised in this curiously heterogeneous belt of mineral matter. The vein, in its course to the southwest, undergoes a considerable change in its character. About two hundred yards southwest from the place already mentioned, it appears to consist almost wholly of *garnet rock* and *Jeffersonite*, some of the latter occurring in enormous crystals, projecting from the face of the rock, but so fissured and readily broken as to render it difficult to procure them entire.

Further still to the southwest, and nearly opposite the Old Forge, are considerable excavations made in former times for *iron ore*. The ore was far from pure, abounding in *Franklinite;* which by the *manganese* and *zinc* contained in it seriously interfered with the conversion of the ore into iron. This ore includes, moreover, a considerable proportion of the *red oxide of zinc*, in some places remarkably pure, being finely lamellated and unassociated with any of the *Franklinite* that generally accompanies it, and which interferes effectually with its reduction into metallic zinc on the large scale.

Could this pure red oxide be obtained in sufficient quantity, it would probably be better adapted for smelting into zinc than the mixed ore of the Sterling Mine, three miles further to the southwest. This somewhat rare ore of zinc, the crystallized red oxide, occupies, in company with the crystallized Franklinite, a metalliferous vein, or more probably a line of nearly continuous veins, in the crystallized carbonate of lime, extending, with occasional interruptions the whole distance from Franklin to a little beyond Sparta, a total length of more than eight miles.

The catalogue already presented, compiled by Dr. Fowler of Franklin, supplies a nearly complete list of the other minerals found in this part of the igneous and altered zone of rocks.

From Franklin we may trace the white crystalline limestone continuous to Sterling, about three miles to the southwest.

Here we find it lying in contact with a remarkable vein consisting exclusively of Franklinite and the *red oxide of zinc;* the former in crystalline granules, often approaching the ochtohedral form, invested by a paste of the zinc ore, which frequently constitutes more than one-half of the mass. The position of this vein is on the eastern declivity of a hill of considerable elevation, where it occupies the same intermediate relation to the gneiss and crystalline limestone which was mentioned of the vein at Franklin.

At Sterling, the metallic vein, where it is visible at the surface, rests with a steep southeast dip *conformably* upon the steeply-dipping beds of gneiss, rising in the form of a bold cliff or wall along the side of the hill. Against this wall of ore, and at the base of the hill, repose the beds of the white altered limestone, presenting unequivocal traces of its original planes of stratification, showing the sedimentary origin of the rock. It obviously dips at the same inclination of from 70° to 80° to the southeast, with the vein and the gneiss upon which it lies.

The metalliferous vein is from eight to ten feet in thickness, and consists of no other minerals but the Franklinite and ore of zinc. From its exposed position on the flank of the hill, the ore could be excavated to an almost indefinite extent with a facility unusual in the history of mining operations. Zinc of an admirably pure quality has been prepared from this ore by Mr. Hitz, under the directions of Mr. Hasler, for the manufacture of the brass for the standard weights and measures now making by the latter scientific gentleman for the several custom-houses of the United States, by order of Congress. An economical method for the separation of the zinc from the Franklinite in this ore, still remains, however, a desideratum in practical metallurgy.

Between Sterling and Sparta, the belt of crystalline limestone is traceable with but little interruption nearly the whole distance, affording in some places specimens of a variegated marble of uncommon beauty. It follows the eastern base of Pimple Hill to the southwestern termination of that ridge, and then appears nearly in the same line at several points on the west of the gneiss hills, west of Sparta, and also within a few hundred yards of the town itself. The narrow valley embraced between those hills and the Wallkill Mountain on the southeast, is in the immediate neighbourhood of Sparta, and for some distance southwest, occupied by the unaltered blue limestone dipping usually towards the northwest.

About a third of a mile northwest of Sparta, the white crystalline limestone crosses the turnpike road. This is one of the principal localities whence mineralogists have supplied their cabinets with specimens of condrodite or Brucite. A better locality, however, may be seen on the west side of the hill, about half a mile further north, where another exposure of the white crystalline limestone affords crystals of the Brucite and gray spinelle in an abundance and of a quality far surpassing those of any other spot yet discovered in this vicinity. At the same place might be opened inexhaustible quarries of variegated and pure white marble; some of the former promising to be, if polished, of uncommon beauty. Care should be observed, in establishing quarries in this rock, to choose those parts of the belt least shattered by the action to which it has been exposed.

Between three and four miles southwest from Sparta, on the northwest side of a low ridge of gneiss, we find a very interesting locality of the altered limestone, very nearly in the prolongation of the belt which passes along the southeast base of Pimple Hill. This spot is remarkable less for the extent or breadth over which the limestone has been affected by igneous action, than for the strikingly convincing evidence which it affords of the nature of the changes induced in the calcareous rock by the series of igneous veins and dykes which we have been tracing. The ridge itself, along the side of which the limestone has been altered, consists chiefly of a thinly-bedded *micaceous* gneiss. Through the summit, or rather on the northwestern flank, which is often abrupt and rugged, there rises a thick granitic dyke or vein of very heterogeneous composition, supporting the steeply-dipping beds of gneiss, whose usual inclination is at an angle of 80° to the southeast. The vein, though various in character, and somewhat difficult to describe, owing to the imperfectly developed nature of its minerals, and their complete interfusion, may be characterized as consisting, in the main, of *mica* in large excess, *quartz, carbonate of lime, felspar*, and *augite*. It contains *spinelle, sapphire*, and *green talc*, besides several other minerals less distinctly crystallized.

When we consider the highly micaceous character of the adjacent gneiss rock, through which the matter of the vein must have passed in reaching the surface, and the abundance of the mica, especially of the brilliant golden variety, found so plentifully not only in it, but in the adjacent parts of the altered limestone, we cannot resist the impression, that a portion of the primary strata along the sides of the dike, have been melted and incorporated into it, floating, in combination with the other materials, to the surface.

Immediately upon the western side of this curious vein, and ranging along the base of the hill, occurs the narrow belt of altered limestone. The gradation of change which here exists between the blue and earthy limestone, and the white crystalline rhombic spar, is distinctly traceable as we approach the igneous dike. In a breadth not exceeding fifty feet, we discover every degree of modification which the rock can undergo by heat. The first intimation which the limestone gives us of its having been subjected to the igneous agency, is its passage from the ordinary earthy texture to a subcrystalline one. We next behold a slight change of colour to a lighter tint of blue, and, at this stage of alteration, we notice the first developement of the *graphite*, as yet seen only in small but very brilliant scales, which are oftentimes hexagonal. Very soon the mass becomes mottled with white, minutely granular carbonate of lime, the spangles of graphite growing progressively larger. Approaching still nearer to the dike, the whole rock assumes the white sparry character, and contains, near the line of contact, besides the graphite, several of the numerous crystalline minerals of the vein itself. So completely has the injected matter of the vein been mingled, in many places, with the fused substance of the limestone, that no distinct line of demarcation is discernible between them.

The series of changes here described may be considered as representing the phenomena in every instance, where superficial deposits have not concealed the vein, the blue limestone, and the intermediate altered belt. The locality above referred to is dwelt on in detail, chiefly because it furnishes a distinct exhibition of each successive stage of the change. The gradation is not more complete at this place than near many other dikes, but it is better exhibited within a small area.

The invariable occurrence of the *graphite,* in portions of the altered belt remotest from the dike, and its never existing in more than a very trivial quantity, even adjacent to the vein where the other extraneous minerals are frequently present in great excess, strongly imply that it has been derived from the elements of the blue limestone itself, which may easily be proved to contain an adequate quantity of iron and carbon for the production of this mineral.

It is not a little curious that, in some belts, the altered rock contains the mineral *condrodite,* in a precisely similar relation as to the degree of crystallization of the mass, and proximity to the vein of igneous matter; that is to say, when it first appears in the portions of the crystalline belt remotest from the line of injected minerals, it is in small imperfectly developed nuclei, which grow larger and better formed as we approach the quarter of more intense igneous action, but which, like the crystals of *graphite,* usually remain but sparsely disseminated through the rock. Showing a strong analogy, in its mode of distribution through the substance of the white limestone, to the nuclei or geodes of *epidote* and other minerals seen in the red shales where these have been baked and altered by the intrusion of dikes of heated trap, the *condrodite* seems to claim a corresponding origin to that generally attributed to the epidote, which is regarded as derived, in these cases, from the constituents of the rock itself. To trace the source of the *condrodite* upon this hypothesis, we have only to conceive that the injected mineral matter, in an igneous state, was poured through fissures in a limestone, possessing, what is very common, a siliceo-magnesian character; and the well known tendency to the production of specific mineral combinations, in a mass whose particles are in a state of at least semifusion, and, therefore, free to obey their several affinities, will readily explain the formation of these insulated crystalline nuclei. The mineral *condrodite* contains about 54 per cent. of *magnesia*, with about 38 per cent. of *silica*, besides trivial proportions of *oxide of iron*, *potash*, *fluoric acid*, and water. These suggestions, respecting the origin of the *condrodite*, receive support from the fact, that this mineral prevails in its usual uniform and moderate proportion through considerable ranges, longitudinally, of the altered limestone, even where not immediately contiguous to the injected veins, while in other parallel zones of the crystalline rock it is almost wholly absent. Thus, in the chain of sparry limestone which stretches at intervals from Sparta towards Lockwood, we find it almost constantly present, though never but in moderate quantity.

From several chemical analyses of the sparry, rhombic varieties of the rock containing only *graphite*, and of the white irregularly crystalline kinds enclosing the condrodite, we have still more conclusive evidence tending to settle this interesting point.

Resuming our progress towards the southwest, we next meet with a succession of detached ridges of the altered sparry limestone, in the valley between the Wallkill Mountain and the primary ridges southwest of Sparta; the latter tract of gneiss separating this belt from that previously described. These ridges first appear nearly four miles southwest of Sparta, at the extremity of an extensive meadow, and range towards Lockwood. They are four in number, the shortest being about one hundred yards long, while the longest exceeds a fourth of a mile. Their width is between two hundred and three hundred feet; they occupy one general line; but between their extremities is usually a space of from half a mile to a mile of primary strata, whose prevailing dip is towards the southeast, though under circumstances of great irregularity.

The white altered limestone of these ridges is rather in the condition of an amorphous crystallization, than in the form of rhombic spar. Such is the case at Franklin and Lockwood. It is in fact a coarse granular white marble imbedding many of the rare and beautiful crystalline minerals found at Amity and Franklin; we may mention *Brucite* and *green spinelle* of uncommon purity.

Notwithstanding the prodigious extent of igneous action to which the limestone has been evidently exposed in these belts, manifested by the width of the space over which a total modification of the rock has been effected, we still discern a very distinct stratification, the beds dipping steeply towards the southeast.

In the same line with this series, and about one mile and a half further to the southwest, occurs another somewhat shorter belt of the altered limestone, a little beyond Lion Pond. The length throughout which the limestone has been modified, does not exceed two hundred or three hundred feet, and the width of the belt is not considerable. The locality is nevertheless an interesting one, for we find well exposed, within a tract not more than a fourth of a mile wide, first, the primary strata on the southeast, then the sandstone, F. I., next the blue limestone, F. II. passing into the sandstone, and assuming near the passage a clear reddish hue, and lastly, the belt of altered limestone in contact with a small elevated hill or dike of felspathic sienite, the cause of the altered structure of the calcareous rock. All of these stratified masses, the gneiss, the sandstone, the blue limestone, and the white crystalline belt, dip alike towards the northwest at a gentle inclination.

Graphite is here present as usual in the calcareous mass; which besides contains other minerals.

Portions of the altered rock are coarsely crystalline, though other parts of it are more minutely granular. A variety which is variegated with numerous blue shades of plumbaginous mineral, might evidently, from its susceptibility of a good polish, be employed as an ornamental marble.

Between the sienitic ridge here spoken of and another lying a short distance to the north, there occurs another smaller belt of the altered limestone, deeply buried between the primary rocks. At this spot some enthusiast in search of mineral treasures, expended at a former day no inconsiderable amount of time and labour, in excavations for silver ore in the sparry limestone.

West of the last mentioned point may be seen, by the side of Panther Pond, another still more unimportant exhibition of the altered sparry rock, not deserving of a special description.

Near Lockwood, not far out of the general line of the larger belts or ridges of the crystalline limestone already treated of, we come upon another band of the calcareous rock which has undergone alteration. Though of rather local extent, this spot is deserving of attention, if only for the perfection in which we here behold the translucent rhombic spar, into which the blue sedimentary limestone has been converted by the agency of heat. Disseminated through the spar, we find the *graphite* sometimes in regular hexagonal plates half an inch in diameter. From a large rhombic crystallization, the calcareous rock graduates to an amorphously crystalline limestone, or a white granular marble.

Some portions of the mass, especially those having the more highly developed crystalline character, include, besides the graphite, several minerals, as *Brucite, mica, talc, quartz,* and *green spinelle;* the mica being in some cases so abundant, as to imply probably its derivation from the contiguous gneiss rocks.

While alluding to the vicinity of Lockwood, it may be mentioned as an interesting locality of granular and crystalline *augite.* Some of the beds of the gneiss in this neighbourhood, being traversed by bands of a deep-green talcose mineral, pervading a mass consisting chiefly of lighter-coloured felspar, would furnish a building material of very beautiful appearance.

Having now described in sufficient detail the numerous bands of altered limestone comprehended in the one general belt of igneous action, which stretches in a nearly straight direction from beyond Amity, in New York, to its southwestern termination near Andover Forge, a little beyond Lockwood, I shall in the next place enter upon a more brief account of the shorter, but no less interesting belt, which pursues the southeastern base of Jenny Jump.

As in the instance of the altered rock near the eastern foot of Pochuck Mountain, the beds of the white crystalline limestone of Jenny Jump do not lie against the flank of the hill itself, but belong to a separate low narrow ridge, or rather series of ridges, parallel with its base, but at a distance sometimes of a few hundred feet. These ridges consist in part of the altered rock, and in part of a succession of intrusive dikes of what, from its general aspect and composition, may be termed a sienite rock, but which contains, besides the ordinary ingredients, various other minerals, as *epidote*, *serpentine*, *indurated talc*, *compact steatite*, and *jade*. In some places the white limestone is wanting, having been evidently removed by denudation, as indicated by the rolled fragments occasionally met with in the adjoining plain. But even where it is absent, we observe the usual narrow ridge with its peculiar dike of heterogeneous mineral matter.

Towards the northeastern end of the belt, about two miles southwest of the road which leads to Long Bridge, the road parallel with the base of the mountain runs in a little narrow strip of meadow between the dike, which here shows a nearly vertical wall, and a second parallel small ridge, rising immediately on the southeast, and which is composed of the sparry limestone and altered chert, dipping at the steep inclination of 80° towards the southeast. The ridge on the northwest of the road, containing the dike, would seem to include, besides a bed of the altered limestone, having a distinct dip at this spot to the north-northeast of 70°, several magnesian rocks, as *serpentine*, *greenish jade*, *Saussurite*, and *indurated talc*.

The primary rocks in this vicinity, in the base of Jenny Jump, display marks of the most violent disruption and compression of their strata, exhibiting an unusual number of intrusive dikes and veins, in which, as in those immediately affecting the limestone, we notice a remarkable diversity of mineral composition. The constitution of the dike, or chain of dikes, directly in contact with the altered limestone, though variable, is essentially different from that of the igneous veins disturbing in a parallel line the primary strata at the base and on the side of the mountain, being characterized by a predominance of the minerals of the magnesian class.

We have evidence that the limestone at one time spread itself extensively along the base and slopes of Jenny Jump; for, not only do we find, on the sides and even summit of the mountain, scattered blocks of the stratum and its included *chert* in considerable number and size, but we observe traces of its having undergone fusion and incorporation with the materials of some of the dikes and veins before alluded to, at the southeastern foot of the mountain. Though the white sparry rock is no longer visible there in mass, its materials, both the carbonate of lime and the commonly prevailing *graphite* and *condrodite*, are frequently mingled in variable proportions with the minerals of the intrusive veins. This incorporation of the altered products of the blue limestone, its *calcareous spar* and its *graphite* and *condrodite*, is much more intimate and more extensively seen in the ridges to the southeast, where the regular belt of the altered rock in contact with the igneous vein has resisted denudation.

Northeast of the locality to which the above descriptions have been principally confined, the belt of white crystalline limestone runs for a distance of between two and three miles, forming in some places a tract of considerable breadth. In some portions of the line the altering rock is a dike of *greenstone*, of a close grain and extreme toughness and density.

About two miles to the southwest of the place first mentioned, and near the road which crosses the mountain going from Hope towards Hacketstown, we cross the crystalline limestone at a point about a mile to the west of the little village of Danville, not far from the southwest extremity of the Great Meadow. At this locality the rock has assumed a somewhat unusual colour and aspect; the carbonate of lime, which chiefly constitutes the mass, being in the condition of rhombic spar, whose tint very much resembles that of ordinary reddish felspar. The presence, in some parts of the rock, of numerous small crystals of greenish *augite*, with occasional scales of *graphite* and even of dark *mica*, impart to the whole mass a very marked resemblance to certain varieties of granite, in which a pink felspar is the prevailing mineral. An inattentive glance at the rock will leave the traveller deceived as to its nature.

The igneous actions affecting the limestone, display their ordinary phenomena at intervals for several miles still further towards the southwest.

A small belt of the crystalline rock is traceable in the prolongation of the general line, occupying a spot a little to the southwest of the small lake called Green's Pond, and not far from the southern termination of Jenny Jump.

We again find it in the same range along the northwest base of Scott's Mountain, in two unimportant bands, the last which we discovered in the State. One of these occurs between the little villages of Oxford and Concord, and the other still further to the southwest, near Davison's Mill, which brings us to within one mile of the Delaware river.

I have been thus full in describing the singular phenomena of induced crystallization, caused in the limestone by igneous agency, and in endeavouring to trace to their several sources the various extraneous minerals which accompany the alteration, from a persuasion of the interesting relations of the whole subject to the important doctrine of the metamorphosis of rocks.

The great thickness throughout which the limestone has undergone a most thorough crystallization from the heating agency of the dikes which traverse it, and the curious law traceable in the developement of some of the minerals, which appear in the light of segregations from elements contained in the limestone, afford unquestionably strong support to the theory, which assumes that gneiss and other primary strata have once been sedimentary rocks, converted by an extremely intense and wide spread igneous action into a universally crystalline state.

Respecting the question of the probable date at which the mineral injections occurred, which have so singularly modified the structure of the adjacent limestone, we can merely hazard some general conjectures, which rest rather upon analogies than upon a foundation of facts.

Economical Relations of F. II.

Perhaps of all the rocks in the State, the formation whose geological structure we have now described, is that which is most extensively and variously applicable to the useful purposes of life.

(*a.*) Among its several important uses, we may advert, in the first place, to its adaptation as a *building stone.* The great readiness with which it may be quarried, the facility with which it may be shaped and cut, its agreeable colour, and, above all, its strength and almost perfect indestructibility by atmospheric agents, unite to recommend it in the construction of dwellings, barns, public edifices, and the structures connected with civil engineering, such as locks, bridges, and aqueducts. Lamentable inattention, however, is frequently displayed in the choice of the material for these purposes, varieties being selected which require an unnecessary amount of time and care to shape; and which, after an exposure of a season or two to the atmosphere, assume a rusty tint, in consequence of containing too large a quantity of oxide of iron. To avoid the former of these defects, it is only requisite to examine closely the form and texture of the freshly fractured surfaces of the rock, which should generally split with a smooth, even, somewhat conchoidal fracture, and present to the eye a very regular and close grain, with a clear, uniform, and decided tint, either of gray, or grayish-blue, or blue. To detect the presence of an injurious proportion of the oxide of iron, calculated in course of time to stain the exposed surface of the rock, one of the readiest and simplest methods is to reduce a portion to powder, moisten it with a little water, and add a little pure muriatic acid. The existence of oxide of iron will be made apparent by a brownish tinge, seen while the material is dissolving.

(*b.*) Another highly useful purpose to which this rock is often applied, is in the construction of McAdam roads. As a road-stone, to be employed where the intercourse does not require a very heavy draught, it is at once the cheapest, most readily procured, and easily broken material accessible to very extensive and important districts, not merely of New Jersey, but of the Middle States. Much judgment, it is believed, may be displayed in the selection of those kinds which will prove the toughest and most difficult to abrade under the wheels. Those possessing a subcrystalline texture, and a rough, irregular fracture, especially when they contain a certain amount of silica and oxide of iron, I have usually conceived to be the best adapted to endure attrition. A little practice with the hammer, will soon enable us to ascertain approximately, the kinds likely to prove most suitable.

(*c.*) *Marbles.*—The great calcareous formation which we have described, is characterized by several varieties which are fairly entitled to the name of ornamental *marbles*, when we consider their fineness of grain and susceptibility of a delicate polish, combined with their several soft and pleasing shades of colour.

Among the beds which pass ordinarily by the name of limestone, we meet with portions uniting the requisites of texture with the most beautiful and delicate tints; some are of a very pale-

blue approaching to *white;* others are of a *dun-colour;* while some are gray and blue marbles, delicately *mottled, veined*, and *shaded.* In the Mendham Valley, a variegated pinkish colour is associated, in a few cases, with a texture deemed sufficiently fine to admit of a good polish. The *white crystalline marbles* of the altered belts have been already spoken of. The *pure white* and granular kind, seen in many places around Franklin and Sparta, and further to the southwest, would afford, if carefully quarried and polished, a superior marble; while the clouded kind, such as we find near Long Pond, might be procured in very beautiful varieties. The presence of the pale-yellow Brucite, in some very white portions of the granular rock, would constitute a beauty rather than a defect. Other portions of this altered rock are in some places delicately arborescent.

A variegated greenish marble, susceptible of an excellent polish, occurs, connected with small injected veins of *serpentine,* near Augusta, adjacent to the anticlinal axis of the Paulinskill Valley. It has all the characters of an ornamental marble, the rock being penetrated in all directions by little veins of serpentine of a lighter and darker green, mingling with the mass of the rock so as to impart to it numerous beautiful shades. The occurrence of minute brightly yellow cubical crystals of *sulphuret of iron* in some parts of the mass, is calculated to heighten rather than impair its beauty. A change seems to have been induced in the texture of the rock by the intrusion of the serpentine, nearly effacing its original marks of stratification, and causing numerous irregular cross joints.

This creates some little difficulty in quarrying it, but if the excavation were attempted on a larger scale for the purpose of finding for this marble a regular market, the rock could be procured in larger and better shaped pieces than at present. It does not show more liability to irregularities in the quarrying, than such rocks usually exhibit.

Character of the Lime for Mortar and as a Fertilizing Agent.—The lime from different portions of Formation II. possesses various degrees of excellence for mortar.

Two principal species include nearly all the varieties of this rock, however they may differ in point of colour and aspect. The first of these is composed chiefly of carbonate of lime, the extraneous ingredients being *oxide of iron*, sometimes a little *oxide of manganese*, a little vegetable or animal organic matter, and water. The second kind, besides all these several constituents, contains a large proportion of carbonate of magnesia, from which it derives peculiar and important properties.

Those beds of the rock which possess, as I have already described, a clear decided tint, especially any shade of blue, and a smooth, sharp, even fracture, and close, fine grain or texture, will yield almost invariably, a pure white lime, admirably adapted for making common mortar; but which is destitute of the property of hardening under water. Some very dark varieties furnish a beautifully white and pure lime, the colouring matter consisting of bituminous substances, which are entirely consumed in the process of burning. Such limestones are apt to emit a disagreeable fœtid smell when broken or strongly rubbed.

The *magnesian limestones* constitute a very important portion of the formation before us. Until my brother, Professor William B. Rogers, of Virginia, first analyzed these rocks, which he has done extensively and systematically as they occur in that State, their existence was hardly recognised, much less their remarkable abundance. My own researches made in Pennsylvania and New Jersey, confirm the fact of the magnesian character of a large portion of this great limestone formation.

Their economical value as *hydraulic cements*, very recently ascertained to be dependent upon the presence of the magnesia, gives additional interest and importance to the developement of these extensive beds.

No certain guide can be given for recognising the magnesian varieties of the limestone, as only the eye of an experienced observer will detect those nice shades of aspect, which denote the presence of both the alkaline earths. The best general criterion, is a certain dulness in the appearance of the surface, even when freshly broken, and the absence of that fine smooth grain distinctive of the pure varieties of the limestone.

The recently discovered general fact, already alluded to, that the property of forming a *hydraulic cement* depended upon the large proportion of *carbonate of magnesia* in the limestone, was first hinted at by M. Vicat, of France, and since confirmed by an extensive series of analyses and experiments, carefully conducted by my brother, not only upon specimens of the formation as it occurs in Virginia, but upon other limestones of New York and Kentucky, the details of which were submitted to the public in his annual report on the geological survey of Virginia for the year 1838. He there demonstrated that the *magnesia* is invariably a prominent ingredient in all the limes which readily set under water, while the other constituents, *silica, oxide of iron*, and *alumina*, seem not to be essential, being variable, and most usually existing in comparatively minute proportions. His researches thus far made, would indicate that in the specimens yielding an active hydraulic lime, the average proportion of the *carbonate of magnesia* to the *carbonate of lime* is about three to five.

In corroboration of these interesting and useful results, I here present several analyses of the magnesian limestones of New Jersey. After determining accurately the chemical composition of each specimen, a portion of the same mass was carefully calcined, made into cement, and left to repose under water, the progress and extent of the hardening being ascertained by an instrument, devised by a French experimenter for that purpose.

The more highly magnesian varieties proved in every instance good hydraulic cements.

Analyses.

Blue Limestone from Lafayette, Sussex county.

Description.—Colour, bluish gray; texture, close-grained and subcrystalline.

Specific gravity.—2·838 at a temperature of 56° Fahr.

Composition.—In 100 parts:

Carbonate of lime, -	53·04
Carbonate of magnesia, -	41·04
Alumina and peroxide of iron,	0·96
Insoluble matter, -	3·24
Moisture and loss, -	1·72
	100·00

Blue Limestone, Johnsonburg, Warren county.

Description.—Colour, light bluish gray; texture, slightly subcrystalline.

Specific gravity.—2·837 at a temperature of 59° Fahr.

Composition.—In 100 parts:

Carbonate of lime,	-	53·52
Carbonate of magnesia,	-	38·74
Alumina and peroxide of iron,		0·73
Insoluble matter,	-	6.29
Moisture and loss,	-	0·72
		100·00

Blue Limestone, near Anderson, Musconetcong Valley, Warren County.

Description.—Colour, dark blue; texture, very fine grained and compact; fracture slightly conchoidal.

Specific gravity.—2·847 at a temperature of 58° Fahr.

Composition.—In 100 parts:

Carbonate of lime,	-	53·59
Carbonate of magnesia,	-	41·58
Alumina and peroxide of iron,		1·38
Insoluble matter,		3·44
Moisture and loss,		0·01
		100·00

This is said to have been employed as a hydraulic cement with success.

Blue Limestone, south of the Paulinskill, on the road from Newton to Swartwout's Pond.

Description.—Colour, light bluish gray; texture, moderately close grained; aspect, somewhat dull and earthy.

Specific gravity.—2·832 at a temperature of 54° Fahr.

Composition.—In 100 parts:

Carbonate of lime,	-	54·95
Carbonate of magnesia,	-	33·99
Alumina and peroxide of iron,		2·10
Insoluble matter,	-	7·45
Moisture and loss,	-	1·51
		100·00

Blue Limestone, Hacketstown Valley, Warren county.

Description.—Colour, dull bluish gray; texture, moderately close grained, and slightly subcrystalline; has interspersed veins of calcareous spar.

Specific gravity.—2·831 at a temperature of 69° Fahr.

Composition.—In 100 parts:

Carbonate of lime, -	50·23
Carbonate of magnesia, -	37·13
Alumina and peroxide of iron,	0·63
Insoluble matter, -	9·93
Moisture and loss, -	2·08
	100·00

The above five analyses refer, it need hardly be said, to Formation II., which will be found, I doubt not, upon an extensive examination, to be more often magnesian than purely calcareous.

Having shown the carbonate of magnesia to be an abundant ingredient in many of the limestones, the lime of which is used among the farmers of those districts for assisting the fertility of the soil, it may be of some service to the agricultural interests of the State, to endeavour in this place to correct the generally prevailing impression, to this day widely propagated by writers, of the injurious action of magnesian lime upon the land. It is now clearly established, that a *large proportion* of the lime employed by the farmers of the southeastern counties of Pennsylvania, for a long series of years past, with such eminent benefit to the permanent fertility of their soils, is, without their being aware of it, *highly magnesian.* This is of itself enough to refute the popular prejudice upon this subject. But the analyses above given, of a number of those of New Jersey, of well known repute as to their agricultural fitness, will enable the farmers of Warren and Sussex counties in particular, to judge of the merits of this question for themselves, by uniting with the chemical results here presented, their own agricultural experience. While the evidence from experiment and trial now brought forward, goes conclusively to show, that the magnesia cannot be poisonous to the crops, agreeably to common belief, it still leaves an interesting and useful question undetermined, whether the magnesia is merely *inert*, or whether, like the lime, it exerts an actively fertilizing influence upon the soil.

Nothing short of a series of agricultural experiments, judiciously planned and perseveringly conducted, aided by chemical analyses performed upon the limestones used, can settle this important economical inquiry. Alive as our farmers are becoming to the inestimable utility of calcareous manures, it must soon prove to them a matter of interest, to ascertain whether the magnesia, constituting often more than 40 per cent. in the lime which they spread, is really salutary or wholly inoperative.

The white crystalline limestone of the altered belt, especially of Sussex county, recommends itself strongly for its purity and whiteness, particularly that procured from the more perfectly rhombic variety.

It has long been made into lime near Hamburg, from whence that material has been transported over the Highlands to the towns of Patterson, Newark, &c., commanding, at times, as high a price as one dollar per bushel. This is admirably adapted for the finer kinds of masonry, by the whiteness of the cement which it yields; and it is especially fitted for making the hard finish for walls and cornice work.

In the neighbourhood of Lockwood there occurs a fine exposure of the crystalline limestone, in a belt already described. This being within about three miles of the Morris canal at Stanhope, where there is a ready transportation to Newark and other towns where lime is in demand, the business of burning the stone is beginning to invite attention. The pure rhombic semitranslucent variety, which is, to a great extent, free from magnesia, and capable of producing, when properly burned, a lime of superior excellence and whiteness, is here in great abundance.

The annexed analysis will show the composition, in 100 parts, of this limestone. Specific gravity, 2.719.

Carbonate of lime, -	95.86
Carbonate of magnesia, -	1.93
Alumina and peroxide of iron,	0.61
Insoluble matter, -	0.07
Moisture and loss, -	1.53
	100.00

It is a matter of surprise to the traveller, that, along this whole range, where the sparry limestone is so accessible, and where wood is comparatively cheap, so very little has been done by the inhabitants of the region, in manufacturing lime, either for transportation to the ready market of New York, or for home consumption, as a fertilizing agent of inestimable value to the soil. Over the whole of the Kittatinny Valley and its branches, in New Jersey, the importance of lime in agriculture has hitherto been singularly overlooked. Along the Musconetcong and German valleys, the practice of limeing has of late years become a common one; but throughout a large part of Sussex and Warren counties, where the circumstances are especially favourable for its general introduction, it remains but little attended it. The example of the southeastern counties of Pennsylvania should convince the people of New Jersey, that, upon *nearly all soils*, whether they lie immediately over the limestone rock itself, or over the slate, or belong to the sandstone and primary rocks of the hills, or to the deep loams of the river flats, the application of lime properly managed leads to sure and permanent benefit.

The magnesian character of some of the white crystalline limestone deserves attention, as it is probable that the rock will produce a *hydraulic cement.* Should the question of the comparative inertness or efficiency of magnesia in agriculture be definitely settled, it may be of importance on this account to know its composition.

By analysis, I find that the white irregularly crystalline, or somewhat granular kind, which abounds near Sparta, and between that place and Lockwood, and which is so apt to contain insulated crystals of Brucite, is decidedly magnesian, as the following results will show.

Analysis of the White Granular Limestone of Sparta, Sussex county.

Description.—White, opaque, coarsely crystalline, or saccharoidal, containing crystals of Brucite and graphite.

Composition.—In 100 parts:

Carbonate of lime, -	82.85
Carbonate of magnesia, -	15.15
Silica, Alumina, Oxide of iron,	2.00
	100.00

Of the Pond Marl connected with the Limestone, Formation II.

At several places in the limestone districts of the Kittatinny valley, we meet with a material which is identical with the *Lake Marl* of Europe, occurring around the shores and in the beds of small lakes or ponds, and throughout some of the swampy meadows of Sussex and Warren counties. This useful deposit is only found where the water is copiously impregnated with the carbonate of lime, and hence it occurs only within, or immediately adjacent to, extensive limestone strata. It would seem to owe its production, in part, to a chemical precipitation from the water; in part, to the decay of myriads of small testaceous animals, of the species usually found inhabiting calcareous waters, which, secreting the carbonate of lime to supply the material of their shells, generation after generation, accumulate it from the water in great abundance. The ponds where this deposit occurs present a rather singular aspect, being fringed with a broad white beach.

Analysis of a Fresh Water Marl, from a pond four miles from Newton.

Description.—Light ash colour; pulverulent.

Composition.—In 100 parts:

Carbonate of lime, - -	90·22
Carbonate of magnesia, -	1·91
Alumina and peroxide of iron, -	0·61
Insoluble matter, - -	3·13
Organic matter, moisture, and loss,	4·13
	100·00

In consequence of the peculiar appearance derived from this deposit, two or three of the ponds containing it are called on the map White Ponds; for instance, two ponds west of Pimple Hill, in Sussex; the more northern one being, however, incorrectly so termed, as the marl is confined to the other. There is also another pond about one mile north of Marksboro', in Warren. These, however, are not the only depositories of this useful substance: I enumerate the following as its localities already ascertained: White Pond, near Pimple Hill; a pond near Brighton; Stickles Pond, two miles south of Newton; a pond a mile and a half northwest of Andover; the White Pond near Marksboro'; a pond at Stillwater; and some of the small ponds and marshy grounds in the neighbourhood of Hope.

The marl likewise occurs in a marshy meadow to the northeast of La Fayette, and again near Peter Merkel's, in the same range. Considering the well-tried value of this material in Europe, its importance to the agriculture of the districts which possess it, and its abundance in the two upper counties of the State, it seems truly strange that its application to the adjoining soils, should hitherto have been almost entirely overlooked by the farmers.

A material so easy of access, demanding no preparation to suit it for the soil, and unquestionably so efficient when judiciously applied, ought to be extensively used. Though much neglected until recently, this useful substance is beginning to attract attention to its valuable properties as a manure. Ample evidence is furnished of its fertilizing agency, by experience in Sussex county, even if we had not the testimony of many districts of Europe in its favour. It should be taken from the pond or low grounds where it abounds, and drawn to some convenient place, to remain in heaps, exposed to the air for several months. By this exposure it becomes dry and pulverulent, and is made to mingle with the soil more uniformly than when in its recent wet condition.

Brown or Hematitic Iron Ore.—Next to the limestone itself, the most useful mineral which belongs to this formation in New Jersey, is the brown, or *hematitic iron ore.* Though much less extensively diffused than in other parts of the same great valley, further to the southwest, this ore, from its excellent properties, is to be regarded as a valuable addition, recently discovered, to the mineral resources of the State.

The main deposit, moreover, is interesting, both in an economical and scientific light, on account of its great extent, and the singular geological circumstances under which it occurs.

As already mentioned, when describing the ranges of the altered white limestone, this large accumulation of the ore occupies the summit and slopes of a narrow ridge of the sparry rock extending parallel with the Pochuck Mountain, at a small distance from its base. The situation of the mine is about two and a half miles northeast of Hamburg, chiefly upon the western declivity of the hill. Very little rock is visible in the immediate vicinity of the ore, which exists in the concretionary state, imbedded in a highly ferruginous clayey loam, which displays the utmost variety of colour, texture, and composition, being mottled and streaked with clays of all shades, white, yellow, red, and brown. The ore distributed irregularly throughout this mass, presents no less diversity of aspect, though it all belongs to one species, denominated *brown iron ore.* It occurs massive and cellular and sometimes fibrous, also in a mamillary and botryoidal form, and is often so hard and compact as to require blasting. The workings are generally dry. The earth in some portions of the mine gives evidence of resulting from decayed felspar and the other constituents of the adjacent gneiss rock, and contains beside much *plumbago* in a disintegrated and pulverulent state, clearly indicating that the dissolution of the crystalline limestone has been, in part at least, the cause of this large accumulation of ore.

The mineral is of excellent quality, yielding a much superior iron to that procured from the magnetic ores of the adjoining primary districts. The facility with which it may be smelted in blast furnaces, compared with the magnetic ore, is another great recommendation, and when we consider that the latter, by the usual process of reduction in bloomery forges, requires from six hundred to eight hundred bushels of charcoal to produce a ton of malleable iron, while this ore may be brought into the condition of cast iron by an expenditure of not more than two hundred bushels, costing between five and six dollars per hundred bushels, we are still further impressed with its value.

Though but five or six years in use, this ore has already become rather extensively worked, being not only smelted at a large furnace recently erected near Hamburg, but hauled over the Wallkill Mountain a distance of twelve miles to Clinton Furnace, and a still greater distance to Ryerson's Furnace, near Pompton.

Another mine of similar brown iron ore, discovered rather before that in the ridge near Pochuck, lies about a mile and three quarters east of Hamburg, above the junction of two small streams called Sand Pond and Mud Pond creeks. This deposit, already alluded to, is embraced between the primary rocks of the base of the Wallkill Mountain and a small knob of gneiss a little west of it, and lies only a short distance from the northern termination of a belt of white crystalline limestone, the disintegration of a portion of which, once occupying this little valley, may have possibly been the source of the ore.

The present excavation is only about 140 feet long, 40 wide, and 40 deep. This deposit of ore was first brought to light, a few years since, in sinking a well.

Owing to the occurrence of much diluvial matter over the surface of the narrow valleys which embrace the altered limestone, it is highly probable that considerable bodies of the ore exist where few or no indications at the surface betray its presence. The prevalence of the mineral near the white limestone, under circumstances that imply it to have come from a rather extensive dissolution of that rock, holds out a prospect of finding it in other localities besides the above. The explorer should carefully note the signs of the removal of the altered limestone, by denudation or solution, in spots where the products of its destruction would, from the features of the ground, be most likely to remain in their usual form of a deep loamy ferruginous deposit. Such places will be the broken slopes of hills and the basins in the centre of confined valleys.

Hematitic brown iron ore occurs occasionally, though not in extensive deposits, in the limestone valleys between Schooley's and Scott's Mountains. It has been found, for example, though in rather humble quantities, very pure, between Mansfield and Anderson villages, not far from the Morris canal. It exists likewise in more abundance in connexion with the belt of limestone which forms the valley of the Delaware river, between Belvidere and Easton, having been excavated to some extent in the vicinity of Foul Rift. Much of the ore in this neighbourhood belongs to the highly valuable stalactitic variety usually denominated *pipe ore.*

Respecting the geological position of the brown or hematitic iron ore, we may give it as a general rule, admitting of no exception in New Jersey, that it abounds only in the highly ferruginous soils, which either immediately cover this limestone formation, or which lie closely adjacent to it. In Pennsylvania and some of the other States such are not its invariable relations, as several of the other rocks of the older secondary series present us with extensive deposits of the same species of ore.

Sulphate of Barytes.—West of Newton about two and a half miles, there occurs a narrow vein of the *sulphate of barytes,* the dimensions of which, where it has been explored, appear to be too inconsiderable to render it an object of profit. It is crystalline and of a pretty pure opaque white, and has been met with in two separate spots contiguous to each other. The locality is near the disturbed anticlinal axis of the narrow belt of blue limestone, immediately northwest of the main range of slate next northwest of Newton, being removed from the principal Paulinskill tract of limestone by a narrow intermediate synclinal zone of slate.

Upon the site of one of the excavations made some years since for this mineral, a very absurd mining project was undertaken, not to procure the sulphate of barytes, which, if abundant, might repay the miner, but in the futile hope of revealing a mine of *silver.* Every informed geologist or scientific miner would pronounce at once, from all the mineral indications here present, and from the nature of this and the other rocks, that such attempts at mining for the precious metals in these strata are likely to prove wholly abortive; nevertheless a shaft sixty feet deep and at a cost of two thousand dollars has already been dug. I deem it my duty to state, that I could discover in this mine nothing that seemed to contain a trace of silver, or any thing to justify the anticipation of finding it.

The barytic mineral has become of recent years a substance of considerable demand in commerce, from the rather extensive use now made of it by the manufacturers of white lead, many of whom have been driven by the spirit of competition to mingle it in a finely levigated condition, in a greater or less proportion, with their manufactured article. This adulteration, if such it can be called, would seem not to affect materially the interests of the consumer, as the mineral appears rather to dilute than injure seriously the quality of the white lead, while the reduction in the price will compensate, or nearly so, for the somewhat increased quantity of the paint which it becomes necessary to employ.

SECTION III.

Of the Slate of the Kittatinny Valley, Formation III.

Geographical Range of the Formation.—Having adopted the ascending order in this description of the rocks of the ancient

Secondary or Appalachian System, the next stratum which presents itself, reposing immediately on the limestone, is the slate of the Kittatinny Valley. This rock, as already intimated when tracing the axes of elevation in the limestone, ranges in several long and narrow belts, the limits of which were specified while treating of their position in the synclinal troughs embraced between the upheaved zones of the limestone. Extending our present enumeration to all the several belts within the State, we have now to include, with those alluded to, the principal tract of the region which occupies the northwestern side of the Kittatinny Valley, throughout its whole length across New Jersey.

Tracing the limits of these different ranges with as much minuteness as the purposes of a general description render necessary, we shall begin, as usual, with those which lie farthest towards the southeast.

The first is that narrow belt at the Wallkill, about three miles northeast of Deckertown, which runs southwestward, passing about a mile northwest of Hamburg, and a little southeast of Harmonyvale and Lafayette. It terminates about two miles southeast of Newton in a narrow point. This low ridge of the slate is in many places not more than a fourth of a mile in width, while its length is about fourteen miles. It owes its position and form to its occupying the long *synclinal axis* included between the anticlinal axes of Pochuck and of Harmonyvale. Its beds dip from each margin at a gentle angle towards the centre of the tract.

Proceeding to the southwest, we meet two other narrow bands of slate, nearly in the prolongation of that already mentioned. One of these commences a little east of Reading's Pond, and extends, passing directly west of Greenville, almost to Sink Pond. The other lies in a parallel position at a short distance to the northwest, the two being separated by a narrow valley of the limestone, where that formation has been elevated along an anticlinal axis. Each of these little belts of slate takes the form of a low synclinal ridge.

Another somewhat larger belt, of nearly similar breadth, commences at Johnsonburg, and ranges past Hope, where it deflects a little, extending to the village of Beaver Brook, near which it terminates. Like the other corresponding tracts, it has the form of a low narrow ridge, bounded on each side by limestone, which dips beneath it, placing it in the middle of a synclinal trough.

The next tract of slate, though in the general synclinal arrangement of its strata resembling the others, is one of far greater extent. Both its southeast and northwest margins have been already defined, when tracing the borders of the limestone, but for the sake of connexion we may briefly recapitulate them here. Beginning at the Wallkill, near the New York State line, the southeast boundary of this tract of slate runs to the southwest, passing near Deckertown, and northwest of Harmonyvale, Newton, and Johnsburg. Here it deviates more towards the west, until it passes the Free Church between Centreville and Hope. There it deflects to the south, passing Beaver Brook, and running thence in a southwest course, reaching the Delaware a little above Belvidere. The northwestern boundary, beginning on the Delaware near the mouth of the Paulinskill, pursues the southern side of that stream to Gravel Hill, near which it crosses it; recrossing a little east of White Pond, it thence extends in a northeast direction for several miles to a point about three miles north of Newton. Here it unites with the southeast margin of a narrow belt of the formation which follows the course of the Paulinskill for several miles. Beyond, where this smaller tract joins the principal one, the boundary which we are tracing proceeds to the northeast, again passing to the southeast of Augusta, and terminating near Coursenville, where the whole zone of slate southeast of the Paulinskill merges in the still more extensive one which follows the base of the Blue Mountain.

The southeast edge of this northwesternmost tract, beginning at the Delaware, about three-fourths of a mile above Columbia, pursues the northwest side of the valley of that stream to Coursenville, passing north of the little village of Walnut Valley, and northwest of Swartwout's Pond. Uniting with the former wide belt at Coursenville, the two tracts beyond that point have for their southeastern limit the boundary already traced, which passes near Harmonyvale and Deckertown to the Wallkill.

The base, or rather the southeastern flank of the Blue Mountain, constitutes the general northwestern boundary of the whole slate formation of the valley. Near the Delaware, the common limit of the slate and the overlying sandstone of the mountain is seen at a moderate elevation above its base; but in Sussex, between Culver's Gap and the State line, the slate rises upon the eastern slope of the ridge almost to its summit, giving a fertile soil to the side of the mountain, and presenting, in a long line of cultivated farms, a landscape full of pleasing and picturesque beauty.

Composition and structure of the rock.—The ordinary character of the third formation of the Appalachian system, as it prevails in New Jersey, is that of a dark blue argillaceous slate; it is, however, very various, both as respects its colour and composition. It occurs in belts of almost every hue, black, blue, dark gray, bluish gray, dingy olive, dull brown, and even sometimes yellow.

It exhibits every grade of relative fineness and coarseness of texture, from that of the finest grained roofing slate, to that of a rough argillaceous sandstone.

At its junction with the subjacent limestone, its beds are often almost black, and more or less calcareous, while the contiguous upper layers of that rock partake in some degree of the argillaceous composition and structure of the slate. Near its upper limit, in like manner, where it and the gray sandstone of the mountain are in contact, it acquires a somewhat arenaceous texture, and in certain layers passes to a gray argillaceous sandstone.

Nearly all parts of this extensive formation, which is evidently of very great thickness, present that highly curious feature of structure denominated *cleavage.* This remarkable tendency of the mass to split into thin plates by planes of cleavage, which preserve a uniform direction and inclination over extensive tracts, independently of all variations in the texture of the rock, and of all changes in its dip, is a feature which belongs to many of the ancient slate rocks, both of the old and new continents; but in few regions can it be studied on a more extensive scale than in the Kittatinny Valley, where it is visible for a great distance on both sides of the Delaware river. While the beds of slate throughout a large portion of the northwestern belt dip towards the base of the Blue Mountains, or to the northwest, and while those of the next great zone to the southeast, especially near the Delaware, have been disturbed by an anticlinal axis giving them both a northwestern and southeastern dip, the planes of cleavage are observed to maintain invariably a southeastern, or, more properly, a *southern* inclination, which is usually between 40° and 60° to the horizon. Their *strike*, or the line formed by their intersection with a horizontal plane, is, therefore, far from coinciding with the prevailing strike of the strata themselves. And it is not a little curious, that this law, of a nearly south-southeast direction in the dip of the cleavage surfaces, holds true, not only of the slate but of all the contiguous formations of the series, except the *coarse sandstone* and conglomerate rocks of the mountain, affecting the softer variegated shales, beds of limestone, and olive-coloured slates of the still higher rocks, which occupy a breadth of many miles to the northwest. But its vast extent is more particularly seen, when we trace the formations in their longitudinal course along the Kittatinny Valley, where we may behold the cleavage planes preserving their southeastern dip, with scarcely an interruption the whole distance, from the Hudson to the Potomac, and indeed to far more distant limits in both directions.

The theoretical discussion of the interesting problem, *the cause* of this truly curious general fact, would be out of place in a work like the present, restricted, as it is, to the description of a comparatively small tract of the extensive region over which this phenomenon prevails. But a hope is cherished, of my being able at some future day, to connect it with views concerning the elevation of our primary chain and the neighbouring axes, sustained by facts, and a train of reasoning which may afford, perhaps, a satisfactory solution of this apparently obscure enigma.

The occurrence of workable roofing slates, is connected with the presence of these cleavage planes. Hitherto they have been discovered only in the belt which ranges near the base of the Blue Mountain, having never been found of sufficient purity but in the vicinity of the Delaware river, near the Water Gap.

The largest quarry is on the west side of the river, in Pennsylvania; a smaller one, yielding both roofing and writing slates of excellent quality, lies nearly opposite, on the eastern side of the river, in New Jersey. In both of these quarries, the true dip of the rock is towards the west-northwest, at an angle of about 30°.

This is detected by the inclination of the numerous thin layers or ribbons, of a different colour from the rest of the rock, marking the sedimentary structure and the true planes of deposition. The dip of the planes denoting the cleavage is towards the south-south-east, at an average angle of 50°, except where it is affected in the Pennsylvania quarry by a small fault, which, traversing a part of the slate, not only causes a local deviation in the dip of the stratum, but an alteration in that of the cleavage also.

Several favourable circumstances of structure and position, must combine to adapt any portion of the formation to being quarried for roofing slate with success.

The rock must be of a fine uniform and compact grain, as free as possible from all crushes or contortions of the stratum, cleaving with facility into thin plates in one direction, and breaking with difficulty in every other. It should be exempt, moreover, from *sulphuret of iron*, which is often found finely disseminated in the coloured seams or ribbons, and which upon exposure to moisture, soon causes a rapid disintegration of that portion of the mass. The quarry should be situated, if possible, where a small rivulet of water may be conducted over the rock, to preserve it in a moist state, in order to render it more easily and evenly cleaved.

In splitting and trimming the slates, care is taken to reject the coloured ribbons, lest, in course of time, they should undergo decomposition.

It is somewhat curious, that while the belt of pure slate between any two of these ribbons is almost perfectly uniform in texture and quality, there often prevails a sensible difference in the respects between two adjacent belts, though only separated by a ribbon of a slightly different colour, less than an inch in thickness. It merely marks a difference in the composition of the sediment, before and after that which formed the more heterogeneous ribbons.

Inferring from the highly cleavable condition and firm grain of much of the slate of the belt at the foot of the Blue Mountain, for many miles east of the Delaware, it would seem not improbable, that a minute examination of the stratum for roofing slate, might be rewarded with success at more points than one.

Except the highly useful article just alluded to, the formation described would appear not to present us with materials of much interest, as respects their economical applications.

Of *iron ores*, this formation has been found to exhibit very few indications in New Jersey, while of other minerals either useful or curious, it would seem to be equally destitute.

Some of its less argillaceous sandstone beds appear adapted to the ordinary purposes of a building stone, but care is requisite in the selection, as too large a share of argillaceous matter leads to a dissolution of the rock by the frost.

The soil over this formation is usually rather meagre and of inferior fertility, yet it is susceptible of remarkable amelioration from the application of lime, which throughout the whole length of the Kittatinny Valley, may be procured at a distance rarely exceeding four or five miles from the remotest parts of the slate districts.

Gray Sandstone of the Kittatinny Mountain, Formation IV.

Geographical Range of the Formation.—Resting immediately upon the great slate stratum above described, with a conformable northwestern dip, there is a thick series of hard and massive gray sandstones, occasionally having the coarseness of a quartzose conglomerate. These rocks are confined to the long, narrow, and nearly straight mountain ridge, remarkable for its steep flanks and almost perfectly level summit, called the Kittatinny or Blue Mountain, which crosses the counties of Warren and Sussex from the Delaware Water Gap, to near Carpenter's Point, but which, in the form of a nearly continuous mountain, reaches from within a few miles of the Hudson, near Kingston, to Cumberland county, in Pennsylvania.

Unlike the somewhat gradual transition witnessed between the slate and its subjacent limestone, the passage from the slate, which occupies the lower half of the eastern slope of the mountain, to this overlying sandstone, is abrupt and every where well marked. Cropping out in many places in a bold and rugged escarpment along the upper part of the southeastern side, it forms the rough but level summit of the ridge, and usually about one half of its northwestern slope.

The relative position of this gray sandstone to the overlying red sandstone and shale formation of the northwestern flank, and to the underlying slate, and the conformable dip of all these rocks towards the northwest, is well exhibited in that fine natural gorge of the mountain, the Water Gap of the Delaware. Here, the entire structure of the ridge is exposed, showing the gray sandstone rising in bold grandeur from the water's edge to the crest of the mountain, an elevation of about fourteen hundred and fifty feet. The ridge preserves this height with a remarkably straight and even summit for many miles, in both directions from the river. This levelness and perfect straightness of the mountain top, the regularity of its grand escarpment on the east, and the striking uniformity in the general dip of its strata, suggests the remarkable equality in the intensity and direction of that force from below, which uplifted from their deep bed under the waves, this ponderous mass of rocks.

Composition and Structure.—The gray sandstone formation of the Kittatinny Mountain consists of a thick series of hard white and whitish-gray siliceous rocks of various degrees of coarseness, from that of a fine-grained pure sandstone to that of a quartzose conglomerate of thickly set pebbles, averaging half an inch in diameter; these several varieties are found interposed in frequent alternations, though the fine-grained sandstones most abound in the upper half of the stratum, while the conglomerates prevail to rather greater amount in the lower division. In the vicinity of the Lehigh river, in Pennsylvania, the main deposit consists of pebbles, often of great size, which compose the lowest beds of the formation, resting in immediate contact with the subjacent slate.

From the Susquehanna river to the district of the Lehigh and Delaware, the formation would appear to augment progressively in thickness and general coarseness of composition, being only about four hundred feet thick near the first river, and almost two thousand feet at the Lehigh; but advancing from the Water Gap of the Delaware towards the Hudson, it again abates somewhat in thickness, retaining, however, its full proportion of the white quartzose conglomerates.

Upon examining the composition of the rock, it will be found to consist of rounded fragments in the condition of sand and fine gravel, derived from the primary rocks lying southeast and east of it, and in part from the three inferior older secondary formations of its own group, ranging parallel with it in the Kittatinny Valley. Among these materials we occasionally meet rounded pebbles of the flint or chert, characteristic of the limestone, though none of the softer carbonate of lime itself; also small flattish fragments of the directly underlying slate rocks.

These constituents, of themselves, imply that some great disturbance of the shores of the Appalachian sea must have taken place suddenly, interrupting the deposition of the slate, and giving rise to a series of new and more violent currents, sweeping into it a coarser class of materials from the neighbouring land and from the freshly risen sediments which now form the Kittatinny Valley. But on this interesting point we are not left to inferences derived merely from the nature of the rock; for towards its north-eastern termination, we find this formation, as we approach the Hudson, resting *unconformably*, with a gentle dip to the north-west, upon the upturned and contorted beds of the slate, giving unequivocal proof of the violence of the subterranean actions which attended the commencement of this extensive sandstone deposit. Whether the lower formations of the Kittatinny Valley emerged entirely above the waves at this epoch, in the tract which they now occupy in New Jersey, is a point open to doubt, though there exists strong evidence for believing, that, over some portions of their range at least, further to the northeast, in the neighbourhood of the Hudson and beyond it, they were thus uplifted. The general augmentation in the coarseness of the materials of the sandstone formation, as we advance from the Susquehanna towards the Hudson, would tend to confirm the opinion, that in this latter quarter the disturbances which ushered in this *fourth epoch* of the ancient secondary period had their greatest energy.

The gray sandstone of the Kittatinny Mountain is the only rock of the whole lower secondary group within the State, from the limestone of the eastern side of the valley to the limestone of the olive slate formation skirting the Delaware in Sussex county, which exhibits none of the oblique cleavage planes so conspicuous in Formation III. Its massive beds are traversed by joints, having the same dip and strike, and attributable, probably, to the same origin.

Its quartzose materials and coarse aggregation have probably interfered with its assuming this structure on a minuter scale. It may be given, indeed, as an almost universal rule, applicable to the whole range of the Appalachian rocks, that wherever this cleavage prevails extensively, it shows itself in the sandstones on a scale commensurate, as to distance between the planes, with the thickness of their beds and their coarse arenaceous character. For even in these coarser strata, though the divisional surfaces are three feet and more asunder, they preserve their regularity and constancy of direction, and their parallelism to the slaty cleavage of the argillaceous parts of the series.

ORGANIC REMAINS.

The relics of organic life imbedded in this great sandstone formation are singularly few, if we except two or three interesting species of *marine vegetation.* These belong to the tribe of extinct seaweeds called *fucoides.* The principal varieties are the *fucoides Brongniartii,* and the *fucoides Alleghaniensis.* The cliffs in the middle of the gorge of the Delaware Water Gap exhibit fine specimens of the former, covering with a beautiful reticulation the faces of the white sandstone beds over many square yards of surface. The latter species abounds where the formation alternates in its upper layers with the lower beds of the overlying red sandstone. Properly considered, it is a fossil more strictly characteristic of the latter rock, being confined in this alternation of the formations chiefly to the red layers. Hitherto I have discovered but one fossil of the animal kingdom in the rock of the Kittatinny Mountain.

This is a small species of terebratula of a nearly spheroidal form, found as yet in few places, and chiefly in the uppermost beds of fine-grained white sandstone. The turbulent condition of the currents in the earlier periods of the general deposit, would seem to have interfered with the multiplication of animated races on the sandy bed of that ancient unquiet sea.

ECONOMICAL GEOLOGY.

The white and light gray sandstones of this formation seem, from their durability and the regularity of their stratification, to be well adapted to some of the purposes of a building stone, though their great hardness, and the difficulty in shaping these rocks, must restrict their usefulness chiefly to those objects where very massive or rough structures possessing great strength are intended.

The white quartzose conglomerate of this range in New York, is used for making mill-stones, which consist each of a single block. They are principally made at Esopus, the rock being taken from that part of the Kittatinny called the Shawunkunk Mountain, where the quartzose conglomerate is in great perfection. It is reputed to be well adapted for the purpose. As strata of the very same aspect and composition occur abundantly on the northwestern flank of the mountain in various portions of its range through Sussex, little doubt can be entertained that were the means of transportation as convenient as at Esopus, this application of the conglomerate would claim attention in New Jersey.

Throughout this State the formation before us is singularly destitute of useful ores or minerals. In a high valley, a little northeast of the Delaware Water Gap, between the two ridges which here form the general summit of the mountain, a small body of very excellent hæmatitic iron ore has been found, not showing, however, any indications of an abundance.

Red Sandstone and Shale of the northwestern base of the Kittatinny Mountain, Formation V.

Geographical Range.—Immediately overlying the formation just described, and occupying the valley at the northwestern base of the same mountain, upon the flank of which it sometimes rises to a considerable elevation, occurs a thick and somewhat varied formation, consisting of red and variegated sandstones and shales.

The general range of these rocks is, of course, in a belt parallel with the mountain, from the Delaware Water Gap to Carpenter's Point, where they enter the State of New York. Between the Water Gap and Wallpack Bend they occupy the narrow zone which separates the base of the mountain from the river; but, northeast of the Bend, they follow in a rather wider tract the valley of the Flatkill, cut off from the river by a parallel belt of fossiliferous limestone, the lower member of Formation VIII.

These red sandstone rocks appear not to reach the Hudson; but, in the opposite direction, they extend a vast distance to the southwest, where they are largely developed, as they likewise are along the southern side of Lake Ontario.

Composition and Structure.—The features of this formation are considerably less diversified where it ranges across New Jersey than where it rises to the surface in some of the other States. The particular belt which follows the base of the Kittatinny Mountain is marked, indeed, throughout its whole course, by very little variety in the composition and appearance of the rock. Its more variegated aspect is confined to the belts which lie at a considerable distance to the northwest. As it occurs in New Jersey, this rock consists, in its lower beds, of a dark-red sandstone of a very ferruginous composition and extreme hardness; and in the middle and upper divisions of the stratum, of a brownish-red shale, and a very argillaceous sandstone, which are sometimes slightly calcareous. These latter layers are occasionally divided by thin bands of a different colour, commonly greenish or yellow, but of the same composition; which, as the whole rock is much affected by cleavage, assist materially in the determination of its dip. Throughout its entire range the formation exhibits the peculiar structure resulting from cleavage; this is particularly well developed in the neighbourhood of the Delaware Water Gap; where it offers some interesting phenomena to the geological student. An anticlinal axis of considerable magnitude traverses the formation for several miles, ranging immediately northwest of the Water Gap, disturbing the rocks from their usual northwest dip, and giving to them a series of undulations, distinctly traceable by aid of the lighter-coloured bands above mentioned. Notwithstanding these irregularities, the direction of the *dip and strike* of the cleavage surfaces continues every where the same, only slightly modified in their inclination to the horizon, where the cleavage and true stratification *nearly coincide*, in which case the latter exerts some influence. The usual dip of the cleavage is to a point between south-southeast and south, conforming entirely in angle and direction to that witnessed in the argillaceous rock on the other side of the mountain.

The only *organic remains* hitherto met with in the belt of red sandstone and shale which traverses New Jersey, are the marine vegetable relics already spoken of; the species denominated *fucoides Alleghaniensis* being by far the most usually found.

ECONOMICAL GEOLOGY.

The argillaceous composition of this rock, and the extent to which it is affected by cleavage joints, unfit it, to a great extent, for usefulness as a building stone. In other parts of its wide range, at a distance from the Kittatinny Mountain, the formation includes a highly valuable seam or bed of fossiliferous iron ore, which is becoming well known throughout the central counties of Pennsylvania and Virginia; but this valuable mineral is wholly wanting where the rock rises to the surface to form its most southeastern belt at the base of the Kittatinny, and this is the portion of it which alone crosses the State of New Jersey.

In that part of the formation which ranges between the Water Gap and Wallpack Bend, two or three spots occur where *copper ore* may be seen in small amount; but all hope of discovering in this region a valuable vein of this mineral, must prove, I conceive, entirely illusory. At an early period in the settlement of the district, two or three excavations were undertaken in search of the ore, at the western base of the Blue Mountain, near Paha quarry, but nothing was reached of sufficient value to reimburse the adventurers. The mining holes are now obstructed by rubbish, but the specimens of the ore indicate nothing to warrant a renewal of the attempt.

A few indications of copper ore, chiefly the green carbonate, amounting in reality to little more than stains upon the rock, occur in the gorge of the Water Gap, connected apparently with the lower portions of Formation V. Nothing in the geology of the Blue Mountain or its neighbouring rocks, so far as the portion of it lying within New Jersey has been investigated, suggests the occurrence of metalliferous veins of any magnitude; indeed, the structure of the whole region is adverse to the supposition, though various legends of the ores of silver and lead having been discovered here, are yet current among those ignorant of the subject.

Fossiliferous Limestone of the Delaware, Formation VIII.

Geographical Range.—Resting conformably above the formation last described, there occurs an interesting and important rock, the uppermost of the older secondary strata embraced within the limits of the State. It is a *blue fossiliferous limestone*, occupying, if we adhere to a simple classification of the strata, a position near the bottom of the *eighth formation* of the series. Its dip is invariably towards the west-northwest, at an angle averaging about 30°.

This rock enters the State at Carpenter's Point, whence it extends in the form of a rather steep ridge, parallel with the general course of the Delaware to the Wallpack Bend, where it crosses the river into Pennsylvania. This ridge has the valley of the Flatkill at its southeastern base, for nearly its whole length, bounding which, it forms in many places a rather steep escarpment. Between its northwestern base and the river, there usually extends a narrow diluvial plain, in one or more low terraces, forming the beautiful and fertile flats of the Delaware.

The rock appears to increase in thickness as we trace it northeastward from the Wallpack Bend. In fact it only begins to develope itself as a separate member in the series of our strata, between the Wind Gap and the Delaware Water Gap in Pennsylvania. This expansion, conjoined with a gradual reduction in the angle of its dip as we advance towards Carpenter's Point, causes the stratum to occupy, in the vicinity of Milford, a considerable breadth. This is the same rock which forms the chain of the Helderberg hills, west of Albany, in New York.

Composition and Structure.—The prevailing aspect of this rock is that of a rather pure blue limestone, embracing the two leading varieties, that consisting of the carbonate of lime alone, and that in which the carbonate of magnesia also forms an important part. It has usually a fine close grain, a smooth fracture, and a clear bluish or bluish-gray colour; other portions of it, however, depart from these characters, being sometimes of an argillaceous and earthy texture, sometimes sparry or subcrystalline, and sometimes so replete in fossil, shells, and zoophytes, as to possess no distinctive uniform grain.

The following analysis will serve to show the composition of this rock, as found at the Wallpack Bend.

Specific gravity.—26·94

Composition. In 100 parts:

Carbonate of lime, -	89.52
Carbonate of magnesia, -	1.45
Alumina and peroxide of iron,	1.03
Insoluble matter, - -	7.00
Moisture and loss, - -	1.00
	100.00

Though it is not difficult, by close attention, to discern its planes of stratification, and thence to recognise its dip, yet, like all the calcareous and argillaceous strata within the State, it is extensively pervaded by the system of cleavage planes, already mentioned as traversing the rocks below it in the series. These sometimes so efface all traces of the dip, as to compel the observer to resort to a careful scrutiny of the position assumed by the shells and other flattish bodies, whose larger diameters will commonly be found in the plane of the stratification. The average inclination to the horizon of the cleavage planes is about 50°, their direction being to the south-southeast, or south.

An attention to these features of structure and stratification will prove important in all cases where quarries are to be opened in this formation.

Organic remains.—It not being consistent with the plan of the present work to offer a series of engravings of the several fossiliferous formations of the State, I must content myself with indulging the hope of doing justice to this interesting subject through the medium of a different publication.

Superficial Deposits.—A somewhat curious deposit of coarse heterogeneous diluvium, cemented into a true conglomerate by the infiltration of carbonate of lime, occurs in a bed of some extent, on the western side of the Flatkill, not far above its mouth, resting immediately under the escarpment of the limestone. The calcareous matter has acted so as to agglutinate the coarse gravel swept to this point from the valley of the Flatkill and from the flank of the adjacent mountain.

The obvious identity as to mode of origin between many rocky conglomerates of the secondary periods, and masses such as this of relatively modern date, in which we behold unequivocal evidence of the short duration and violence of the action by which the miscellaneous debris from the adjacent rocks was hurled together, will aid us, when adverted to again, to understand the nature of the circumstances that gave rise to the patches of calcareous conglomerate which form the uppermost deposit of the middle secondary strata, immediately at the southeastern base of the Highlands.

ECONOMICAL GEOLOGY.

The purer varieties of the limestone of this formation produce, by burning, a lime in no respect inferior to that derived from Formation II., either for building purposes or for agriculture. The numerous beds of *magnesian limestone* furnish a source for *hydraulic cement,* which may, at any future day, where circumstances shall warrant it, be manufactured along the Delaware at a very small expense. It is this same rock, in its range to the northeast, which has for some years past, at Rondout, near the Hudson, yielded a superior cement at a low price, and in large amount.

Travertine occurs in two or three localities in Sussex, at the base of the ridge formed of this limestone stratum. The water percolating through the rock, carrying with it only the carbonate of lime and leaving undissolved the oxide of iron, silica, and other impurities of the stratum, must of course, in depositing its calcareous particles, produce a material of great purity. This deposit, called *travertine,* is usually in the condition of a yellowish, porous, concretionary limestone, which burns into lime with great facility, and yields a product of extreme purity and whiteness. It usually collects near the base of limestone rocks, where copious springs, highly charged with the calcareous matter of the stratum, enter moist meadows or swampy grounds. It is of two kinds, concretionary or stony, and pulverulent. The first is well adapted for making into lime, or, when procurable in sufficiently large blocks, forms a good building stone. The latter kind is often beneficially applied to the soil, being identical, in fact, with the pond or swamp *marl* already spoken of.

The *travertin*, or *calcareous tufa*, which is another name it bears, exists in both these varieties, on the Little Flatkill, about two miles southeast of Dingman's Ferry, being deposited a few hundred yards from the base of the Limestone Hill by a small rivulet. A similar collection of this material occurs nearer to the river side, a little above the ferry; and traces of its existence, though in rather small deposits, are not unfrequently noticed along both bases of the ridge for a distance of several miles.

Subjoined is an analysis of the travertin deposit, as found near Dingman's Ferry.

Composition.—In 100 parts:

Carbonate of lime, - - -	93·53
Carbonate of magnesia, - -	0·15
Alumina and peroxide of iron, -	0·42
Insoluble matter, - - - -	4·24
Organic matter, moisture, and loss,	1·66
	100·00

The position which the limestone belt holds in relation to the valleys of the Delaware and the Flatkill, enables the farmers of this favoured region to avail themselves of its fertilizing treasures, throughout its whole range through Sussex, as it is nowhere more than two or three miles from the two cultivatable tracts which border it. But notwithstanding that the beneficial action of lime on the soils along the river, and on the more gravelly lands of the Flatkill and its adjacents hills, has been long admitted by experience, there still exists on the part of many farmers, a singular indifference to this most important agent in agriculture.

Of the Circumstances which attended the Production and Elevation of the several Appalachian Rocks above described.

To comprehend fully that succession of actions which gave to the northwestern side of New Jersey its present symmetrical geology, would require us to go aside into some of the adjoining States, where many of the phenomena essential to the inquiry are best beheld, and to take more ample latitude in some descriptions of a speculative kind, than is compatable with the design and scope of the present work. I shall restrict myself, therefore, in this place to a concise examination of a few points only, connected with the origin and present position of the Appalachian rocks.

The previous descriptions embracing but the five lowermost members of the series and a subdivision of the eighth in the ascending order, it is necessary for the discoverer to extend his researches into the adjoining State of Pennsylvania to behold the rest of that enormous group of strata, whose elevation from the bed of what I have ventured to term the Appalachian Sea, gave to a large part of the eastern half of our continent nearly its present configuration.

He will then perceive, in the first place, two important formations, absent from the series, as it is developed in Sussex and Warren, but of great thickness and vast range in other parts of the Appalachian chain. These occupy a geological position between the top of the red shale and sandstone rocks, Formation V., and the bottom of the fossiliferous limestone of Formation VIII. The lowest of these, Formation VI., is a bluish limestone, very analogous in aspect and composition to that which ranges between the Wallpack Bend and New York. The next, Formation VII., whose true place, when all are present, is between these two limestones, is a coarse white sandstone, of very distinctive features.

Above the fossiliferous limestone of the Wallpack Bend, or lower member of Formation VIII., rest the olive and brownish slates of Formation VIII., forming a stratum of great thickness, which extends over a belt of many miles in breadth northwestward from the Delaware.

Pursuing the same ascending order, and tracing the rocks in the same northwest direction to the Coal Measures of the Wyoming basin, we meet next with the red shales and argillaceous red sandstones of Formation IX.

Overlying these are the white and gray siliceous sandstones composing Formation X., then another series of red shales and soft argillaceous red sandstones, constituting Formation XI.; and upon these are the coarse quartzose conglomerates of Formation XII., surmounted by Formation XIII., or the anthracite coal measures. This last formation, or its equivalent, the bituminous coal measures further west, occupies the highest place in the series of our older secondary or Appalachian rocks.

The several members of this multifarious group of strata give evidence, from their mutual parallelism, to which there is but the one local exception in the unconformable contact near the Hudson between Formations III. and IV., that they are the results of one strictly continuous series of sedimentary actions.

Though the chemical agencies which precipitated the limestones, and the various currents which introduced into the bed of the same great sea the mechanically suspended materials of the land, gave place to each other in frequent alternations, or underwent, from time to time, a total change, yet do we never find those geological proofs which would indicate an interruption in this prodigious sequence of deposits. Commencing in the remote period, which also saw the accumulation of the *silurian* strata of Europe, their precipitation, unlike that of the latter, was continued, unarrested by any widely influential physical revolutions, to the close of that remarkable epoch which witnessed the exuberant vegetation of the *coal;* whereas, in many portions of Europe an interval of unascertained duration must have elapsed between the elevation of the silurian deposits from their oceanic bed, and the beginning of the new order of things which brought together the materials of the great carboniferous formation. In the region of the Appalachian rocks no pause occurred in the train of sedimentary actions by the elevation and resubmersion of any part of the vast secondary sea. We therefore find, in confirmation of the other proofs of the absence of such revolutions during the accumulation of the Appalachian strata, that the fossils, the remains of the organic races of that sea, and its shores, exhibit a gentler gradation in the changes which they have undergone as to species, comparing them in the different formations of the series, than is presented when we compare the silurian and carboniferous fossils of Europe.

The conglomerate character already stated, as belonging to certain portions of the Kittatinny limestone, would seem conclusively to imply, that perfect regularity or quiescence of action did not prevail during the second epoch of the Appalachian period. And the fact of the superposition of the sandstones of the Shawunkunk Mountain *unconformably* upon the slates of the Kittatinny Valley, near the Hudson, is an evidence of another and seemingly more extensive disturbance, terminating the third epoch. To the turbulent interval which immediately resulted and brought together the coarse siliceous materials of the fourth formation, succeeded the relatively tranquil eras, as evinced by the nature of their strata, of the fifth, sixth, seventh, eighth, and ninth rocks of the series; then followed evidently two epochs of widely diffused agitation, along the Appalachian shores, the tenth and twelfth.

The heterogeneous nature of the conglomerates visible over an immense space along the mountain chain of the middle and southern States, goes plainly to establish the extensive changes in the physical geography which were taking place, in preparation, as it would seem, of that wholly new state of the surface, which so clearly characterizes the last and most striking interval of all, the *epoch of the coal.*

It is not a little curious, as casting additional light on the occurrence of a movement of elevation in the region of the Kittatinny Valley, at the close of the third epoch, that the rounded fragments of the slate of Formation III., and of the chert of Formation II., mingled with the quartz pebbles from the primary rocks still further east, occur in considerable abundance in both of the higher conglomerates, but especially in that which composes Formation XII., encompassing all the anthracite and bituminous coal fields. These fragments of the secondary rocks suggest this inference, inasmuch as they show that part at least of the slate and limestone formations had already been lifted out of their parent waves, and that the rocky strata of the land were exposed to the denuding agency which broke and rounded them into pebbles, to form a portion of these later conglomerate deposites.

As the conformability of the Kittatinny sandstone to the slate is presented throughout their whole great range, across New Jersey and Pennsylvania, and is only locally interrupted in New York, the inference seems just, that much of the Kittatinny Valley continued, at least to a late date in the Appalachian period, beneath the waves. But the geological phenomena of the primary chain southeast of the valley, go to show, with equal force, that from that quarter probably came the principal portion of the fragments of Formations I., II., and III. These, rounded by attrition while on their journey, now constitute an interesting part of the pebbles of Formation XII.

Respecting the precise geological dates of *all* the great anticlinal axes, the results of the enormous elevatory actions which have upheaved the Appalachian strata from out of their ancient sea and given them their present inclined positions, it would be idle to speculate in the present imperfect state of our information. But the whole evidence yet collected on the subject, manifestly leads us to this striking generalization, namely, that one great and general disturbance of the strata terminated the epoch of the coal. Comparatively sudden, and immeasurably more energetic than those that preceded it, it produced the almost simultaneous elevation of the whole Appalachian chain, and was attended by a commensurately violent denudation, from the abrupt and tremendous drainage of the ancient Appalachian sea. There arose, uplifting with them a vast belt of strata, the nearly innumerable anticlinal axes of our Appalachian rocks, inclining and folding, and breaking these into all their present irregular and contorted attitudes.

CHAPTER III.

OF THE MIDDLE SECONDARY ROCKS.—GEOLOGY OF THE COUNTRY BETWEEN THE BASE OF THE HIGHLANDS AND A LINE JOINING TRENTON AND NEW BRUNSWICK; ALSO, OF THE GREEN POND MOUNTAIN.

General Description.—In the two preceding chapters, having treated in detail the geological features of the primary and the lower secondary rocks, we propose in the next place to describe the *middle secondary strata,* embraced principally within the third and remaining district of the northern half of the State.

In general aspect and composition, this group of rocks is one of the most uniform and well marked in the country, and in detailing its characters as they are beheld in New Jersey, we shall be describing, in fact, the prevailing geological structure of the whole belt, from the Hudson to North Carolina.

The formation consists of dark reddish-brown sandstone, almost invariably argillaceous, of soft crumbly brown shales and coarse conglomerates, the latter frequently of very heterogeneous composition. The prevailing, we might say the almost invariable direction of the dip of the strata is towards the north, at angles varying from 15° to 25°. The lower beds, or those which show themselves along the southern edge of the tract, consist most frequently of rather coarse sandstones alternating with red shales, the sandstones being formed of somewhat angular fragments of quartz, felspar, and other ingredients of the neighbouring primary rocks, cemented by a paste of brown argillaceous matter. The central parts of the series consist more exclusively of brown shales and brown argillaceous sandstone, while the uppermost beds, occurring along the northwestern margin of the formation, have frequently the character of coarse conglomerates, made up of pebbles derived from a very great variety of rocks, chiefly those which occur at the base or on the sides of the adjacent primary hills of the Highlands. Where a large proportion of the pebbles are of limestone, and the cementing red earth which unites them contains an adequate quantity of the same material, the rock possesses the character of a marble, being susceptible of a good polish, and resembling certain highly variegated breccias.

Though this conglomerate constitutes the uppermost member of the red sandstone group in various places, both in New Jersey and Pennsylvania, there are other neighbourhoods, for example, near Bainbridge, on the Susquehanna, where it would seem rather to occupy a position at the base of the series. All these rocks of the middle secondary date, of which the argillaceous red and brown sandstone is the predominant and characteristic variety, appear, from numerous geological indications, to have been produced at a period subsequent to the elevation of the lower secondary strata, including the coal deposits. They seem to have originated in a long narrow trough, which had its source as far south at least as the eastern base of the Blue Ridge in Virginia and North Carolina, and which probably opened into the ocean somewhere near the present position of the Raritan and New York bays. Their materials give evidence of having been swept into this estuary, or great ancient river, from the south and southeast, by a current producing an almost universal dip of the beds towards the northwest, a feature clearly not caused by any uplifting agency, but assumed originally at the time of their deposition, in consequence of the setting of the current from the opposite or southeastern shore.

Numerous ridges and dikes of trap, some of them many miles in length, traverse the area occupied by this formation in New Jersey. The date of their appearance at the surface was manifestly subsequent to the deposition of the red argillaceous strata through which they have burst, overflowing, while in the melted state, the adjacent beds, and greatly altering their texture, colour, and mineral aspect.

In what exact period during the secondary ages of the earth's geological history, this widely-diffused series of sedimentary strata, and their accompanying igneous rocks, originated, we are at present unable to determine with strict scientific precision, but we are not without data for a somewhat satisfactory approximation.

The organic remains hitherto discovered are extremely few, and the evidence they afford is not sufficient to establish within near limits the era to which these strata should be referred.

They consist merely of a few rather imperfect relics of one or two species of *fishes*, some indistinct impressions of *fucoides*, or other aquatic vegetation, and occasional thin bands of a *ligniform coal*, in which the fibrous structure, apparently that of the wood, is traceable. The other organic remains, particularly of the fishes, imply a date somewhere intermediate between that of the coal and that of the greensand, and indeed suggest it as probable that the deposition of these beds commenced at an early period after the elevation of the carboniferous and other strata of the Appalachian series. That they are not so recent as the *greensand* or *newer secondary* strata of the State, is proved by their passing *unconformably* beneath that group, along the whole of their common boundary, from near Trenton to the Raritan river, and that they are more modern than the coal is, I think not less conclusively shown by their reposing unconformably, and without signs of disturbance, upon the lower members of the Appalachian rocks, in districts of the country where the uptilting of these, and of the carboniferous strata at the top of the same series, has obviously been contemporaneous.

A remarkable feature in the stratification of the whole of this red sandstone belt, is the almost invariable inclination of its beds to the northwest or north, towards the base of the Highlands, where the older secondary strata are to be seen in many places with a steep southeastern dip, passing beneath these newer rocks, which therefore abut against them in the opposite direction. Had any portion of these red rocks been produced at a period *previous* to the last, and incomparably most violent disturbance, which shook the great Appalachian basin, and which originated most, if not all, of the principal axes of elevation in the Highlands and the region to the northwest, laying bare the coal and all its attendant rocks, it is extremely difficult to conceive how they should have remained unaffected in their gentle northwestern inclination.

Later, therefore, than the carboniferous rocks, and earlier than the greensand, the most appropriate title claimed by this group of strata, would seem to be that of the *middle secondary series.* Though they present an obvious analogy in general aspect and composition to the new red sandstone rocks of Europe, and may in fact have originated somewhere about the same epoch, yet I much prefer the above designation in the present stage of geological research, because the other name* involves the notion of an identity of age, which, from the singular paucity of organic remains in the American group, may probably never be susceptible of demonstration.

The whole middle secondary series, even where we find it, as in Pennsylvania, presenting its most varied composition, is divisible strictly into not more than three separate formations, the lowermost and uppermost of which are conglomerates, while the middle one, the main body of the series, is composed of the ordinary red sandstone and red shale. In New Jersey, we find the whole properly classified to embrace but the two upper of these divisions, the red sandstone portion, and the uppermost conglomerate, usually calcareous.

Adopting, in conformity with our general plan, the ascending order, we shall therefore describe in the three following sections:

I. The red argillaceous sandstone formation.

II. The variegated calcareous conglomerates.

III. The trap rocks intruded among and overlying both of these deposites.

SECTION I.

Of the Red Argillaceous Sandstone.

Geographical Range.—The southeastern margin of the red sandstone formation coincides, from the northern State line to the mouth of Newark bay, with the eastern boundary of the State. Emerging from beneath the range of trap rocks called the Palisadoes, on the west shore of the Hudson, it skirts the river and its bay the whole distance, in fact, from Stony Point, in New York, to the outlet of Newark bay, called the Kills, or Killvan Kiehl. Between this spot and Perth Amboy, the edge of these rocks crosses Staten Island.

From Perth Amboy, we trace it along the north side of the

* Employed by Professor Hitchcock, for the corresponding rocks in the valley of the Connecticut river. See Report on the Geology of Massachusetts.

Raritan river, which it crosses nearly opposite Lawrence's brook. Its course thence is along this latter stream for several miles, until it is interrupted by a prolongation from the ridge of trap rock which passes south and east of the Sandhills. On the south of this belt of trap, the sandstone is again seen near the head of Heathcote's brook, from whence it takes an almost westerly course to Kingston. Here its margin deflects south, keeping a little to the southeast of the Raritan canal, to the head of the Shipetaukin swamp, the northwestern edge of which it pursues nearly to the junction of the Shipetaukin with the Assunpink, from whence to the Delaware river, a course of about five miles, it follows the northwest border of the Trenton belt of the primary strata.

The northwestern border of the formation, commencing at the State line, pursues for several miles the course of the Ramapo river, in contact with the primary, until it is fringed by a short narrow belt of the overlying calcareous conglomerate, east of Pompton. From this place, its route is again along the primary strata, by the base of the Pompton Mountain to Montville, where it is a second time overlaid on the north, by a small tract of conglomerate.

From Montville we follow it, abutting against the primary at the base of the Trowbridge Mountain, to Mendham Valley, where it is interrupted for a narrow space by a belt of the limestone of Formation II. of the older secondary series, which it partially overlaps on its eastern side from about a mile west of Mendham to Pepack. From this point its course is to the Lamington river, and it is for the third time covered on its northern side by the calcareous conglomerate which borders it in a nearly continuous belt, passing New Germantown, to a spot nearly north of Lebanon, on the turnpike. Curving around the base of a small hill of trap, and another of gneiss, it next skirts the edge of the tract of limestone of the south branch, where its range is nearly westward along the limestone, by Perryville and Pattonburg. In the neighbourhood of the Old Hickory Tavern, it meets the gneiss at the foot of the Musconetcong Mountain. About two miles beyond that spot, about the head of Milford run, it is once more, for the fourth time, bordered by the superior beds of the calcareous conglomerate, lying here at the foot of the Musconetcong Mountain. Following the southern edge of this narrow belt for about six miles, it finally quits the State by crossing the Delaware river, near the mouth of Gallows run.

Composition and Structure.—While the prevailing and distinctive rocks of this formation are a dark brownish-red sandstone, and a soft and friable argillaceous red shale, it presents a considerable diversity, especially among its lower beds, both as respects its aspect and composition. In some parts of the series, we find the argillaceous matter so predominant, that certain beds assume almost the character of a homogeneous consolidated clay, of a brown or dark purple colour, in which the laminations are hardly discernable. On the other hand, the rock is not unfrequently composed mainly of sand, cohering into a true arenaceous sandstone, by a slight amount of clay, usually red, but sometimes white. In these cases it often contains a notable quantity of mica, and is then a red flaggy sandstone, easily divisible in the plane of stratification. In the inferior part of the formation, beds of rather coarse and heterogeneous sandstone passing into conglomerate, are not unusual. But the pebbles rarely make up the chief part of the mass, and the larger kinds are somewhat sparsely scattered, in the midst of what ought rather to be termed a coarse and angular sand. The materials of these beds seem to indicate a derivation from the contiguous primary rocks, southeast of the formation, consisting principally of rather angular grains of quartz and felspar, the latter most usually passing by decomposition into clay or kaolin, together with a less proportion of mica, and a little of the red argillaceous matter so predominant in the formation. We sometimes find in the coarse conglomerates, besides the abraded fragments of the primary rocks, flattish pebbles of the red shale, which give to the rock a rather mottled aspect.

An accurate conception of the diversified contents of this extensive formation will be best conveyed by a somewhat detailed description of its several portions, as they are exposed along a section transverse to the strike of the beds. I shall select the district bordering on the Delaware river, where the series is more entire and better developed than in any other tract of the State, and treat of each natural division in succession as it presents itself in the ascending order. Commencing, therefore, with the lower margin of the formation, about one mile northwest of Trenton, we find a well marked belt of strata occupying a breadth of about two miles, between that point and Hill's Creek, its northwestern limit. This consists of conglomeritic sandstones of the kind above referred to.

The materials of this lower set of rocks are pebbles and grains of sand of the same minerals which compose the primary strata, upon the upturned edges of which these rest. The rounded fragments are from the size of coarse sand to an inch in diameter, and comprehend grains and pebbles of quartz, some of which are of the semi-transparent, partially opalescent kind, pretty abundant in certain strata of the gneiss. Associated with the quartz there is much felspar, white or yellowish, and partially decomposed; also, a small share of mica and a considerable quantity of hornblende. Throughout some of the strata there is a greater or less proportion of hydrated oxide of iron, dispersed in minute yellow specks. The decayed condition of the felspar, and the stains from the oxide of iron, impair to some degree the value of these rocks for the purposes of architecture. The dip of the beds is to the northwest about 20°. A want of parallelism in the planes of stratification, and some minor irregularities, interfere with the value of many of the quarries in this range, by preventing that uniformity of structure which building stone, for many purposes, must have. A good display of these rocks, in all their distinctive features, is to be witnessed in Dean's Quarry, a mile and a half from Trenton, upon the feeder of the canal. The same varieties show themselves on the Delaware and Raritan Canal, about six miles northeast of Trenton, where the beds agree in all particulars with these inferior strata along the Feeder.

Overlying these more heterogeneous rocks at the bottom of the formation, there succeeds a belt of a somewhat different character, having a breadth of about two miles, from Hill's Creek to the stream at Abner Scudder's. The prevailing rock is a coarse-grained pinkish sandstone, consisting of transparent quartzose sand, with numerous white grains or specks of somewhat decomposed felspar, and small flattish pebbles or flakes of the more argillaceous kind of red sandstone. The chief ingredient in this rock is siliceous sand, either transparent and white, or stained yellowish by oxide of iron. The predominant reddish colour of the rock is due to the minute particles and fragments of the red shale which it contains. The beds here described yield altogether the best building material upon the Delaware. The rock is pretty extensively quarried at the State Prison Quarry, Green's Quarry, and Hill's Quarry, and upon the opposite side of the river at Yardleyville. Its stratification is usually very regular, and it is easily wrought; and some of it seems capable, from its composition, of resisting decay from atmospheric sources. This and the next inferior group are discernible over a considerable range, pursuing a direction nearly parallel to the canal towards Princeton, beyond which they disappear beneath the overlapping strata of the upper secondary or greensand series, a little to the east of Stony Brook, and south of Kingston.

Between the stream at Scudder's, five miles above Trenton, and the small stream above the Alexsockin creek, near Centrebridge, the next extensive belt is embraced, occupying a breadth of many miles. The rocks of this portion of the formation are well exhibited near the Delaware, having been artificially excavated in numerous places to make room for the bed of the Feeder of the Raritan canal. They consist principally of those varieties which form the usual and predominant materials of the whole formation both in New Jersey and the adjoining States. The ordinary species is a rather fine-grained brown or red argillaceous sandstone, varying between soft argillaceous shale and hard arenaceous and micaceous sandstone.

The colour, though most usually red, is sometimes dull bluish, or greenish. Much of the rock exhibits cross joints, in great number and regularity, and gives proof of its having been somewhat consolidated by an elevated temperature, if we may judge from its compactness, its baked aspect, and the ringing sound which it returns when struck, and from the extent to which it is divided by these cross joints. With one single exception, in its whole breadth along the Delaware the *dip* is invariably to the northwest, at about the usual inclination of nearly 20°. The exception referred to, occurs between Alexsockin creek and the ridge of trap about a mile above it, where the dike has burst up through the stratified rock and thrown it out of its usual inclination, and caused it to dip to the south and southeast. This disturbance of position does not, however, prevail over perhaps more than half a mile; and it is singular enough, that adjacent to and between the three other bold ridges of trap which cross the strata nearer Trenton, no similar displacement of the prevailing dip has taken place. I may mention in this place, the same interesting fact in connection with nearly all the principal outbursts of trap rock in the State, which produce no disorder in the original attitude of the strata, though conclusive evidence will be offered presently, that the trap must have issued through the stratified rocks after their deposition. The stratified sandstone rises almost to the top of Goat Hill on its eastern slope, dark and altered in texture, but preserving its ordinary dip to the northwest.

Upon the northwest side of the large ridge of trap called Goat Hill, there have arisen changes in the mineral contents and structure of the adjacent strata which are highly curious and important when regarded in a scientific point of view. I allude to the existence in the sandstone of a profusion of nodules and crystals of *epidote*, *tourmaline*, and other minerals hardly ever found but in igneous and volcanic rocks, but caused here by the heating influence of the vast mass of trap, as it issued from the interior, in a molten state. When treating of the trap rocks of the red sandstone region generally, I shall dwell more at length upon these interesting mineralogical changes.

This broad tract of argillaceous red sandstone and shale is intersected in its range to the northeast by the valley of the Raritan, where its beds are finely exposed to observation the whole distance from Perth Amboy to Boundbrook. To the northeast of the Raritan, nearly the whole of that part of the middle secondary region included between Staten Island and the Hudson on the east and the trap ridges on the west, consists of this division of the formation. Resting upon this rather uniform portion of the series, we find near the Delaware another somewhat more varied set of strata extending between the small stream below Centrebridge and the Wickhecheoke, about two miles above its mouth. They consist of a series of alternating red sandstones and coarse yellowish conglomerates, occasionally divided by narrow beds of the softer argillaceous red shale. These conglomerates resemble closely those which occupy an inferior position in the formation, and which appear within three miles of the gneiss at Trenton. A large portion of the pebbles, which frequently are half an inch in diameter, consist of quartz and felspar; the latter occasionally in a decomposing state. With these are mingled flatter pieces of red shale, the whole being bound together by a small amount of ferruginous matter acting as the cement. Much of this latter rock is merely a coarse sandstone, and in the vicinity of Centrebridge, and at intervals for a mile and more above, it occurs of a quality excellently fitted for architectural uses, having been fully tried in the bridges upon the upper end of the Feeder.

This rather arenaceous part of the formation, extends nearly to the mouth of the Lockatong, if we follow the bend of the river. Commencing a little above that stream, we meet with an elevated table-land, the surface of which is about four hundred feet above the Delaware. At the valley of the river this is about three miles wide, but it expands towards the northeast, until it reaches the valley of the South Branch of the Raritan. Its lower edge is traced by a line, commencing at Bull's Island, and passing west of Sergeantsville and Flemington. Here it bends to the north to follow the South Branch to within three miles of Clinton. The upper or northwestern limit is less clearly defined, as the highly indurated strata pass, by nearly insensible shades in some places, into the less altered rocks of the tract to the northwest. An approximation, however, to its boundary, will be had by drawing a line from a little below Smithsville, on the Delaware, through Pittstown, to near the south branch of the Raritan.

Throughout this area, the rock preserves a moderately uniform external character; being a highly indurated altered shale and sandstone, the prevailing colour of which is a very dark dull blue, sometimes a deep gray, and sometimes an olive-green. It has a great tendency to split into rhomboidal fragments, with a somewhat splintery fracture; and certain varieties yield, when struck, a clear ringing sound, which has procured it the name of clinkstone in the neighbourhood.*

The tract where this rock exists, goes in Hunterdon county under the name of the Swamp, owing to the wet character of the prevailing soil. Little or no true trap rock is visible in the dis-

* True clinkstone, or phonolite, is a felspar rock of the trap family, usually fissile, and is sonorous when struck; whence its name.

trict, except along the southern border, where, as for example, northwest of Flemington, it may be seen following the direction of the altered strata. It is likely that numerous dikes of trap do exist, especially next the southwestern limit of the table-land, but concealed beneath the soil, or perhaps existing as narrow injected veins, not reaching the surface of the rock. The regular stratified structure and northwestern dip of the strata seem, however, not to have been changed, even where the rock appears to have undergone the most decided alteration in all its external features from the extremely elevated heat, to which it has evidently been subjected since its original deposition. There is a frequent alternation of the highly indurated beds with others, exhibiting but little departure from the commoner features of the red shale and sandstone.

In the range of country northeast of this tract, the strata, except where intersected by some trap ridges, hereafter to be mentioned, seem to have sustained no corresponding alteration of texture and colour; nor are the changes which appear in the rock for a small distance from the trap which occurs in that region, of precisely the same nature as witnessed in the strata of the Swamp.

The next belt of the formation which we meet with in our progress northwestward, commences at the verge of the altered or indurated rocks of the *Swamp*, and extends nearly to the Nischisakawick creek.

In a part of the series the rock is a compact fine-grained, but somewhat argillaceous, red sandstone, splitting into regular flagstone ayers, which render it a convenient building stone, for which purpose it would seem to be, in other respects also, well adapted. Its colour is a brighter red than that which distinguishes the set of beds that next overlie it.

Between the upper border of this more arenaceous tract, and the southern edge of the variegated calcareous conglomerate, one mile north of Milford, the predominant material is a very argillaceous sandstone, with much soft friable shale, the whole being of a deep reddish-brown colour. This extends over a width, measured along a straight line parallel with the river, of about four miles. The Nockamixon cliffs, upon the Pennsylvania side of the river, exhibit a fine display of these upper beds. The angle of dip to the northwest is very gentle, though considerably greater than it seems to be from looking at the face of that precipitous escarpment, the line of which is not sufficiently in the direction of the dip to make the full degree of inclination apparent. The chief part of the beds in this portion of the series are apparently arenaceous enough to furnish a very good sandstone for the ordinary purposes of architecture.

In other parts of their range, these beds, lying immediately below the conglomerate, are generally of the composition exhibited near the Delaware. Near Pompton, however, where the very top only of the series is exposed, the red sandstone and shale occur in somewhat different features. In a quarry near that place, the red sandstone may be seen of its ordinary character, alternating in thin beds with a very heterogeneous fine-grained conglomerate, made up of a great variety of materials, and presenting, as it were, a miniature of the variegated conglomerate above it. These sandstones are parted by very thin layers of the soft shale, almost in the state of a compressed red clay. At the dividing surface of the harder and softer layers, may frequently be found organic impressions of a class evidently belonging to some of the older aquatic tribes of the vegetable kingdom, apparently fucoides.

Upon these sandstones there rests a thin bed of a gray siliceous slate, very schistose, though of too coarse a texture to warrant its being usefully applied. Besides the sand in its composition, there is a moderate proportion of mica. Its laminæ coincide with the planes of stratification; the thickness of the whole mass is inconderable. The variegated conglomerate of this neighbourhood rests in a conformable position upon this slate. All these rocks dip to the northwest.

Having in the foregoing sketch described the several subordinate members of the red sandstone formation, as we find them developed along the valley of the Delaware, both in their ordinary condition and in their more or less altered state as affected by the neighbouring trap, let us in the next place follow some of the more continuous of these, in their range across the State towards the New York line. In consequence of the modification of texture which some of these rocks have received, by the numerous outbursts of trap, by which the northwestern half of the region, more particularly, has been invaded, it becomes impossible to trace with any accuracy the limits of the several subdivisions, even presuming them all to have been once continuous strata ; I shall, therefore, merely attempt an account of a number of localities, referring the beds described as nearly as practicable to their respective belts, as seen along the Delaware, and in doing this shall observe the usual ascending order, proceeding from the southeastern members of the formation to the northwestern.

Advancing from the Delaware towards the northeast, the first or lowest beds, reposing on the gneiss rock near Trenton, retain their coarse heterogeneous composition until they pass beneath the marshes of the Shipetaukin creek, and the canal south and east of Princeton, beyond which they are buried by the overlapping white sands and clays of the upper secondary series. On the declivity, or low escarpment, which bounds the valley of Stony Brook, near Princeton, about a mile southeast of the town, we find, near the canal, a gray arenaceous sandstone, which appears to constitute the upper part of this division, being overlaid by the more argillaceous and reddish group of beds next north of it. The rock at this place has been quarried, and supplies an excellent building stone. The main edifice of the college, and several recently erected edifices, in Princeton, are constructed of it.

The next belt, extending on the Delaware from Hill's creek to Scudder's creek, crosses the canal near Kingston. Here, and along the southern side of the Sand Hills, it encounters the trap ridge, prolonged from Rocky Hill, its beds undergoing some interesting modifications of structure, which will be more fully described when we come to treat of the trap rocks specially, and the changes induced by them.

Viewed comprehensively, the next subdivision of the formation should embrace the entire series of argillaceous red sandstones and shales, included between these arenaceous rocks and the calcareous conglomerates which overlie the whole, for it is obvious that some of the varieties separately described as occurring near the Delaware, owe their peculiar texture to igneous actions of a merely local nature. Such is the case with the thick group of beds composing the tract called the Swamp. Other subordinate strata, like the coarse sandstones near Centrebridge, would appear not to have a sufficiently continuous range across the State to make it necessary to carry out the subdivisions of the formation, as they were detailed when describing the rocks along the Delaware.

Convenience, however, recommends that we consider separately the wide belt of argillaceous rocks, embraced between the arenaceous ones of Scudder's creek and the still coarser ones of the vicinity of Centrebridge.

The inferior margin of this zone of strata, after passing by Princeton, is prolonged to Lawrence's brook, where it constitutes also the southeastern edge of the whole middle secondary region, being overlaid unconformably along the southern side of that stream by the lowest of the upper secondary series. Beyond the mouth of Lawrence's brook, the same rocks extend every where to the eastern boundary of the State, fringing the western shores of the Raritan, of Staten Island Sound, and of the Hudson river.

The upper or northwestern margin may be traced from the stream east of Centrebridge, past Middlebrook, on the Raritan, and thence along the eastern base of the easternmost principal ridge of trap. The occurrence, in the neighbourhood of Patterson, of a coarse siliceous sandstone and conglomerate rock resembling that near Centrebridge, and the occasional appearance of a similar material at points adjacent to the line designated, seem to mark this as a boundary not altogether conventional. Within the two limits thus traced, the almost invariable aspect of the rock is that of a brownish red shale, including beds of a more or less argillaceous and micaceous sandstone of a somewhat lighter tint, some localities of which furnish good building stone and flag-stone.

Between the Delaware and the Raritan rivers the unaltered varieties of the rocks of this belt are seldom quarried, and present but few features of either economic or scientific interest.

The altered portions, important in both these points of view, will be described somewhat in detail when allusion is made to the several ranges of trap with which they are connected along the Raritan, where, as already mentioned, occur fine opportunities for studying this portion of the formation.

At New Brunswick, the dip and structure of the red shale are beautifully exposed on the bank of the canal for a mile above the town, exhibiting the nearly parallel planes or laminæ of deposition, dipping with extreme uniformity to the northwest, at an angle of about 15°. Some of the more argillaceous layers contain a considerable amount of the carbonate of lime in small disseminated crystals, also in the form of hollow nests, lined with crystals forming bands of two or three inches thickness and of thin seams or plates of satin spar, filling the fissures of the shale. The planes of lamination are often marked by thin bands of a light bluish-green calcareous shale, which owe their peculiar colour to the iron so copiously present in the formation, usually as a peroxide, but in these instances reduced to the condition of protoxide. These bands are erroneously supposed to contain *copper*.

Northwestward, as far as Boundbrook, the stratum retains very nearly the aspect which it exhibits near New Brunswick. The only fact of interest is the gradual declension in the angle of the dip towards the northwest. Between Boundbrook and Middlebrook the rocks are well exposed on the south side of the river by the excavations made for the canal. Here the dip exhibits an unusual direction, being towards the southeast, but at an angle not exceeding 5°. This change in the inclination of the strata is not merely local, but prevails over an area of several miles to the northwest and west, the whole way to the vicinity of Pepack in the one direction, and the junction of the north and south branches of the Raritan in the other. Tracing the dip along the Millstone river, in a succession of fine exposures from Griggstown towards its mouth, we perceive it to be to the northwest, but gradually diminishing until we approach the Raritan, where it becomes horizontal, and soon after assumes the contrary direction, as beheld in the vicinity of Middlebrook. The line of no dip or synclinal axis is traceable continuously from Boundbrook, taking a west-southwest direction through Millton, or Rogers' Mills, to Flaggtown. Along the southeastern base of the ridge of trap, which extends from the Bridgewater Copper Mine towards Pluckemin, the southeastern dip is towards the hill obliquely, indicating that it is not a result of the protrusion of the trap, which, throughout the region, has usually exerted very little influence in disturbing the direction assumed by the red sandstone formation at the time of its deposition.

An explanation of the probable cause of the unusual dip assumed by the strata in this quarter will be attempted under another head, while discussing some of the physical circumstances which attended the formation of this whole series of middle secondary deposits.

Extending our observations northeast of the Raritan, we meet with few features in the geology of this belt of the red sandstone tract deserving of a special description, until we reach the neighbourhood of Newark. The direction of the dip, wherever this can be noticed, is towards the northwest at an angle rarely exceeding 15°. Between Boundbrook and Scotch Plains, along the valley of Greenbrook, so general is the covering of diluvial matter for three or four miles east of the base of the first trap ridge, that it is impossible to ascertain whether the synclinal axis passing from Flaggtown to Boundbrook is prolonged in this direction. The existence of a regular northwestern dip in the strata between the first and second trap ridges, at points north of Plainfield and Scotch Plains, renders its continuation far to the northeast of the Raritan very improbable.

The surface of the formation is covered throughout nearly the entire distance between Rahway and Plainfield, by a deep sandy loam, imbedding occasionally loose fragments of sandstone and some rolled masses of primary rocks derived from the Highlands. A level, sandy plain, stretching for some miles in length, from northeast of Scotch Plains to southwest of Plainfield, exhibits a succession of fine farms, and several thriving villages. An abundance of excellent water is usually procured by descending about fifteen or sixteen feet into the diluvial sand and gravel.

The country included between Rahway, Elizabethtown, and Newark, on the east, and Scotch Plains and Springfield, on the west, is very similar in its general aspect, being rather level, with occasional gentle swells and undulations of the surface. The soil is a fertile reddish sandy loam, well cultivated. Boulders and loose fragments of rock are fewer on the surface here than a few miles further towards the northeast. Throughout much of this area the underlying rock is deeply covered.

Pursuing our course to the northeast, the sandstone is exposed in a quarry above the village of Jefferson, in the immediate vicinity of the trap rock, dipping to the usual quarter, the northwest, at an angle of between 12° and 15°. The main mass of the rock in the quarry is a dull red siliceous sandstone, of a uniform grain, having numerous interspersed specks of mica.

In the neighbourhood of Newark the more arenaceous variety of the red sandstone is moderately abundant, affording much good building stone. About half a mile north of the town quarries are extensively worked, giving a good exhibition of the composition and arrangement of the strata.

The rock here is for the most part a siliceous sandstone of a dull brownish-red colour, and an even grain. It contains a little mica. Alternating with the beds of sandstone are thinner layers of red, argillaceous shale, which soon disintegrates upon exposure to the air. In some of the lower beds are thin plates of carbonaceous matter, and a minute seam of a pure ligniform coal between one and two inches in thickness. The dip of the planes of deposition in this vicinity is about 10° to the northwest. Between Newark and Paterson the rock displays little or no departure from the usual character which it preserves further to the southwest in the same belt, being the usual mixture of red shale and more or less arenaceous red sandstone. Its dip is every where the same, or northwest between 10° and 15°: no change in this respect is perceptible as we approach the trap ridge to its west. Between East and West Bloomfield villages are some quarries affording a moderately good building stone. The rock is the common red sandstone of the region divided by thin interposed bands of red shale. It displays a northwest dip, the angle being 12°. In one of the sandstone beds there is seen a thin layer of coal, of a variety approaching to lignite.

Near the Passaic Falls at Paterson, the sandstone is seen under a considerable diversity of aspect, varying from a coarse conglomerate, containing numerous pebbles of white and reddish quartz, limestone, and other rocks, to a close-grained, siliceous sandstone, moderately well adapted for building stone. There are occasional interposed layers of red shale. This conglomerate and sandstone rock bears a near resemblance to that on the Delaware below Centrebridge, and would appear to occupy a corresponding position in the general series of beds which together constitute the red sandstone formation.

To the southwest of Paterson, at the Little Falls of the

Passaic, a sandstone of a somewhat different composition and appearance occurs on both sides of the river, though in the immediate vicinity of the trap dike of the second mountain; it preserves its almost invariable dip to the northwest, which is here at an angle of from 10° to 15°. This sandstone is of a very superior quality, both for the purposes of architecture and sculpture, and the quarries which have been opened furnish blocks of almost any dimensions. One of these quarries has been conducted under the direction of Mr. Thom, the celebrated sculptor, who has found in it a material extremely well adapted to receive the admirable delineations of his chisel.

From Paterson eastward to the Hudson, and northwestward to the New York line, the formation exhibits little or no departure from its ordinary type, as respects its composition, structure, and the direction and degree of dip of its planes of stratification.

The upper or northwestern half of the red shale and sandstone formation, extending on the Delaware, between the mouth of the Lockatong and the overlying conglomerate at Spring Mills, and between the first trap ridge and the foot of the primary hills in the country north of the Raritan, is nearly identical in composition with the belt already described; the chief departure from uniformity of structure in either district arising from the changes induced by the numerous ridges and dikes of trap to be presently considered. Adhering in this place to the plan proposed of presenting a brief account of the formation in the different portions of its range, by selecting a few characteristic localities where the rocks are plainly disclosed in their prevailing features unaffected by igneous agency, let us glance at the northwestern belt of the formation beginning as before at the end next the Delaware.

To the west of the wide area of altered shales, composing the tract called the Swamp, we find a zone of ordinary red shale and argillaceous sandstone, in the prolongation of the Nockamixon rocks on the Delaware. Between Evittstown and Mount Pleasant these strata are well seen under their usual type, dipping regularly and gently to the northwest. To the southeast and east of Evittstown an arenaceous variety of the sandstone affords an excellent material for architectural uses. Approaching Baptistown, the rocks begin to manifest, by a change of colour and texture, their proximity to the trap dikes of the Swamp.

From that neighbourhood northeastward this portion of the formation presents little that is worthy of record until we reach the eastern side of the Round Valley Mountain. About a mile southwest of the White Horse Tavern, and nearly opposite the curve of the Round Valley Mountain, there occurs a rather singular ridge of considerable elevation, extending southeastward from the trap. On the southwest of this long ridge the beds of the red shale have their prevailing gentle dip to the northwest, but immediately after crossing it towards the White Horse Tavern, there is a total change in the direction of the dip, which is to the northeast, at an angle exceeding 40°; the change is sudden and strongly defined. This ridge, apparently forming the axis of dislocation, extending southeastward from the curve of the Round Valley Mountain towards the Raritan, the angle of dip in the strata gradually diminishes as we proceed north, or towards New Germantown, assuming a more *eastern* inclination, and becoming, east of the Lamington river, the *southeastern* dip already spoken of.

In the valley of the Passaic river, east and south of the trap ridge, called Long Hill, the shale and sandstone, in many places, appear finely exposed for examination. They constitute an escarpment of some height on the southeastern declivity of the hill, rising nearly half way up the steep ascent, exhibiting great regularity of stratification, and an undisturbed dip to the northwest, at an angle of 15°, directly towards the trap in the body of the hill. In several spots along the base of this ridge the shale has sustained a change of aspect from the heating action of the trap. Being soft, friable, and, when wet, of a nearly black colour, it has given origin to a mistaken notion in the neighbourhood, that these strata contain *coal*, and hence many fruitless explorations have been undertaken here in search of that mineral. In fact, it is said a company was organized, and expended $1000 in digging and boring for *coal*. A little geological knowledge would have shown the absurdity of anticipating coal any where in this red sandstone formation.

On the eastern bank of the Passaic river, at a point about a mile and a half above Chatham, where the Morris and Essex Railroad crosses the stream, the red shale has been exposed to view in a quarry, from which the building stone for the viaduct over the river was procured.

Beneath several feet of alternating bands of lead-coloured and yellowish slate, lies a very extensive bed of compact red shale, in thick and solid layers. This mass has evidently been partially acted on by the elevated temperature of the adjacent trap dike of Long Hill to its west.

It is traversed by natural joints, generally several feet asunder, extending parallel with each other from northeast to southwest, separating the whole into immense blocks and tabular masses, which are readily cleft into pieces of any desirable size for masonry. In many places the laminæ of the rock are somewhat contorted. Towards the bottom of the quarry the material acquires more of the character of a sandstone. The dip is at an angle of 15° towards the west. On the same side of the Passaic, about a mile above Chatham, near a mill, the sandstone is again exposed to view by the erosive action of a small tributary stream.

At Lindsay's Mill, three miles southwest from Madison, denudation has exposed the rock in many places. It has the aspect of a thinly laminated shale, with layers of a bluish and yellowish slate, containing cubical crystals of *sulphuret of iron*. A yellowish ferruginous sandstone is also visible in one or two spots.

The indications at this place imply, that by removing the overlying shale, a good building stone, which is much wanted in this vicinity, might be procured. The dip in some places is slightly irregular, being in certain spots horizontal, and again being directed eastward at an angle of not more than 5°.

A deep diluvial bed of sand and gravel covers the plain from Morristown to the end of the ridge of trap, which extends northward from Green Village by Spring Valley; but west of this outburst of trap the sandstone appears. In the vicinity of New Vernon the red shale is often exposed, dipping generally at about 8° to the westward. South of the last named village the shale and sandstone display their ordinary features, although they show in some places traces of alteration from their proximity to the trap. The same remarks apply to the vicinity of Basking Ridge. East from this place, and northward from Long Hill and Green Village, there is an extensive level tract called the Great Swamp, consisting chiefly of meadow, the rocks here being covered throughout by a wide deposit of diluvium.

North of Plainfield, the red shale occasionally shows itself between the first and second trap ridges. A clay is found here of which good bricks are made. In the next little valley northeast of this, and still between the first and second belts of trap rock, and north of Scotch Plains, the red shale is well exhibited along the banks of the stream, presenting a low but regular escarpment in the hill side. About the middle of these beds of shale, and running parallel with them throughout the whole face of the rock, is a thin belt of *limestone,* a material of unusual occurrence, particularly in this central portion of the formation.

It is thinly bedded, in layers varying from an inch to six inches in thickness, constituting together a bed between one and two feet from top to bottom.

On the other side of the stream, in the northern face of a deep ravine, a similar, in all probability the same, bed of limestone is exposed for a considerable space. It is more massive than at the other spot, being a solid seam between two and three feet in thickness; above it and beneath it occurs the ordinary red shale, the whole dipping to the northwest, at an inclination of about 12°. The upper beds of shale along the whole valley, are here very regular, but in the bottom of the ravine above mentioned, the trap seems to have invaded the strata, inducing considerable confusion. Besides producing much alteration in the shale and sandstone, it has in places modified the limestone, giving rise to a mass of white semi-crystallized carbonate of lime. These unusual features, so easily understood by science, have led to several fruitless mining enterprises in this neighbourhood.

On the northwestern side of the mountain, near the road from a paper-mill, there is a quarry of slaty sandstone, furnishing an excellent flag-stone. It is also used for tombstones, being both neat and durable. It exhibits signs of having been baked by an adjacent dike of trap.

Following the course of the Passaic, from Chatham to the semicircular valley enclosed by the Hook Mountain, (laid down on the map as Towakow Mountain,) we pass over a wide and nearly level tract of almost uninterrupted *diluvium.* But in the recess of the Hook Mountain, the red sandstone sometimes appears along its southeastern base.

About one-third the distance from its eastern to its western termination, there is a quarry from which much good building stone has been procured, though the rock is rather thin bedded. Notwithstanding, that it is in almost immediate contact with the trap of the Hook Mountain, the sandstone appears in this place to have undergone very little change from igneous action, nor is the usual northwest dip disturbed.

West of the Hook Mountain, between Parcipany and Montville, and again at Montville, we find the red shale and sandstone formation retaining its prevailing aspect and direction of dip. At Montville, it is overlaid by a coarse heterogeneous conglomerate, composed of very loosely cohering fragments.

The somewhat diversified character assumed by the shale and sandstone, near its contact with the variegated calcareous conglomerate of Pompton, near Ryerson's, has already been described in sufficient detail. Beyond this last named point to the State line, these rocks are occasionally exposed, but with no peculiarities of composition or structure demanding from us any special description.

The district east of the Ramapo river, for several miles is extensively overspread with diluvial matter, imbedding numerous bowlders of primary rocks, the whole having evidently come from the elevated belt of primary hills and mountains, composing the broad chain of the Highlands lying to the west and north.

Variegated Calcareous Conglomerates.

Description and Geographical range.—This heterogeneous though well characterized rock, may be regarded as a distinct formation from the group of red shales and sandstones beneath it, being the result of a wholly different train of physical causes. It constitutes the uppermost member of the middle secondary series, overlying the red shale along its northwestern margin, not in a continuous belt, but in several insulated patches that range in one general line, near the foot of the primary hills. In almost every portion of its range, the materials of this rock are extremely heterogeneous, consisting of pebbles or water-worn masses of all sizes, from that of a man's head down to that of a small pea, belonging to most of the older formations discovered in the region. A large portion of this very motley mass is made up of variously coloured sandstone pebbles. Sometimes there is a considerable mixture of pebbles from the primary rocks; and in certain parts of its range, the stratum consists, throughout nearly the whole thickness, of pebbles of limestone, firmly cemented by a limestone paste. Usually, the cement or imbedding paste contains a sensible proportion of the materials of the red argillaceous shale of the stratum beneath. In fact, where the Baltimore and Ohio railroad crosses this rock in Maryland, the chief part of the cement is nothing else. This admixture of red matter in the rock in New Jersey is easily explained. The harder sandstones and the limestone have retained the fragmentary state, while the soft red shale has been reduced to powder or mud, by the violent action which brought together this vast mass of water-worn materials.

A large portion of the formation in its course across New Jersey, exhibits all the characters of the rock which forms the columns of the Hall of Representatives at Washington, and which has received the name of the Potomac Marble. The most northeastern locality of this rock which occurs within the State, is on the Ramapo river, near the village of Pompton. It is traceable in all its obvious features, in a belt of more than a mile in length, passing in the immediate neighbourhood of Ryerson's. Here its actual contact with the inferior sandstone formation was detected, and the conformability of the rocks clearly ascertained. Over the red sandstone rests a bed of rather thin siliceous slate, the upper portion of which is somewhat calcareous; and immediately upon this reposes the very close conglomerate containing a pretty large share of limestone pebbles. This occurs near the Ramapo, a mile to the northeast of Ryerson's. The dip of the whole is to the west, the angle being between fifteen and twenty degrees.

The conglomerate is seen again with the same dip about half a mile to the west of this, and contiguous to a ridge of gneiss, which appears to have caused some local displacement of the neighbouring strata. This is upon the border of the plain through which the Ringwood stream passes. It seems altogether probable that the difficulty of tracing the conglomerate more extensively in this quarter arises, first, from the irregularities in the direction of the strata, caused by the intrusion of the trap; and in the next place, from the western part of the formation resting beneath the deep covering of diluvium which forms these plains. At the spot last mentioned, the conglomerate was disclosed by some over-credulous miner in an excavation for silver ore, led astray by the occurrence of very minute crystals of yellow sulphuret of iron. The rock is nearly all limestone, and specimens which have been polished, prove exactly identical in character with the Potomac marble. The conglomerate is traceable along the side of the Ramapo river, near Ryerson's barn, where it has the same dip and general composition as elsewhere, though it is less calcareous.

The next place at which we witness unequivocal traces of the formation, is at the foot of the inclined plane, upon the Morris canal, at Montville. It there forms the abutments of a mill-dam, where it will be found to agree very strictly with the slightly calcareous variety which forms the lowest part of the stratum upon the Delaware. At Montville the pebbles are often very large, and consist principally of primary rocks and red sandstone, so that it would be useless to attempt burning it for lime, although a more calcareous layer may possibly occur nearer the top of the stratum, or which is the same thing, a little farther to the northwest, that being the direction of the dip of the stratum at this place.

Another interesting belt of this formation is that which skirts New Germantown upon its northwest, in a tract perhaps half a mile wide and several miles in length, extending nearly as far north as the Lamington river. At New Germantown it is an almost pure limestone, and is somewhat extensively used for making lime. The pebbles are of various shades of colour, blue, yellowish, and red, and much of the cementing matter is tinged red. It is susceptible of a high polish, and constitutes a beautifully variegated conglomeritic marble. The dip of the rock in this portion of its range, is somewhat various in direction, but at a uniform angle of about 20°. The usual diameter of the pebbles is about an inch, though many are much larger. They are not fully rounded, but occasionally exhibit edges and angles, though much blunted and worn, as if by attrition. The superposition of this rock to the red shale or sandstone series upon which the village of New Germantown rests, is very evidently shown in its vicinity. On the northwest side of the little valley which borders the town, we see the conglomerate; while upon the southeast side we behold, within a few hundred feet, and dipping in the same direction and at the same angle, the northwestern edge of the red shale.

The relation of the calcareous conglomerate to the underlying stratum is well shown on the route from Pepack to New Germantown, east of the Lamington river. The rock is generally a siliceous conglomerate or coarse arenaceous sandstone, with some thin layers of shale, all dipping at a moderate angle to the west and southwest.

At New Germantown, a little north of the village, the red shale is seen dipping westward, changed to a greenish-gray colour near the brook by its vicinity to a narrow dike of trap.

At the same spot an argillaceous limestone occurs, also dipping westward and occupying a place in the strata a little lower than the red shale nearer the town. About a quarter of a mile to the northeast of the bridge over the brook, are several quarries in a field east of the road, exposing the calcareous conglomerate, which is here used for burning into lime. Some of its pebbles are very large, consisting of limestone of various colours, a small proportion only belonging to other rocks. The cement is also highly calcareous. The dip of the stratum at this place, is west 5° south, at an angle a little exceeding 20°.

Half a mile northeast from this is another quarry more recently opened, exposing a calcareous conglomerate similar to that in Ogden's quarry, next to be mentioned. The beds have a gentle dip towards the southwest.

Lying about three quarters of a mile still further to the northeast, is Ogden's quarry, at present the most extensive in the tract. The cement uniting the pebbles is at this spot generally very calcareous; it is of a reddish colour, and some portions are highly stained by the brown matter of the red shale. The aspect of the rocks is singularly diversified, owing to the variety in size, shape, and colour of the imbedded pebbles. Specimens may be obtained here susceptible of a beautiful polish, and affording an ornamental marble of considerable beauty and novelty of appearance. The dip of the beds in this neighbourhood is *eastward*, at an angle of 20°. The conglomerate is not found beyond Ogden's quarry, a high ridge to the east seeming to arrest it in that direction.

About two and a half miles to the northeast, on the Lamington river, a limestone appears; not, however, in the form of a conglomerate, but resembling that at Pepack and Mendham, and belonging evidently to Formation II. of the older secondary series. Between the Lamington river and the valley of the Pepack, this limestone is again buried under a high ridge of the arenaceous sandstone, which in this neighbourhood underlies at a short interval the calcareous conglomerate.

Tracing the conglomerate westward, we find it next in a belt separated by a space of about half a mile from the New Germantown tract. It commences on the Rockaway creek, a little north of the road to Potterstown, and ranges near the foot of the gneiss hills, for a distance of about four miles to a point a little north of Lebanon, where it is intercepted by a low ridge of the gneiss.

In aspect and composition the rock here is very similar to that at New Germantown, being equally, if not more calcareous, and therefore well adapted for burning into lime. It has evidently been much denuded, the surface being strewed with large, irregularly-shaped blocks. The dip, where it can be noticed, is towards the northwest at a gentle angle.

As the farmers of this belt of country along the base of the gneiss hills are becoming alive to the importance of lime in agriculture, a motive is furnished them for discovering this whenever it may be found; and little doubt exists that excavations will disclose it in many spots where it is now hidden by the superincumbent soil.

Another smaller tract of this useful and curious stratum, protected from the general denudation, which has obviously removed so large a portion of it along the base of the primary hills, exhibits itself on the surface near a small stream, about two miles and a half southwest of Clinton. Apparently inferior in order of stratification is a siliceous conglomerate, met with north of the stream. South of this there occurs a red shale, exhibiting considerable local derangement of dip, inclining to the southeast at an angle of 35°.

Alternating with this, and apparently underlying it, lies a calcareous slaty rock, also considerably disturbed; the prevailing dip of which is also rather steep, and to the southeast. It contains thin layers of moderately pure limestone. On the opposite side of the stream and southward of the former beds only a few hundred yards, is the calcareous conglomerate, having the same composition with that north of Lebanon and New Germantown. Its dip is apparently to the northwest.

Pursuing our course to the Delaware, we next meet the conglomerate in a belt of more than a mile wide, between Milford and Spring Mills, coming to the river nearly opposite Gallows run. It rests conformably upon the upper layers of the red sandstone, which it joins probably about one mile to the northwest of Milford. Dipping to the northwest, or directly towards the eastern base of the Musconetcong Mountain, its near proximity renders the conclusion certain, that it meets the strata of the hill in an unconformable position.

Upon the Delaware, the rock which immediately overlies the argillaceous red sandstone, and soft argillaceous shale, is a siliceous conglomerate of great thickness, which is finely developed along the banks of the river for the distance of a mile, crossing the strike of the beds at an acute angle. The principal part of the pebbles in this portion of the formation are from the primary rocks, being chiefly quartz. They present a great diversity of size, varying from the dimensions of a pea to huge rounded masses, weighing from sixty to one hundred pounds.

Higher up the river we meet with another conglomerate, the representative of the true calcareous variety, differing obviously in composition from that just described, from which it is probably separated by intervening beds of red shale. This upper conglomerate is a less finely cemented rock, and includes a considerable proportion of calcareous matter, both in the limestone pebbles and in the imbedding paste. The fragments are less rounded and water-worn than in the conglomerate below. Somewhat angular fragments of a bluish compact limestone are frequent in the rock, while the siliceous mass exhibits but little corrosion from atmospheric agency; this more calcareous stratum presents on its surface a loose cellular structure, showing innumerable pits and cavities, from whence the limestone pebbles have been dissolved. A little below Johnson's Ferry, the rock near the road is thus greatly weather-eaten.

This upper calcareous conglomerate rarely occurs, except in the neighbourhood of the regularly stratified limestone of Formation II., along the base of the primary hills. It is in this position accordingly, that we find it upon the Delaware, where its beds, observing a gentle northwest dip, abut unconformably against the highly upturned strata of the older limestone, reposing with a steep southeastern dip upon the primary rocks in the flank of the Musconetcong Mountain.

The more calcareous variety of this rock, where the cementing matter is not too soft, affords a material of the highest beauty for ornamental uses; and it is a subject of surprise that so little has been done to call attention to its numerous applications. The rock is frequently so exclusively composed of materials derived from limestone, that it makes as good a lime by burning as many strata which do not possess the conglomerate structure. It has been in reference to this, its most valuable property, that I have felt especially solicitous to fix as nearly as possible the range which it pursues across the State, that farmers in the northern portions of the red sandstone district, needing lime for the improvement of their agriculture, might be induced to seek it from this formation, which, when it is sufficiently calcareous, is of course the nearest source.

The theoretical views respecting the mode of origin of these masses of calcareous and siliceous conglomerate which overlie the red sandstone formation, suggested by their various geological relations, will be presented in a subsequent section, after treating of the trap rocks and the changes induced by them.

To that part of the Geology of the middle secondary region, I now proceed.

Of the Trap Rocks, and Phenomena evincing Igneous Action.

Geographical range.—Between the Hudson and Delaware rivers, the middle secondary or red shale region is traversed in a longitudinal direction, from north-northeast to south-southwest, by a number of nearly parallel ridges and dikes of trap rock, some of which are of great length and uniformity of structure. Some of these are nearly straight over a course of many miles, others are considerably curved, and several again are of a nearly semicircular form. The height of the larger of these belts is about four hundred feet, while many have not more than half or even one-fourth of this elevation. In one class of these ridges, the entire hill consists of no other rock than the trap, the huge weathered masses of which, covering the summit and flanks, impart an aspect of extreme ruggedness. In other instances, the predominant rock at the surface is the red shale, indurated, baked, and altered in colour, by the excessive heat that has been applied to it, while the trap either does not appear at all, or has reached the day only in a series of narrow dikes. The hills of the latter class, have a more round and swelling contour, than those consisting solely of the trap, and admit of tillage to a certain extent.

To enumerate the principal trappean belts of the region we shall commence on the northeast with that called the Closter Mountain. This long range follows the western shore of the Hudson, from the Tappan Sea to Bergen Point, presenting a bold, unbroken ridge, which overlooks the river in the lofty mural precipice of many miles' length, known as the Palisadoes. The next belts west of this are the two extensive parallel ranges usually called the First and Second Newark Mountains. They commence at the Passaic, near Paterson, and keeping east of that river, pursue a course about south-southwest almost to its source, observing a nearly straight line until they approach the Raritan, where they curve, first gently westward, and afterwards more abruptly northwestward. The more eastern of these ridges is usually single; but the westernmost, especially near its southern termination, where it takes the name of Stony Hill, is in parts of its course double or even triple. West of the Passaic and east of Pompton river, Preakness Ridge, with its spurs, which united compose a continuous belt of trap, having almost the form of a horseshoe, encircles the Preakness Valley.

Somewhat similar in shape is the next principal outburst of trap rock called the Hook Mountain (Towakow on the map), which has the form of a nearly perfect semicircle, embracing in its concave the bend of the Passaic river, called the Horse Neck.

Still further to the southwest we meet several partial exposures of the trap, in the ridges west of the Passaic, near Bottle Hill, Green Village, and New Vernon, and in the more continuous belt called Long Hill.

If we add to these the hill extending from south of Basking Ridge to Pluckemin, immediately east of Mine brook, we shall have enumerated all the conspicuous elevations of the trap north of the Raritan river.

Between the Raritan and the Delaware we have first the Rocky Hill range, commencing, properly considered, on Lawrence's brook, east of the Sand Hills, and extending across the Millstone, north of Kingston, into Rocky Hill, which forms the other half of this belt, to its western end.

Almost in the prolongation of the Rocky Hill line of trap occur the hills between Pennington and Woodville, and upon the Delaware those called Smith's Hill and Bellmont.

Northwest of Rocky Hill lies the nearly parallel range of the Rock or Sourland Mountain, having the features of a broad table land, rather than of a rugged dike of trap, its superficial rocks being chiefly altered shales.

Nearly in a southwestern direction from the end of the Sourland Mountain, the trap, probably of the same belt, shows itself near Rocktown, ranging hence to the Delaware, where it constitutes the bold ridge known as Goat Hill.

Higher up the Delaware, above the mouth of the Alexsockin, we find another shorter belt of trap, showing itself near the river.

The last principal outbursts of the rock towards the northwest, are the Round Valley Mountain, and the dike or dikes which traverse somewhat obscurely the elevated table land styled the *Swamp*, and which are traceable from near Black's Eddy for several miles to the northeast. Several other narrower dikes exist, some of which will be mentioned hereafter.

Composition and Structure of the Trap, and its Relation to the other Rocks.

The ordinary aspect of the rock varies from that of a fine-grained, compact *basalt*, to a coarsely crystallized greenstone trap. It contains, in different localities, besides its more essential components, *hornblende*, *felspar*, *augite*, and *titaniferous oxide of iron*, various other minerals of more rare occurrence, such as *epidote*, *prehnite*, *zeolite*, *stilbite*, *analcime*, and *datholite*.

The rock to which we have here given the generic name of trap, consists in reality of several varieties, differing somewhat in composition, the more important of which it may be proper to describe. Its essential constituent is *felspar*, which is united in some cases with *hornblende.* It then belongs to the class of rocks denominated *greenstones.* In other instances the felspar is associated with *augite*, a very common case along the Delaware; and this mixture is a true *dolerite* rock. Again we find it constituted of felspar, augite, and the titaniferous oxide of iron, a composition which entitles it to the name of *basalt.* This basalt, however, often contains hornblende, as we may behold in the rock of Goat Hill. A fourth variety, of more rare occurrence in New Jersey, is the kind called *toadstone*, an amygdaloidal trap composed of a vesicular cement or paste, usually of fine-grained, rather earthy basalt, embracing small spherical or ellipsoidal cavities, occupied by extraneous minerals. A trap rock of this character occurs in the ridge north of Scotch Plains.

The crystalline structure of these trappean rocks is no less various than their composition, presenting every gradation, from that of a homogeneous paste, in which all traces of a distinct grain disappears, to a coarsely granular aspect, in which we may plainly detect the several constituent minerals. The same ridge or broad dike frequently shows all these shades of crystallization, disclosing usually the more compact varieties near the outskirts of the belt, and the conspicuously granular kinds near its centre.

The structure of the trap is usually that of a massive or amorphous rock, destitute of any greater regularity in its divisional joints than such as occasion a prevalence of the cubical and trapezoidal form in the blocks into which it separates. But in some instances is displays an approach to the *bedded* structure, as if, while in the melted state, layer had flowed over layer in a nearly parallel arrangement. This may be seen at several localities on the Delaware. In other cases, for instance at the Little Falls of the Passaic, we find it assuming the true basaltic character, separating into regularly formed perpendicular prismatic columns. At the same locality the lower portion of the mass of trap has the *spheroidal* structure, being a confused assemblage of concentric nodules.

Almost every relation which igneous rocks ever present to the strata intersected by them, may be witnessed in these trappean belts of the red sandstone region. But the usual modes of position are, first, where the trap reposes unconformably upon the secondary strata, as may be seen in a number of interesting exposures; and, secondly, where it intersects or traverses the strata in nearly vertical dikes, conceived, from the known volcanic nature of the rock, to exist in every trappean ridge, but only occasionally disclosed to observation.

That the trap is of posterior origin to the red sandstone formation which it overlies and intersects, is obvious, but at what precise epoch we are to suppose it to have been etruded to the surface, and whether all its numerous outbursts were contemporaneous or occurred at successive periods, are points open to discussion. After reviewing all the phenomena of igneous action in the region, we shall touch upon these interesting questions.

Throughout the whole district where the trap abounds, we notice instances of its superposition to the stratified shales and sandstones through which it has burst its way to the surface. Interesting proofs of this occur along the shore of the Hudson, at the eastern base of the Palisadoes, where several varieties of the sandstone are visible near the water's side, dipping at a gentle inclination westward and into the ridge. The same thing is well displayed in the bed of the Passaic river below the Falls at Paterson; the trap reposing over the westerly dipping beds of the sandstone, and presenting some curious evidences of its having reached this position while fluid and in a state of intense ignition.

Of the Local Features of the Trap and the Alterations induced by it on the Adjacent Strata.

I now proceed to a particular account of some of the more striking features of these injected dikes, and of the modifications they have produced in the contiguous stratified rocks. Many of these changes in the texture, contents, aspect, and properties of the neighbouring rocks, attributable to the intense heat originally imparted by the intrusive trap, are of a kind familiarly noticed in the vicinity of igneous veins and dikes; but there are some which I shall have occasion to describe, that are of a less common character, and which tend, by the views connected with them, to corroborate some fundamental doctrines recently advanced by geologists.

The first Newark mountain is an elevated range of trap, displaying in many places south of Paterson, fine mural escarpments of considerable height, especially along its eastern side. The face of these cliffs is often remarkably smooth and regular. Near Paterson, the trap rock is seen at the Falls of the Passaic overlying the red sandstone, which displays near their contact a modification of structure not unusual in such cases.

The interesting waterfall at this spot, seventy feet in height, is caused by the dike of trap which crosses the river in the form of a fine natural dam. The entire mass of water precipitating itself over the brink of this dam, passes first into a lateral cleft or chasm in the dike, and thence descends into a deep pool or basin, which it has excavated for itself in the subjacent softer sandstone. The trap rock of the cliffs around, presents a strong tendency to the columnar structure. Within a few yards above the level of the river, beneath the Falls, we behold the junction of the igneous and the sedimentary rocks. Between the true trap rock above and the altered sandstone below, there occurs a mass, of five or six feet thickness, possessing the structure of a toadstone or amygdaloid, enclosing geodes filled with prehnite, analcime, zeolite, and several other minerals. Immediately beneath this, we discover a layer of the sandstone, a few inches in thickness, bearing all the marks of partial fusion, being filled with small vesicular cavities, as if from the extrication of steam, and looking like an overbaked mass of brick or pottery.

At a gorge in the same ridge, near Plainfield, the rock departs somewhat from its ordinary aspect, being easily splintered, rather metallic in its lustre, and containing frequent streaks or fine lines of the red oxide of copper. Near another notch in the mountain, a little north of Scotch Plains, a credulous miner seeking for the precious metals, has disclosed an interesting mass of cellular or amygdaloidal trap, of a peculiar light yellowish-green colour. In this neighbourhood minerals of the zeolite family are frequently found.

While mentioning the thin seam of limestone in the narrow valley of Greenbrook, between the first and second trap mountains, a few miles north of Scotch Plains, reference has been already made to the changes induced by the trap of this locality, both upon the limestone and the red shale.

The next belt of the igneous rock towards the northeast worthy of especial mention in this place, is that called the Second Newark Mountain. Where this ridge crosses the Passaic river, forming the gorge of the Little Falls, the structure and relations of the rock are finely developed. A little below the Falls, the trap is seen in direct contact with the red sandstone, overlying it in a mass from twenty-five to thirty feet in thickness, and presenting a rather unusual appearance. The lower portion, about fifteen feet in thickness, resting immediately on the stratified rock, is an assemblage of irregular spheroidal ba ls of a somewhat concentric structure, traversed in all directions by small fissures or joints; externally these are of a rather rusty hue from atmospheric action oxidizing the iron in the rock, but when broken they show a dark, iron-gray colour, with a somewhat metalliferous aspect. The material filling the interstitial portions between the balls, is a dark-coloured, close-grained, very earthy basalt. It sometimes includes crystalline quartz of various colours; among others the amethystine and smoky varieties.

Above this confused mass of nodular concretions, the rock assumes the true basaltic structure, exhibiting regular columnar prisms, beautifully symmetrical, extending up to the superincumbent soil.

At this locality, the trap rock includes crystals of prehnite, stilite, carbonate of lime, and other minerals.

Somerville Trap Ridge and Bridgewater Copper Mine.—The next point on this first belt of trap at which we meet with any phenomena of a specially instructive nature, is in the neighbourhood of Somerville, where the ridge has curved round to assume a northwest course. In the various excavations of the old Bridgewater copper mine, we have an opportunity of beholding the action of the trap upon the rock into which it has been intruded.

At this mine we have ocular evidence that the igneous rock issued through the strata through fissures of contracted width, when compared with the base of the ridge which it constitutes.

A level extends from a shaft near the southern base of the ridge in a north direction, towards the centre of the hill, or beyond it, reaching upwards of seven hundred feet. The rock which it chiefly traverses is the red shale, not much affected in structure by the trap which overlies it in the hill, until we approach very near the point of contact of the two materials. The refuse matter at the mouth of the gallery of the mine itself, shows that very little genuine trap was intersected in cutting this tunnel across the strata.

The copper ore, which was the object sought, was found chiefly adjacent to the slightly altered shale, or immediately before it becomes excessively changed in structure, near its contact with the trap. This interesting circumstance of the position of the ore, which embraces principally the carbonate, red oxide, and silicate of copper, is by no means confined to the locality before us, but seems to prevail in relation to all the explorations of any magnitude hitherto made for copper within the State. The theory of the origin of these ores, suggested by this and other facts, will be presented under another head, when the copper mines have been specially described. The ore, as in nearly every copper locality in the State, is connected with no true *gangue* or vein stuff, implying a genuine metalliferous lode or vein, but is diffused as if by sublimation through the altered red shale, filling or lining its minutest fissures, and presenting, therefore, a large surface of bright green ore to the eye, while the metalliferous coating is in reality extremely thin.

Deeper in the hill, there occurs a more highly altered variety of the red shale, but this is usually destitute of metalliferous matter. In external aspect and structure it resembles somewhat the trap rock, but its texture and composition show it to have been the stratified shale changed by heat. Its fracture is conchoidal, very nearly resembling that of the trap, and it has the same tendency to form numerous spherical balls.

New Brunswick.—The next locality which deserves description, belongs to a more eastern belt of trappean injections. This ridge is one and a half miles west of New Brunswick, of gentle elevation, composed principally of red shale, apparently underlaid in part by trap rock. The shale has an altered colour, and in some of the higher parts of the hill, the trap obtrudes itself at the surface in loose fragments. At one point in the immediate vicinity of the trap, there occurs a considerable quantity of the *sulphate of baryta,* scattered in detached pieces over an area of perhaps a fourth of an acre, which is nearly barren of vegetation. Precisely the same circumstances exist in a locality of the same mineral, in Bucks county, Pennsylvania; the sulphate of baryta lying adjacent to the trap, and giving rise to a remarkably sterile soil.

In some deep borings made at New Brunswick in search of water, it is evident, from the description given of the materials which were encountered, that more than one narrow dike or perhaps *bed* of trap rock was met with, whose outcrop on the surface has not been detected.*

Rocky Hill and its Prolongation.—The next trap belt, interesting from the phenomena connected with it, is that of Rocky Hill. Commencing at its eastern termination near Lawrence's brook, we observe the shale on both sides to assume, as we approach the dike, a bluish colour, and an extremely compact structure. On the southern declivity of the hill it is of a purplish or chocolate tint, and excessively hard and tough. It is studded throughout with small spherical knots or crystalline nodules, consisting apparently of the minerals epidote and hornblende, in a state of incomplete crystallization. This belt of altered shale extends from a point about half a mile southeast of the straight turnpike to the Millstone river, which it crosses at the foot of Rocky Hill, near Kingston. The changes induced in the whole lithoid character and structure of the shale, by the intruded igneous rock, are very finely exhibited along the canal, at both the northern and southern bases of the Rocky Hill dike, evincing a curious gradation in the crystalline action, as we approach the trap.

Near the southern base of the ridge, the red argillaceous sandstone displays the series of changes already noticed, its colour becoming deepened, and dark crystalline knots or kernels abound-

* I may here mention as adding another locality to the numerous ones already observed, both in Europe and this country, showing the increase of the earth's temperature as we descend, that in one of these artesian wells, the water derived from a depth of 175 feet being 52° Fahr., upon reaching a depth of 275 to 300 feet, its temperature was 54° Fahr. This last is exactly the permanent temperature of a fine natural spring, which issues from the side of a hill about a mile southeast of the town.

ing in it; we then come to the true trap, which at the river is not wide. Immediately upon the northern side of the trap, the sandstone rock re-appears with its usual dip to the northwest, but presenting some remarkable modifications. These may be seen opposite the toll-house, at the village of Rocky Hill, upon the canal, in a quarry one hundred feet to the north of the trap rock. The inclination of the strata being not more than 15°, the lower beds in the quarry cannot be fifty feet remote from the subjacent trap. They are filled to such a degree with various crystalline matters, and show therefore so much inequality of composition and hardness, as to be unfit for building stone. As we descend in this quarry, the rock departs from its character of a sandstone, though at a certain depth the change of texture is precisely that which is desirable in a material ordinarily too easily acted on by the weather. About one hundred feet from the trap, the rock has the condition of a very close-grained, compact, and reddish, or purplish sandstone, of a somewhat argillaceous texture, while it is full of dark spheroidal kernels or nodules, of a radiated structure, of the dimensions of a pea or less. The nature of the mineral is rather obscure, from the absence of all definite crystalline character. This stratum is a very durable rock, and is extracted in regular masses, furnishing a building stone which is in considerable request. In the middle of this stratum, there is a thin bed, four feet wide, which seems originally to have been a sandstone containing much felspar. It is full of small irregular cavities, the sides of which are studded with a black mineral, crystallized in regular prisms. This is schorl, regularly and perfectly developed. Numerous fissures or joints in the rock are occupied with the same black mineral, which is always highly crystallized. The rock of this bed is rejected as a building stone. Near the top of the thick stratum, of which this is but a narrow layer, the rock acquires a less altered aspect, being redder, softer, and having less of the jaspery texture, but containing kernels of pure epidote, well developed. This variety extends from where it first shows itself, which is from the trap, about one hundred and fifty feet in the thickness of the stratum, to a distance of a fourth of a mile, where it is well exposed, being excavated at another quarry. It gradually and regularly acquires the ordinary unaltered features of the red sandstone; but is even in the second quarry remarkable for the distinctness and size of the green spheroidal masses of epidote. The degree of baking which it seems to have received even at this distance from the trap, has given it a closeness of texture which fits it finely for purposes requiring a durable building stone. Near the same quarry, the rock contains a narrow band of nearly pure epidote, about an inch and a half thick. Beyond this second quarry, towards Griggstown, the rock soon assumes its usual soft slaty texture and deep red colour.

The zone of altered shale, having the structure above described at the Millstone river, extends particularly along the northern flank and base of Rocky Hill, to its western termination, rising high on the slope of the ridge, whose southern crest alone contains the trap.

North of Princeton the southern belt of the altered rock lies in a lower ridge, parallel with the ridge of trap, but separated a little from it, the intervening depression having resulted from the comparatively easy disintegration of the highly altered rock lying directly in contact with the trap. When we trace this belt of discoloured shale westward, we find it disappearing before we quite reach the termination of the prominent portion of Rocky Hill, whose actual termination is, however, much beyond the point indicated on the map. It forms, in fact, a continuous though irregular chain with the trap hills east of Herbertstown.

Near the head of Jacob's creek, at the abrupt termination of one of these trap hills, there is an old mine, where excavations to some extent have been made in search of copper ore, the rubbish discharged from the diggings, showing some traces of that metal.

The same series of nearly continuous dikes extends to the Delaware, forming two conspicuous elevations near the river called Smith's Hill and Belle Mount. In this western portion of the belt the trap has produced effects on the shale and sandstone similar to those seen along Rocky Hill. Upon Moore's creek the strata are much altered, having a dark bluish or purple colour, and being excessively indurated. Their nearly black hue, when wet, has led to the notion that these shales are the dark carbonaceous slates of a coal formation.

In the hill called Belle Mount the trap rock is well exposed, having been excavated in making the feeder of the Raritan canal.

It possesses less of the basaltic character than belongs to much of the trap in the Newark ranges. It is of a gray colour, rather coarse texture, and consists of a large proportion of felspar, united with augite, and is therefore a true *dolerite* or augitic trap. Some portions contain hornblende instead of the augite, being in these cases the rock called greenstone trap. These two varieties are distinctive of nearly all the belts of this rock in this neighbourhood, including the important one of Goat Hill.

Sourland Mountain.—The next zone of trap and altered rock which claims our attention is that of the Sourland Mountain and its prolongation, Goat Hill. This lies northwest of the belt just described. Viewing the general topographical features of the Sourland Mountain, and the wide plain of red shale and sandstone around its base, from any part of the Somerville trap ridge distant several miles, we are led to some interesting reflections regarding the small degree of violence which has accompanied the protrusion of the trappean rocks of this region generally. Standing on the large rubbish banks of the old Bridgewater copper mine, where we are elevated scarcely one hundred feet above the general surface of the wide level tract of red sandstone spreading to the south, southwest, and west, we overlook the country for a great distance, and behold the Sourland Hill rising like a broad solitary island from the smooth surface of the extended plain. The very features of the scene are enough to indicate the absence of any great convulsive disturbance of the strata during the outpouring of the trap, which seems to have made its way to the surface through a series of long and narrow fissures, produced by the mere gaping asunder of the rocks, and not, as in some regions, by enormous vertical disruptions and irregular uplifting movements, imparting invariably a broken or undulating contour to the scene.

In the Sourland Mountain the trap rock is confined chiefly to its broad rounded summit, forming the axis of the hill; while, from this position to beyond its base, reposes, on each side, in undisturbed and regular stratification, a thick belt of the indurated and baked shale. On the northwestern flank of the mountain, towards Flaggtown, the rock in some places shows striking evidence of the intensity of the igneous action, for it has all the aspect of the fused slag or cinder of a furnace. Portions of it are excessively hard and tough. At the base, near the northern termination of the hill, the shale still manifests a great degree of induration; it is of a blue colour and compact grain, but retains its slaty structure sufficiently to fit it excellently for flagstones, for which it is quarried. The condition of things in and around the Sourland Mountain is well seen by crossing it northward from the little village of Hopewell, near its southeastern base. Immediately north of Hopewell we pass over a ridge of little elevation, at the base of which is a light gray arenaceous sandstone, easily disintegrated, containing both the micaceous and brown oxides of iron in considerable abundance. The summit and northern declivity of this low ridge consist of blue shales somewhat indurated. Crossing a narrow valley to the southeastern foot of the main Sourland Mountain, we find its entire slope composed of the shale in a highly altered state, being blue, compact, and greatly indurated. It is excessively tough, difficult to fracture, and produces a clear ringing sound when struck. The loose masses often exhibit externally a peculiar glazed aspect, analogous to that upon the surface of some kinds of slag. These altered strata extend to the highest parts of the mountain. Crossing a slightly depressed belt, the trap rock next displays itself, and continues to the northwestern declivity, where it gives place again to the altered rocks composing the other flank. The whole mountain is thus formed of a series of nearly parallel elevations, with more or less considerable intervening depressions, or valleys, which are by no means regular, the single axis of trap rock occupying a nearly central position.

In the southwest prolongation nearly of the Sourland Mountain we find the same or rather another almost continuous and parallel dike, which passes a little south of Rocktown, and thence to the Delaware, making there the axis of Goat Hill. This elevation ranges about half a mile southeast of Lambertsville, and crosses the Delaware in an oblique direction, appearing on the Pennsylvania side below New Hope, where it displays some interesting phenomena. Along the northwestern base of this ridge, on both sides of the river, the strata dip as usual, but are affected in a striking manner in their structure and composition for at least a fourth of a mile from the trap. In the quarry northeast of Lambertsville, we discover the commencement of the change. There the red sandstone, varying but little from its ordinary colour and being only rather more compact, contains a multitude of the large spheroidal nodules of pure green *epidote*, many of which are at least an inch in diameter. They seem not to be distributed promiscuously through the rock, but to be arranged somewhat in layers, parallel to the planes of the strata, though they are often several inches asunder. Two or three hundred feet nearer to the trap, we find the rock darker and harder, and the number of nodules greatly augmented, though they are generally of much smaller size. The common colour of the rock is here a very dull purplish blue, and that of the included nodules a dull black or a deep blue. They are of all sizes, from minute specks to the dimensions of a large hazle-nut, and possess every shade of distinctness contrasted with the material enclosing them. They seem to consist of some imperfectly formed mineral, apparently tourmaline in a semi-crystalline state. These spherical nodules or specks, are oftentimes surrounded by a crust or coating of another material, usually nearly white; and I have remarked that the more obviously formed this crust appears, the more crystalline or fully developed is the interior kernel, which, at this spot, seems to approximate in its features to black schorl or tourmaline. A few hundred feet nearer to the trap, or almost at its base, the rock presents a still different aspect, being of a dark gray hue, and somewhat coarse-grained. It seems to have been a sandstone, containing little or no clay, as it has nothing at all of the baked jaspery texture of that previously described, which has plainly been either a shale or a very argillaceous sandstone. This gray rock is speckled with innumerable small crystals of very regularly formed *tourmalines*, some of which are more than half an inch in diameter. Upon the opposite side of the river, below New Hope, we meet with very nearly the same order of things, except that the rock containing the completely formed tourmalines is absent.

In one thin layer of the altered red argillaceous rock on the Pennsylvania side, the mass, which is of a pink hue, contains, blended with the crystallized *epidote*, some minute but perfectly formed crystals of a mineral, apparently *idocrase*, of a beautiful wine colour.

The altered belt here described, ranges northeastward from the river for several miles, being continuous, in fact, with that already spoken of, which forms the northwestern flank and base of the Sourland Mountain. About a mile southeast of Mount Airy, the blue and purple shale contains an abundance of epidote in oblate spheroidal concretions of very regular shape. The average breadth of the belt is very considerable, amounting at least to a quarter of a mile.

West of Ringoes the shale in some places exhibits a considerable degree of change from its proximity to a bold dike of trap, which shows itself in a hill above the mouth of the Alexsockin creek. In crystalline structure this trap departs even more widely from the fine-grained basaltic variety seen in the hills near the Passaic, than does that of Goat Hill and Belle Mount, lower down the Delaware. It is coarsely granular and crystalline, consisting chiefly of a yellowish-white felspar, traversed by bladed or elongated tabular crystals of green hornblende of considerable size. Much of this rock bears indeed a closer resemblance to some varieties of sienite than to ordinary trap rock, exhibiting the justness of that generalization which makes the trappean family of rocks to include those sienites which are composed of the two minerals, felspar and hornblende. Between this belt of trap and the Alexsockin creek we find a disturbance in the direction of the dip, being the only irregularity of this kind of any magnitude in the whole red sandstone region, which is referable to the protrusive action of the igneous rock. On the southeastern side of the dike the strata of shale and sandstone are in some places much contorted and broken, but their prevailing dip is towards the southeast, or directly opposite to the usual quarter. This contrary order of the dip throughout the district along the Raritan and its north branch, I attribute to the peculiar direction taken by the currents which precipitated these sediments in this portion of the basin, and not to any upheaving force.

I have already when describing the several zones of the red shale and sandstone formation along the Delaware, mentioned the altered aspect of the strata over the wide tract called the "Swamp," the general limits of which were at the same time defined. With the exception of some occasional exhibitions of the trap rock, particularly in the vicinity of the southeastern margin of that table land, the only material generally visible upon its surface, is the highly indurated and altered shale; the igneous matter itself having apparently in but few instances reached the day. Along the Delaware, however, about two miles above the mouth of the Lockatong, and nearly opposite the mouth of the Tohickon, near Black's Eddy, the trap appears on both sides of the river in a somewhat massive dike. On neither side of the Delaware does the trap appear at the surface on the top of the ridge or table land; and would never have been exposed, but for the denudation which excavated the deep channel through the rocks, by which the river now flows. The existence of the trap rock under these circumstances, lends confirmation to the opinion already implied, that the induration of the strata in many of the broad belts described, is the result in part of the heat propagated from masses of igneous rock which have never reached the surface.

Regarding this conclusion as almost demonstrable from the phenomena, does not analogy furnish us ground for the interesting doctrine, which attributes the crystalline structure of gneiss and other stratified rocks of the primary class, to the modifying influence of subjacent bodies of granitic, and other igneous matter intensely heated, acting upon sandstones, slates, and similar sedimentary strata?

Reviewing the several facts presented in the previous description of the principal belts of altered shale and sandstone, we find many of them of a kind calculated to add weight to this hypothesis.

In the great thickness of the zone of strata throughout which such remarkable changes have been induced in the texture, and even the molecular structure of the rock, by the heated trap, we have evidence of the magnitude of that cause, which when exerted in far greater intensity and universality upon the sedimentary deposits of the earlier periods of our planet, may have been fully adequate to produce that more entire change to general crystallization, which the metamorphic theory assumes. A curious and important proof that the modifications in the strata described, have resulted wholly from the high temperature of the molten trap, is to be found in the circumstance that all the indications of alteration or an approach to a semifusion of the mass, augment regularly as we approach the dike. The crystalline nuclei, first extremely minute and faintly marked, become progressively larger and better defined, assuming when within a certain, though still considerable distance, all the characters of a fully developed mineral, possessing in some instances the structure of a perfectly regular isolated crystal. As this gradual segregation of certain specific mineral combinations increases, we notice a progressive obliteration of all the ordinary features of the rock.

Another highly interesting point is the intimate connexion, chemically, in every instance, between the composition of the stratum acted on, and the *species* of mineral secreted. Thus in all the principal localities of the *epidote,* we find the red shale containing by analysis all the constituents essential to that mineral, even the *lime.* Moreover, the red sandstone, so usually destitute of lime, is singularly enough the stratum in which the tourmaline, a mineral not holding any lime, abounds.

Where the rock has been a calcareous and very argillaceous red shale, the mineral produced has *invariably* been *epidote,* the ingredients of which are silica, alumina, lime, oxide of iron, and a little manganese, the five prevailing constituents of the red shale. On the other hand, where the rock has been originally a somewhat more arenaceous compound, such as usually goes by the name of argillaceous red sandstone, a triple mixture of alumina, silica, and peroxide of iron, there we find, in place of epidote, a profusion of black tourmalines, the composition of which, as analyzed by Kloproth, is 40 alumina, 35 silica, and 22 oxide of iron.

There are several other imperfectly crystalline minerals sometimes associated with the above, but I have not yet found time to investigate their composition and probable origin.

A careful examination of the altered rocks near the trap would, I doubt not, result in much useful information of a strictly practical kind, in reference especially to a right selection of stone for purposes of architecture. I conceive that the very best varieties of building rock in this region of the State, will be found in the indurated strata, contiguous to the ridges of trap, where the baking process has obliterated the slaty cleavage, and destroyed that soft friable texture which usually renders so large a portion of the red sandstone of the district of no value. As this section of the country is not well supplied with building stone capable of withstanding the weather, the hint that durable varieties abound near the trap ridges, may prove of service. From what has been said, it will be seen that the most probable position for the better kinds, is neither too near the trap nor too remote from it, but is indicated by the amount of *baking*, which the rock appears to have undergone. This should not be too great, lest the rock be very hard and difficult to cleave into regular blocks; nor yet too little, as it will be then soft enough to be operated on by the frost. When a rather compact and extremely durable kind is sought, I would suggest that it will usually occur within one or two hundred feet of the trap, and may be known by a bluish or dull purple colour, and by a multitude of dim round spots, the commencement, as it were, of the crystalline nodules. On the other hand, when a rock of rather softer variety, but cleaveable into larger blocks, is desired, then I would propose the beds rather more remote from the trap, where the stone retains a pretty bright red colour, and contains large, fully formed nodules of green epidote.

It is not asserted that these altered strata will always appear bordering the ridges of trap; but I find them in frequency far greater than might be expected, and their importance therefore, is considerable. By following the base of a range of trap, though we may not at once meet with any rock of that exact degree of induration which we seek, we cannot pursue the search far in the longitudinal direction without falling upon a locality where all the requisite varieties present themselves. Much aid will be derived from inspecting the spots and nodules upon the fragments scattered over the surface of the soil.

OF THE COPPER ORES OF THE RED SANDSTONE REGION.

The ores of copper, especially the carbonate, red oxide, and blue sulphuret, exist in many places in the red sandstone region, though hitherto they have never been procured in abundance. Their position in every case would appear to be contiguous to dikes of trap; the present seems therefore the appropriate place in which to describe them.

The particular manner in which these ores occur, gives to the inquiry concerning them, some degree of interest both as respects the question of their origin, and the probability or not of a lucrative return for the expense of mining them. Several vigorous and persevering attempts have been made at successive times, to open mines of copper in this region, but invariably without success; and it becomes an important point to trace, if practicable, the cause of the general failure, and to ascertain in fact, whether it is not mainly referable to an actual deficiency in the amount of ore, and to its diffused state through the rock. As it is desirable that the information collected should have a practical and salutary bearing upon future mining enterprises in the district, much capital having been already absurdly wasted, I shall submit such details as have been collected, believing that the conclusions they suggest, if not positively demonstrable, are highly probable.

The principal points where mining operations have been undertaken at different times, are near Belleville, Griggstown, Brunswick, Woodbridge, Greenbrook, Somerville, and Flemington. For details concerning the early history of the mines at Brunswick, Belleville, and Somerville, I refer the reader to Gordon's Gazetteer of the State; at the same time expressing my belief, that far too favourable an impression is conveyed in that work of the metallic riches of those localities. With the exception of the Flemington Mine, which has lately been worked to some extent, and which is a more recent enterprise, these several works are all at present in such a state of decay, as to make it impossible to ascertain *by direct inspection,* the mode in which the ore occurs. My information upon this head, has been derived from examining the masses of ore and rubbish near the mines, and especially from the testimony of persons familiar with the works while they were in operation. Every thing that I have witnessed or collected in regard to it, has led me to the opinion, that the ore does not exist, in any instance, in the shape of a *true vein;* in fact, we have no evidence that a regular copper *vein*, properly so called, has hitherto been met with any where in the formations of the State.

By a true vein is meant "the mineral contents of a vertical or inclined fissure nearly straight, and of indefinite length and depth." Such veins have usually a well-defined line or plane of separation between their contents and the rock on each side, which is named the *wall* of the vein. Now the chief peculiarity in the copper ores of the region before us is, that they occur, not in regular sheets of mixed metalliferous and mineral matter traversing the rock, but in irregularly ramifying and intersecting strings and bunches, in which the masses of ore are not mingled with the usual foreign materials of metallic veins, but blended with the adjacent red sandstone or shale, which is in a more or less *altered* state. The nature of these accumulations of metalliferous matter will be best understood, however, from a description of the position of the ore at two or three of the principal mines.

In the Schuyler Mine, near Belleville, in Essex, the principal body of the ore is stated to be imbedded in a stratum of sandstone, twenty or thirty feet in thickness, and to dip about 12° from the horizon, rather by steps than regularly. It has been worked two hundred and twelve feet below the surface, and one hundred and fifty feet horizontally from the shaft. The chief ores are sulphuret and carbonate of copper, and they occur almost invariably blended with portions of the indurated red sandstone. Judging from the latter fact and the gentle dip of the mass, which appears to be about that of the neighbouring strata, it is pretty obvious that it has but little claim to the character of a true vein, though it is not asserted that the quantity of ore in this mine may not be considerable. It would seem as if a particular band of the rock had been injected with the metalliferous matter, not filling a cleft or fissure, but dispersed and as it were dissipated by sublimation through the substance of the sandstone. There is no trap exposed on the surface any where in the immediate district of the Schuyler Mine.

At the Falls of the Passaic, near Paterson, traces of copper, in the form chiefly of the *green carbonate*, occur near the foot of the high cliff of trap rock, on the north side of the river, immediately at the base of the Falls. A fruitless excavation was formerly made at this spot, in quest of a regular vein. Huge perpendicular rents or chasms divide the trap, of unknown depth, and in a direction nearly coincident with that of the ridge. It is into one of these great clefts that the waters of the Passaic precipitate themselves at the Falls.

In the red sandstone between East and West Bloomfield, green *carbonate of copper* is occasionally seen, but always in the form of a very thin film or crust, filling the minute seams and divisional joints of the rock, and never but in very inconsiderable quantity.

At several points in the neighbourhood of New Brunswick, ores of copper have been found; and prior to the revolutionary war, an extensive and costly attempt was made to establish a mine here, but without success. The red shale is in many places coated by the *blue* and *green carbonates* of the metal, in the form nearly of a thin pellicle. In a few instances the metal occurs in the pure state, soft and malleable, in the shape of a thin plate, injected into the body of the rock, rarely more than the twentieth of an inch in thickness. In every such case, the contiguous rock is more or less indurated, as if by heat; and in immediate contact with the vein of metal, its ordinary brownish-red colour is changed to a light-gray for the thickness of a third of an inch or so.

The Franklin Copper Mine, near Griggstown, in Somerset county, is situated on the western declivity of a hill, whose summit is occupied by trap rock, but up the side of which the shale rises to a considerable height. It is in this shale, which is considerably altered by the trap, that the copper ore has been found. The mine is in a dilapidated condition, and no longer accessible. Judging from the character of the materials brought out from the mine, and from the testimony of those who were familiar with it when open, the excavation runs for some distance horizontally through an altered shale of a dark purple colour, which becomes afterwards paler and more siliceous. The ore occurs diffused through this altered shale. Occasionally it has the aspect of existing in very narrow short strings, or little veins of injection, being in such cases mixed with carbonate of lime, felspar, hornblende, and other minerals, constituting what approximates to a true metalliferous gangue. The best ore found here is a soft *blue sulphuret*, associated always with carbonate of lime; but the principal species is the usual carbonate of copper and the *red oxide*, mingled through the altered shale, which abounds in little geodes or crystalline nodules of epidote and black tourmaline, sometimes beautifully crystallized. The principal shaft is said to have been one hundred feet deep; and the mine was drained by a long adit which commences near the base of the hill, not far from the canal. A considerable sum has been expended without success, in opening this mine.

Interpreting all the appearances connected with the nature and the mode of distribution of the ore, it would seem to be so diffused throughout the altered shale, as to preclude its being ever profitably wrought.

At the base of the trap ridge north of Somerville, occurs the Bridgewater Copper Mine, once worked to some extent, but with a serious waste of capital. Several facts respecting the position of the ore in the midst of the altered shale, at some little distance from the dike of trap, have been already mentioned. It was found here principally in the *moderately* altered rock, near to which it is excessively baked by proximity to the igneous rock. The ore is pronounced to have been very rich, consisting of a considerable proportion of massive red oxide of copper. There was also found some *native copper*. The chief variety of ore, however, was the usual *green carbonate*, mingled occasionally with *green phosphate*, and some of the *green silicate of copper*.

This mine has been for a number of years closed up. Judging from the character of the rubbish outside of the mine, which gives a tolerably correct conception of the mode in which the ore occurs, we infer that it is here accompanied by very little true gangue or vein stuff, being sometimes in the form of thin partial injections, but much more frequently existing in a disseminated state among the altered shale and sandstone.

The Flemington Copper Mine, the only one recently wrought to any extent, being open to inspection, gives an opportunity of ascertaining accurately the usual mode of position of the ore. In this mine the appearances are almost conclusive, as regards the *absence of a true vein*, and corroborate strongly the opinion already advanced, that the chief portion of the ore has penetrated the minute crevices of the impregnated rock, rather by a species of sublimation, than by intrusion or injection in the fluid state.

There seems to be a belt of metalliferous rock of very variable breadth, sometimes twenty or thirty feet wide, which preserves a nearly north and south direction for several hundred feet. What the total length of this may be no one pretends to know, but two miles due south from where it is exposed in the present Flemington Mine, there are strong indications of a belt of precisely similar character. In the Flemington Mine, the ore, which is a mixture chiefly of *gray sulphate* and *carbonate of copper*, exists intimately blended or incorporated with the semi-indurated and altered sandstone, and parts of the mass have therefore somewhat the aspect of a conglomerate of re-cemented fragments, the metalliferous part acting as the cement. Though usually minutely disseminated, it occurs occasionally in lumps of great purity and considerable size. The line of rock containing the ore has no definite separation from the unaltered red shale outside of it, and it is therefore not always easy to judge of the precise space which it occupies. The ore in this mine is of good quality, and so far as I have been able to ascertain, the dimensions of the band containing it, are such as to admit of the existence of a large mine here, should the proportion of metallic matter in the rock prove profitable. The mine seems to have been very judiciously worked; cuttings being made across the ore in a series of east and west alleys to ascertain its extent and position. But while mining is of all arts the most precarious, it is especially so where the metalliferous deposit does not occur under the shape of a regular or true vein or lode. The doubts which some entertain regarding the final success of this and other copper mines in the State, proceed chiefly from the views entertained regarding the manner in which the copper ore is diffused.

The Nechanic Mine lies apparently on the metalliferous belt of rock above spoken of. The ore occurs under circumstances very similar to those at the Flemington Mine. It is not at present productive.

From the excellent quality of the ore of this belt, it is to be regretted that a regular vein of some extent cannot be discovered, the disseminated condition in which the ore exists, rendering all mining operations very expensive, and limiting the supply of ore. These mines are all near a narrow dike of trap of scarcely perceptible elevation, which runs southward from the main ridge of trap and altered rock, northwest of Flemington, and extends a considerable distance to the south. The adjacent strata are in most places considerably altered, and in some spots coated with flakes of the green carbonate of copper.

Recurring to what we have adduced respecting the copper ores of the State, it will be seen that they do not occur under circumstances to make the adventurous miner sanguine in pursuing to a costly issue, the indications of this metal which so frequently meet us throughout the red sandstone region. Numerous cases exist in other countries, it is true, where rich mines have been wrought in masses of ore that were not genuine veins, nevertheless, when the deposites are like those common in the copper region of New Jersey, mining becomes peculiarly precarious. I have been thus explicit upon this subject, from a persuasion, that one main advantage to be anticipated from a rightly conducted geological survey, is the aid which it is capable of affording to enterprise, by stimulating every branch of wholesome industry, and checking rash and visionary undertakings. It should furnish a faithful statement of what every district possesses, and when necessary of what it does *not* possess. The one is as needful as the other, if our motive be to give the industry of the community a right direction. It may depress, and it cannot strengthen the spirit of useful enterprise, to permit capital to be misapplied to purposes that, when pursued, lead to loss and disappointment.

When we contemplate the singular degree of uniformity which attends the copper ores of the State, their strict resemblance in point of composition, and the *identity* of the geological relations under which they are found, we are strongly impressed with the persuasion, that they all owe their production to one epoch, and to one generally-operating cause. Finding them in almost every case adjacent to igneous dikes, but not in contact with them, we are led at once to the inference that they entered the crevices of the somewhat crushed shales at the time of the outpouring of the molten trap, and that hence, like it, their presence at the surface is the consequence of an intense heat. The remarkable manner in which the carbonate of copper is diffused among the minutest fissures of the shale, its great *relative* abundance, and the well known property of its ready sublimation, together with the curious circumstance that both it and the other ores are rarely in immediate contiguity to the trap, but among the *moderately altered less heated rocks* at a little distance, all go to indicate that a considerable proportion at least of the metalliferous matter, especially the *carbonate*, entered the strata in a gaseous or *volatile* condition, and not that of igneous fusion. This latter was more probably the state in which the metallic copper, such as occurs near New Brunswick, and perhaps some of the less volatile ores of the mine at Griggstown, were injected.

In reference to the above speculation, it should be recollected that the mass of the trap rock itself is not unfrequently seen to contain both metallic copper, and its ores.

ECONOMIC GEOLOGY OF THE RED SANDSTONE REGION.

Several subjects have been already discussed, which from their obviously practical importance, are entitled to a place in the economic geology of the red sandstone region, but it was deemed more expedient to introduce them in immediate connection with the descriptive details which respectively suggested them.

Thus, in the general description given of the several members of the red shale and sandstone formation, mention was made in every instance of the degree of adaption to useful purposes, such as those of architecture, statuary, paving, &c. of each particular belt of rock examined. A similar allusion was also made to the uses of the calcareous conglomerate, its fitness for burning into lime and for cutting as an ornamental marble being both alluded to. Care was taken to point out the precise position and dimensions of any thin beds of limestone found interstratified with the red shale or sandstone, and suggestions offered concerning the most suitable situations in which to seek for good and durable building materials among the altered rocks contiguous to the belts of trap. In like manner, in treating of the copper ores of the formation, whatever was of a practical bearing was fully considered.

I proceed to mention one or two other subjects of a somewhat desultory nature, not yet adverted to, which appear to come appropriately under this head.

Peat.—In the meadows and low boggy grounds about Springfield, and also near Connecticut Farms, occur large quantities of excellent *peat* or *turf.* It is rather extensively dug, and employed in the neighbourhood as fuel. According to the statement given, a cord of it properly prepared is as productive of heat as a cord of good oak wood. The mode of preparing it is, to cut it into regular quadrangular masses about two feet in length, with a base four or five inches square. These pieces are carefully dried and sold by the cord like wood.

Back water on the Passaic, caused by the trap dike at the Little Falls.—The Passaic and Pompton rivers, for many miles above the Little Falls, are sluggish and half stagnant streams bordered in most places by extensive meadows and marshes, which are subject to frequent inundations, deemed prejudicial to the health of the neighbouring country. This want of current is manifestly produced by the bold dike of trap rock which intercepts the stream at the Little Falls, forming a sort of natural dam, that backs the water for a great distance along the level country above. The mere removal of this dam of rock from the bed of the river, to a depth of twenty or thirty feet, and over a width sufficient to prevent inundation in times of high water, would be a measure extremely beneficial to a large district bordering on the two streams. A great extent of level meadow land along the Passaic, at present too wet to be productive, would be rendered dry and arable, and might become, when under the plough, some of the best grain land of the State. Such a step would, moreover, ameliorate the quality of the water in the wells of the district, materially benefit the roads, and, a consideration far above all others, it would improve the health of the inhabitants. The expense would be in the removal of the obstruction, and in the compensation to the owners of the water-power which would be destroyed, but its entire amount would fall far short of the great gain to the community, which many conceive would result from the undertaking.

GENERAL VIEW OF THE CIRCUMSTANCES UNDER WHICH THE MIDDLE SECONDARY ROCKS WERE DEPOSITED.

In the general description of the middle secondary system of strata presented in the beginning of this chapter, the notion was advanced, that these materials were deposited by an extensive ancient river, having its source in the southern States, and its estuary in the region of the Raritan and the Hudson, and having its course for the most part southeast of the chain of the Blue Ridge and the Highlands. Several important facts connected with this trough, such as its present *configuration*, the uniform dip and direction of its slightly inclined beds, implying a steady current, their singular constancy of character, so indicative of one general source for the whole, and the obvious identity of their materials with the soils *now* furnished by the ancient rocks from whence we would derive these deposites, all go to confirm the above supposition.

When the details of the geological surveys of Pennsylvania, Maryland, and Virginia, now approaching to completion, shall have been united with the delineations herein given of this interesting group of rocks, the long and narrow tract which they occupy, will be seen to possess in a striking degree the features of a noble river, taking its rise in the primary region of the southern States, and meeting the ocean, probably, at and beyond the outlets of the Raritan and the Hudson.

The traveller passing along the red sandstone belt from the Hudson to the northern confines of North Carolina, will, if his mind be directed to these considerations, become early impressed with the accordant nature of the evidence which accumulates as he advances. In commencing his journey, he will see the whole formation, occurring in part still beneath in part above the present level of the ocean. Passing the Raritan, where, for a certain distance, the tide washes a portion of it, he will next find it on the Delaware, elevated above the ocean level throughout its entire width from Trenton to Durham. Advancing to the Schuylkill between Norristown and Reading, he will observe its height above the tide to have augmented; and crossing thence in succession the Susquehanna, the Potomac, and the James rivers, he will perceive the tract still gradually and uniformly to ascend, until it attains a level of several hundred feet above the sea, marking an inclination nearly corresponding to that which belongs to many of our large rivers now descending from the Appalachian chain into the ocean.

The progressive diminution in the breadth of the formation is strictly in accordance with these facts. At the Delaware, adjacent to the presumed ancient estuary or mouth of this supposed stream, the width of the deposit amounts to *thirty* miles; at the Susquehanna to about *twelve;* at the Potomac to between six and eight, and at the James river to not more than *four* miles.

It may be objected to the argument above advanced touching the regular and gentle ascent of the formation towards the southwest, that the existing slopes of the whole district southeast of the mountains may have been produced during the elevation of the greensand and tertiary strata, at periods subsequent to that which witnessed the drainage of the red sandstone valley.

Did the scope of the present treatise authorize the detailed discussion of this curious point, we think that a comprehensive investigation of the existing levels of the respective tracts, or, in other words, the *relief* above the ocean of the several parallel belts of country conceived to have successively emerged from beneath the sea, would go far to convince us that the channel which received the red shale deposits, possessed to a considerable degree, at least its present gentle slope towards the northeast, *during the epoch of its formation*, which was apparently soon after the cessation of those disturbances which finally elevated the coal.

Let it be observed that the Kittatinny Valley, formed of rocks uplifted at the close of the older secondary or Appalachian epoch, has the same regular and gradual declension in level from the interior of Virginia to the Hudson which we find in the red sandstone belt of the parallel valley southeast of it. From an elevation in the vicinity of the New River, approaching one thousand feet above the level of the sea, it slowly descends northeastward, until, at the Hudson, its general surface rises not more than one hundred feet above the tide. While this is true of the plains occupied by the *older* and *middle secondary rocks,* no such variation in the level of the more recently lifted *tertiary* plain along the sea-board is discernible. From the Roanoke to the Delaware the tide every where penetrates this latter, and its surface in that distance does not descend probably more than one hundred feet. It seems, therefore, altogether improbable that the whole of the northeastward descent in the first two valleys, that northwest and that southeast of the Blue Ridge chain, should have been acquired at the time of the elevation of the tertiary, or at any period later than that of the final drainage of the middle secondary trough. The disturbances of level which took place at the close of the *newer secondary* or greensand period are still further in favour of the same conclusion; for, while the strata of that date were raised to a moderate height, averaging sixty or eighty feet above the ocean in the latitude of New Jersey, they underwent no permanent elevation above the tide in the region further to the southwest, between the Chesapeake and the Roanoke.

That the almost universal inclination of the planes of deposition in the red shale and sandstone formation is the result of the oblique or slanting mode in which the sediment has been laid down by a rapid and *steady* current, and is not due to any upheaving action, admits, I conceive, of very little doubt. If it were a consequence of the latter cause, the vast width of the region in New Jersey over which this northwest dip prevails would imply a thickness for the deposit so enormous as to be beyond all precedent among stratified formations. But we have conclusive evidence of the comparative shallowness of this group of beds, in the fact, that, in several localities, even in the interior of the belt, it has been washed off in patches by denudation, so as to expose the subjacent Appalachian limestone, which appears in these places to have been the original floor of the basin. The denudation along the southeastern border of the tract has, in like manner, in many neighbourhoods, cut away the coarse sandstone and conglomerate beds—the first deposited, and undermost, by order of dip—making the now undermost layers to consist of the red shales. This could obviously not occur if the materials had been precipitated in a nearly level position, as in that case they would have spread themselves along the bottom of the trough too far to the northwest to be removed by local denudation along its southeastern margin.

The very general dip of the strata towards the northwest and north seems plainly to imply the side from which the sedimentary matter chiefly entered this valley. That the lateral influx was principally from the belt of country immediately bordering the basin upon the *southeast* there can be little doubt; and we have only to observe the nature of the rocks skirting that side of the belt in a broad tract, the whole length from the Susquehanna to North Carolina, to find at once the red soil of which these strata consist. Throughout this distance, talcose, chloritic, and hornblendic rocks compose nearly the entire zone of country lying immediately southeast of the red shale; and the red soil which they produce is so identical in aspect and composition with the shales, and is at the same time so *copiously* furnished by their disintegration, as to point plainly to these primary strata as the source of most of the matter of this middle secondary trough. If we conceive the northwestern side of the valley next the base of the hills to have been, as it probably was, the deepest portion, and the red ferruginous materials to have entered this large river from the neighbouring talcose rocks, by currents setting obliquely *across* and *down* the channel, we may at once explain, not only the origin of these beds but their inclined position, and their predominant northwestern and northern dip.

In attempting thus to account for the prevailing dip of the red shale and sandstone strata, I am aware of the local exception to be found in the southeastern inclination of the beds between Middlebrook and Pepack, and its seeming incompatibility with the above views. I would direct the reader's attention, however, to the peculiar position of the Mine Mountain, jutting out into the estuary of the red shale, considerably to the southeast of the general line of coast. It is easy to conceive that its influence must have been to intercept the regular northward current, and to deflect it over a certain area into a species of *eddy*, in which the sedimentary matter would of course assume an unusual direction in its gently inclined surfaces of deposition. Proceeding east from the Round Valley Mountain, we find the dip at the White Horse to be nearly northeast, then *east*, and near the mouth of the Lamington river, southeast, and beyond Somerville, nearly south, affording an almost convincing proof that such an eddy prevailed, and presenting ample evidence, if such were wanting, that the inclined posture of the strata is not the result of an elevatory action.

Respecting the variegated calcareous conglomerates which overlie the red sandstone formation, but little difficulty exists in explaining both their source and the nature of the circumstances which accompanied their production. The fragmentary materials of which they consist, can be traced in every instance to the older rocks of the neighbouring hills immediately bordering the middle secondary plain upon the northwest; and we can discover a relation between the amount of the several kinds of pebbles, and that of particular sorts of easily abraded strata along the flanks of the valley. Thus, in every case where calcareous pebbles and a calcareous cement are abundant in the conglomerate, the older secondary limestone (Formation II.) may be seen at the base of the adjacent hills, and usually at an elevation that indicates it to have been sufficiently above the waves to undergo extensive destruction from a sudden and powerful rush of waters.

In order to account for such a violent denudation along the base of the Highlands, we have only to advert to the state of things attendant upon the outbursting of the trap. This rock, intersecting and overlying equally all portions of the red sandstone, both its earliest and latest formed beds, was manifestly of simultaneous date throughout the entire region. The violent agitation of the whole belt of country, and the vertical rising of the bed of the red shale valley to a higher level, would necessarily set into rapid motion the entire body of its waters. These, rushing impetuously along the shattered strata at the base of the hills confining the current on the northwest, would quickly roll their fragments into that confused mass of coarse heterogeneous pebbles which we see, and strew them in the detached beds of conglomerate which they now form. The protrusion of the trap, the formation and deposition of the conglomerate, and the elevation and final drainage of the whole red sandstone basin, have hardly been consecutive phenomena, so nearly simultaneous appear to have been these events. The whole time occupied by these stupendous changes must have been extremely brief, compared with the period which produced the main mass of the materials of the basin—the red shales and sandstones—which occupy so large a part of it.

Of the Middle Secondary Rocks of the Green Pond and Long Pond Mountains.

When describing the older secondary rocks of the long, straight, and narrow valley which separates the two principal ranges of the primary strata of the Highlands, it was stated that those formations where they appear in the neighbourhood of Green Pond and Macapin Pond, were overlaid unconformably by a group of much newer date, conceived to have been produced in the middle secondary period. I propose to offer a brief account of the position, structure, and probable origin of these insulated strata.

Geographical range.—Tracing these unconformable rocks from New York towards the southwest, they are found to constitute a nearly continuous mountain chain, extending from the western side of Long Pond, past Macapin and Green Ponds, to a point west of Succasunny. From the State line to the Pequannock, the belt consists of a single ridge, somewhat broken down in some places by denudation—this is known as the Long Pond or Raffenberg Mountain; but from the Pequannock southwest for several miles the belt is double, the shorter range forming the Copperas Mountain, and the longer parallel one the Green Pond Mountain, ending north of Succasunny.

These ridges are for the most part remarkably straight, while their summits are nearly level. Throughout considerable distances they present a succession of bold precipitous escarpments, facing invariably the east-southeast. The strata dip in all cases towards the west-northwest, at an angle which is somewhat variable, but which is usually about 30°.

The almost perpendicular outline of these ridges on their southeastern side, the repetition of the same rocks in the two adjoining ranges, and their dipping towards the same quarter, are facts which strongly indicate the existence of one or more extensive longitudinal dislocations of the strata. We can hardly conceive how a mere denudation of the surface, unaccompanied by a disrupting movement along certain lines, could have given to the topography of this formation its present peculiar features.

The Green Pond Mountain terminates in three oval-shaped outlying hills in the prolongation of the main ridge, separated from each other and from it by transverse valleys or notches; through one of which the Morris canal has been carried. A fourth low hill, not precisely in the same line with the others, commences a little south of these and extends longitudinally towards Flanders. It would appear to belong to a different formation from the others, being manifestly an insulated remnant of the sandstone, Formation I., of the Appalachian series.

Composition and Structure.—The formation we are describing embraces two principal members, which preserve their respective characters with very great uniformity. The lowest of these, which reposes sometimes on the primary rocks at the foot of the adjoining hills, sometimes on the lower strata of the older secondary series, originally forming the bed of the valley, is a conglomerate easily recognised. This rock consists of a rather fine-grained compact red sandstone, occasionally argillaceous, imbedding rounded, water-worn pebbles of various dimensions, generally composed of white quartz. When these pebbles are large and diversified in their colour and composition, as happens in certain beds, and when the paste is less abundant and more argillaceous than usual, the whole mass possesses a considerable resemblance to the less calcareous varieties of the Potomac marble. Bowlders of a rock having these features lie strewed in great numbers in many parts of the red sandstone region east of the Highlands, extending as far as the Hudson, and traceable to this stratum of the Green Pond Mountain.

In the inferior beds, the character of the rock is somewhat different; being in many places almost white, and consisting chiefly of a white sandstone, thickly studded with white quartz pebbles. These layers are conspicuously seen in the outlying low hills, near the southern termination of the Green Pond Mountain; they are also visible at many other points, as, for example, ten miles north of Macapin Pond. Their contiguity to a tract of white sandstone of the older series, Formation I., suggests this rock as the probable source of the arenaceous materials of these beds. We thus find in this, as in other formations, that the lowermost layers are derived from the more immediately adjacent rocks, being deposited during the first influx of the currents, before time had elapsed for the introduction of the sediments from more distant quarters. Ascending a little, the beds of the lower part of the conglomerate become progressively more tinged with the red matter, so prevalent throughout the higher portions of the formation.

The other division of the formation overlies the former, and is a compact argillaceous red sandstone, much resembling the firmer varieties of the red shale of the district east of the

Highlands. It is seen well developed about one mile north of the head of Green Pond, where it forms the point of the Green Pond Mountain, near the notch or dislocation which traverses it two miles south of the Pequannock. Both in this vicinity and in other parts of the range, this stratum is divided by a system of oblique cleavage joints, which cross the general plane of the dip nearly at right angles, having an inclination of about 45° towards the southeast. These joints impart to much of this rock a slaty structure, calculated readily to mislead the observer respecting the true direction in which these strata have been elevated. The conglomerate is in like manner jointed by planes of cleavage, but at far wider intervals; being divided into large massive cuboidal blocks. These joints observe the same direction and dip as those in the overlying fine-grained red sandstone and shale.

The total thickness of the formation, including the conglomerate and the red sandstone, probably exceeds six hundred feet; but from the appearance of great faults or dislocations in these strata, the determination of their precise depth is attended with much uncertainty.

Of the probable Origin of the Formation.—From the wholly insulated position of these unconformable strata, encompassed on all sides by rocks of older date, and from the nonappearance hitherto of any organic remains of a distinctive kind, by which to infer their age and mode of origin, we are prevented from arriving at any very satisfactory views regarding the particular circumstances under which they were produced. The striking analogy which they bear, however, to the strata of the middle secondary series both in composition and appearance, and their lying in the same unconformable manner upon the previously uplifted rocks of the Appalachian group, induce us to consider them as deposits from the same mass of waters. This suggestion acquires additional weight, when we reflect that the long and narrow valley embracing this belt of conglomerate and sandstone, opens immediately into the great basin of the middle secondary series. From the denuded condition of the southwestern portion of the Green Pond range, and from the apparently natural outlet which German Valley would afford for the waters in their passage across this mountainous district, it seems not improbable that these rocks once filled the bed of this valley throughout its whole length as far as Clinton. At the final elevation of the red shale and sandstone rocks, if, as we suppose, *these* strata were also uplifted, the extensive dislocations to which they have obviously been subjected, will account for the removal of a portion of the beds, exposed as they must then have been to the full violence of the floods thus set in motion.

PART II.

GEOLOGY OF THE SOUTHERN DIVISION OF THE STATE.

Introductory Remarks.

The strata of the southern half of the State arrange themselves in two distinct groups, and belong to two separate periods. The oldest or earliest deposited of these groups is proved, by the character of its organic remains, to have originated during the latest eras of the *secondary period,* while the more modern belongs to an earlier epoch of the succeeding *tertiary* dates.

In tracing these deposits over any considerable area, we discover that the whole series, though nearly horizontal, possesses an appreciable dip towards the southeast. As a consequence of this slight inclination, the lower strata rise successively to the surface as we advance towards the northwest; those at the bottom of the series forming the northwestern boundary of the region, where they repose upon the more steeply dipping beds of the middle secondary and primary formations, between Trenton and the Raritan river.

A gently undulating line, drawn from Shark Inlet on the Atlantic coast, to Salem, separates the secondary and tertiary groups. The district to the northwest of this line comprises only the former, while that to the southeast contains the latter. The tertiary region is extensively overspread, however, by a deep covering of nearly white oceanic sand, destitute of organic remains. We are thus precluded, not only from ascertaining definitively to what precise date we ought to refer this superficial stratum, but the extent to which it conceals the tertiary and secondary deposits. The tracts in which the former are actually exposed near the surface, are comparatively inconsiderable.

CHAPTER I.

OF THE UPPER SECONDARY SERIES, EMBRACING THE GREENSAND FORMATION.

General Description.—Adopting as hitherto the ascending order, we shall describe first the upper secondary formations lying to the northwest of the line above designated. This series includes naturally five separate sets of beds, the characteristic features and composition of which, commencing with the lowest, are as follows:

First. A group of *sands* and *clays* of several colours and of somewhat variable constitution, but frequently of extreme whiteness and remarkable purity. Among these occur beds of pure potters' clay. This division of the general series rests, along its northwest margin, from the Raritan to the Assunpink, in an unconformable manner upon the middle secondary rocks, and from the Shipetaukin to the Delaware upon the upturned strata of the primary belt. It contains towards its upper beds much of the dark blue sandy clay, which is also associated with the overlying greensand, from which it is not separated by any well-defined limit.

Second. A somewhat mixed group, consisting of beds almost wholly composed of *greensand* in a loose and granular condition, alternating with and occasionally replaced by layers of a blue, sandy, micaceous clay. This is the "greensand formation," properly so called. The greensand having become extensively employed in agriculture as a fertilizer of the soil, the bed in which this mineral is the chief ingredient has acquired the name of marl. The various features assumed by these strata in the different parts of the extensive tract which they occupy, will be specified in another place.

Third. Immediately overlying the greensand formation near its southeastern border, we find several limited exposures of a yellowish granular limestone of rather crystalline structure, and frequently siliceous composition. This rock exists in rather irregular thin flaggy bands, usually from one to three inches thick. Between these we often find thin layers of loose granular calcareous sand, identical, or nearly so, with the matter of the rock, but destitute of cohesion.

This formation contains a profusion of organic remains, many of which belong in like manner to the underlying greensand, though some occur in it alone. Resting usually in direct contact with the greensand stratum, it contains often a moderate proportion of the green granular mineral, sprinkled throughout its mass.

Fourth. A yellow very ferruginous coarse sand, containing sometimes a small proportion of the green mineral. This stratum is in some places thirty feet thick. In the Nevesink Hills and in one or two other localities, it occurs as a soft sandstone, containing hollow casts of several characteristic fossil shells of the greensand formation. Throughout much of the central portion of the greensand region, this bed is in the condition of a loose sand, but abounds in organic remains in the state of solid casts, showing the interior form of numerous bivalve and univalve shells. The thin limestone next under it being very partially developed, this yellow sand generally rests in immediate contact with the greensand deposit, the two beds sometimes blending almost insensibly into each other.

Fifth. Resting upon the former and constituting the highest ascertained member of the upper secondary series in the State, there occurs a coarse brown ferruginous sandstone, sometimes passing into a conglomerate. It is composed of translucent quartzose sand, small fragments of felspar, and pebbles of white quartz, cemented together by a dark brown paste of oxide of iron. The green mineral in detached grains is likewise a common ingredient. The position of this rock is usually upon the summits of the insulated outlying hills, which rise occasionally above the general plain of the "marl region."

In employing for these upper secondary deposits of the State, the title of "greensand series," and for one member of the group that of the "greensand formation," I wish not to convey the impression that I regard these strata as the equivalents in the strict sense of the word, of the greensand formation, so called, of Europe. The remarkable abundance of the green granular mineral in some of these beds, and its existence in greater or less degree in all, besides the obvious identity between most of the fossil genera in this and the European group, suggest the propriety of adopting the above name, as characterizing the peculiar composition of the deposit, and its relationship to the rocks of a well known system in other countries. But much yet remains to be ascertained respecting the organic remains of the two deposits in the respective continents, before we can determine more than approximately the true amount of *affinity* subsisting between them. The existence of but *one or two species* common to the European and American formations, renders it indeed a question of much uncertainty, to what part of the cretaceous period as defined in Europe, we are to refer the origin of these deposits of New Jersey, nor are we able positively to decide, merely by the relationship of the genera, whether the cretaceous period embraces both the commencement and termination of the American greensand series.

SECTION I.

Of the Potters' Clay Formation; Geology of Middlesex and part of Mercer counties.

Geographical Range.—The southern edge of the middle secondary district marks the northwestern boundary of this formation, from the mouth of Lawrence's brook to the Shipetaukin creek, between which and the Delaware, the gneiss rocks of the Assunpink form its limit. Advancing southwestward, the formation occupies a narrow belt along the Delaware, from Bordentown to a point opposite New Castle, the southeast bank of the river being its northwest boundary. Its inferior beds do not appear in Pennsylvania, having been washed away by the currents which excavated this part of the valley of the Delaware.

In some places the river in its meanderings cuts across the belt almost to the southeastern margin, where it is bordered by the lower beds of the greensand deposit. This is the case at Bordentown, where the greensand approaches the Delaware within half a mile. Where the river on the other hand recedes towards the northwest, as for example opposite Tullytown, the lower beds of the series are preserved; and hence we have in that locality the white clays and sands of the "clay banks."

This lowest division of the upper secondary series passes into the greensand formation by a gradual transition; we cannot, therefore, delineate very precisely, the limit which separates the areas of the two formations. It will be traced with as much minuteness as practicable when we give the ascertained boundaries of the greensand or marl tract, being the northwestern margin of that important belt. It will be sufficient for our present object to state that this line, bounding these inferior clays and sands on the southeast, ranges nearly parallel with the railroad which unites South Amboy with Bordentown, lying southeast of it at an average distance of about three miles. Between Bordentown and Salem it preserves a rather greater distance from the Delaware.

Besides the tract thus traced, embracing most of the deposits of pure potters' clay in the State, there occurs an isolated bed of remarkably pure white clay and sand, which obviously belongs to this formation: it lies between Woodbridge and the Raritan, having escaped the destructive diluvial action which has swept away so large a portion of these lower beds of the formation in other places.

Composition.—White and yellowish sands, and white-blue and mottled-blue, and pink clays, used in pottery, occur abundantly in the lower and middle portions of this formation. Higher in the series these beds become less predominant, and we meet with a larger proportion as we ascend, of darker, more ferruginous and carbonaceous sands and clays. A very common material among these is a *dark, sandy, micaceous clay.* This deposit when moist, is usually lead-coloured or a dark-blue, or sometimes almost black. In this state it is somewhat plastic, becoming as it dries, of a light bluish-gray colour. It is rarely free from a considerable proportion of ordinary siliceous sand and mica, both usually in a state of minute division. The dark colour seems chiefly to arise from a small quantity of carbonaceous matter in a diffused condition. Relics of vegetation, such as carbonized wood or lignite, amber, and retinasphaltum, often occur in it, but particularly the first. It exhales the smell of marsh mud, though this gives place occasionally to that of *sulphur*, emitted by the decomposing *sulphuret of iron,* which is often copiously present.

To the reaction of the *alumina* and sulphuret of iron, assisted by the oxygen of the atmosphere, we are to attribute the incrustation of sulphate of iron and sulphate of alumina sometimes seen upon its surface, imparting to the mass an astringent and acid taste, and endowing it with properties very noxious to vegetation. Some layers, containing a larger quantity than usual of the sulphuret of iron, acquire even a brown colour at the surface, caused by the amount of the hydrated oxide of iron produced by decomposition. The impervious texture of this material, causes the water which reaches it through the overlying porous sandy beds, to appear along its upper margin in the ravines and other depressions of the surface wherever its outcrop occurs. Much of this water passing through the adjacent beds of greensand, which are often charged like the blue clay with the decomposing sulphuret of iron, becomes impregnated to some extent with the sulphate of iron, producing a precipitation under favourable circumstances, of the hydrated peroxide of iron, in the form of *bog iron ore*, and *yellow ochre.*

To exhibit more definitely the composition of this blue earth, I here submit a chemical analysis of a specimen procured from the base of the Nevesink hills, on the Raritan bay, which will show the average composition of a very abundant variety of the stratum.

Analysis of the Blue Astringent Micaceous Clay.

Silica, - - - - -	35·75
Alumina, - - - - -	39·25
Protoxide of iron, - - -	12·10
Sulphuric acid, - - - -	1·95
Carbonaceous matter, - -	1·00
Potash, - - - - -	0·30
Magnesia, - - - - -	0·25
Muriate of soda, - - -	a trace.
Oxide of manganese, - - -	a trace.
Water and volatile matter, - -	7·00
	97·60

That certain portions of this deposit may be rendered available for enriching the soil, I firmly believe. The statement already made, that there sometimes exists in it a considerable share of the *greensand*, in other words, of the fertilizing material of the marl, is enough to encourage those who possess it and not the genuine marl, to give it their attention. Notwithstanding the very frequent, we may say the almost invariable occurrence, of the astringent matters, which are in themselves so unequivocally deleterious to vegetation, certain precautions may be adopted, such as must make it a valuable auxiliary to the farmer in places where the genuine marl lies too remote. The recommendations respecting the mode of using it, will be found in the chapter on the economic geology of the greensand formation.

This material alternates both with the lighter coloured clays and sands already spoken of, and with the greensand, which it overlies in some parts of Monmouth county. It is well exposed for examination in the cuttings upon the Camden and Amboy railroad. Containing occasionally a small proportion of the green grains, and resembling somewhat, when moist, the true greensand or marl, it is frequently applied to the soil through a misconception of its true nature, to the serious detriment of the crop.

ECONOMICAL GEOLOGY.

White Clay of Woodbridge.—About one mile southwest of Woodbridge, near the level of a small stream on the road to New Brunswick, there occurs an insulated deposit of white clay and white sand, in which both materials are of remarkable purity.

This local bed is surrounded by the red shale rocks of the middle secondary series, and would seem to be a remnant of the lowermost layers of the upper secondary group, lying in a depression of the surface where it has escaped removal during the general denudation of the strata.

Beneath about ten feet of reddish diluvial matter, derived from the adjoining red shale, we find a bed of pure white sand, regularly stratified, and dipping gently westward. Its thickness is about ten feet. This sand is much esteemed as an ingredient for the manufacture of fire bricks. Underneath the sand lies the white clay, in a bed about eight feet thick; when dry it is very nearly white, some portions of it, however, have a very slight bluish tinge. It is much used in the manufacture of pottery and fire bricks. The purer varieties are admirably adapted for making the glaze for paper-hangings, being employed for this purpose.

About three-fourths of a mile southwest of this excavation, another similar deposit is exposed in some recent diggings. The clay at the latter place surpasses even that of the former in whiteness, and in its exquisite smoothness of texture.

In the descending order, the beds at this place are, first, diluvial matter ten or twelve feet thick, then a layer of sand, and under this again the clays between seven and eight feet thick. These consist of an upper bed, somewhat sandy, but well adapted for making fire bricks, two feet in depth, and a lower layer, also two feet thick, remarkable for its whiteness and fine texture. This latter kind is particularly esteemed for making the glaze for paper. Immediately below this lies another bed of pure clay, having also a fine texture. It is white with reddish or pink blotches; its thickness is from three to four feet. It is an observation of the workmen, that when the clay is pure the sand associated with it is so likewise.

White Clay, Albion Mill.—A similar deposit of white clay and sand, occurring like the last near the bottom of the series, is to be seen not far from the Albion Mill, about five miles southeast of Trenton.

The clay at this spot, though moderately white and free from ferruginous matter, is mingled with rather too large a proportion of fine white sand, to suit it for making the better kinds of stoneware. It is not improbable, however, that its composition is such as to fit it for the manufacture of good fire bricks.

Clay Banks of the Delaware.—About half way between Bordentown and Burlington, beds of clay of somewhat analogous composition occur along the southern shore of the Delaware, in the line of cliffs called the "Clay Banks." The deposit in this place presents more variety than is visible in the other localities described.

The clay, though in some layers nearly white, is in many places slightly tinged or spotted with pink or bluish stains. It is dug to some extent and employed for making pottery. Besides the whiter varieties, there occur others of a dark blue colour, having more or less sand and ferruginous matter in their composition. Imbedded between the layers of clay are seams of white and yellow sand.

The clay beds of this locality would appear to occupy a middle position in the formation, being higher than those southwest of Woodbridge, but inferior to the strata of potters' clay near South Amboy, to be next described. They lie very nearly in a range with the white sandy clay seen near Albion Mill, with which also a dark blue argillaceous bed is associated.

Potters' Clay, South Amboy.—Somewhat higher in the order of stratification, we find beds of bluish white and mottled clay, well suited for the manufacture of a much esteemed variety of stoneware.

This highly useful material occurs in a bed several feet thick, ranging along the shore of the Raritan Bay from South Amboy, for a space of about two and a half miles, to the marshes called the Cheesequakes. The stratum is nearly horizontal. Its upper surface is washed by the tides upon the beach; a mile farther to the southeast, it rises twenty-five feet above the shore, and a few hundred yards beyond this, it gently sinks again, so that two miles from Amboy it is overlaid by the ordinary dark-blue astringent clay. There are two principal banks or quarries where this clay is procured on a rather extensive scale. In that nearest to South Amboy, which goes under the name of Churchill's bank, the mass has been excavated to the depth of twenty-five feet. The lowest bed, which is that principally used, is a grayish blue clay, which, on drying, becomes nearly white. Besides a large proportion of alumina, it contains a large quantity of silica, in a minutely subdivided condition. Scattered through it occur numerous *dark specks*, which seem to be sulphuret of iron in a state of decomposition. After the surface of this clay has been exposed for some time to the air, these specks acquire a light yellow colour, which most probably arises from the oxidation of the iron. It is a curious fact, that the clay in which these dark specks are seen, is preferred in the manufacture of the stoneware, for which the material is chiefly used. Resting immediately above this layer, there is a variegated or mottled variety, often most beautifully stained with red, green, and other coloured blotches. This, which is called *peach blossom clay*, is mixed with the former sort to make a particular variety of the pottery. About a fourth of a mile further to the southeast is another very extensive clay bank, the property of Mr. C. Morgan. At this spot, the lowest layer seen above the beach, is a variegated gray sand of unknown thickness, its surface being near the level of the tide. Immediately upon it rests the bed of clay, which varies in thickness from nine to twenty-one feet. It closely resembles Churchill's in composition, and is a very superior clay for making the kind of pottery called stoneware. In one part of the bed the clay contains a little mica in very minute scales. This is said greatly to injure its value as a material for making pottery. Other portions contain the dark specks supposed to be useful. Some bands in this portion of the stratum are reddish, and furnish the peach blossom clay. A white astringent efflorescence, probably a sulphate of alumina and iron, or a kind of alum, is found upon a certain layer near the upper part of the bed. This seems to be derived from the decomposition of the sulphuret of iron, which appears to be a characteristic component of the whole series of strata of which this clay bed is a member. The upper surface of the clay, though slightly undulating, is pretty nearly horizontal. Immediately upon it there occurs in many places a layer of sand of a few inches thickness, which contains vegetable relics, such as fragments of wood completely carbonized, and in the state of lignite, and also small pieces of nearly pure charcoal. *Amber* also occurs here, called rosin by the workmen.

Resting on the top of this layer is a bed of variegated sand, streaked with white, gray, red, and other colours. This is in some places ten feet thick, and over it, at various elevations, is a layer, generally about two feet thick, of the tough dark-blue astringent clay, showing a yellowish efflorescence of copperas upon its exposed surface. It contains, as this material very frequently does, a good deal of mica in minute scales, and a considerable proportion of common siliceous sand. This upper bed increases in thickness as we advance towards the meadows of the Cheesequakes, and southeast of Morgan's excavations none of the underlying clay has been found. In all probability it lies a little below the level of the beach, though it is possible that it may either thin out or graduate into the dark clay that elsewhere lies above it.

On the top of the uppermost bed of sand above described, but somewhat nearer South Amboy than the commencement of the dark astringent clay, there is a yellow and much coarser sand, extending up to the soil. In this place its total thickness above the white clay is twenty feet. The materials of this uppermost layer are sometimes as coarse as gravel; and it seems to belong to the superficial diluvium, as it has an irregular undulating outline which strongly contrast with the nearly straight surfaces of the beds beneath. A similar exhibition of the diluvial sand and gravel reposing upon the other sands and the dark clay here described, may be witnessed at various places upon the Camden and Amboy railroad, and also conspicuously in the banks at White Hill, where the line separating the two deposits is very distinct. It is *undulating*, as if the original surface of the lower bed had been scooped by the currents that carried along the sand and gravel now forming the upper or diluvial stratum.

Analysis.

Potters' Clay, Morgan's Bank, South Amboy.

Description.—Mottled white and red throughout the mass, but more particularly on the surface; highly gritty between the teeth; by calcination at a full red heat becomes of a brick red colour.

In 100 parts it contains:

Silica, - - - - -	67·6
Alumina, - - - -	15·8
Peroxide of iron, - -	5·6
Water, - - - - -	9·3
Loss, - - -	1·7
	100·0

SECTION II.

Greensand Formation—"Marl."

Geographical Range.—The second division of the upper secondary series, which, in allusion to its peculiar composition, I have entitled the *greensand formation*, is by far the most interesting portion of the whole deposit, whether we consider the curious properties of its chief constituent, the interesting relations of its numerous fossils, or the highly valuable use as a fertilizing agent, to which a large portion of the stratum is applicable.

Dipping at a very gentle inclination towards the southeast, its lower layers rise to the surface, and are finally lost towards the northwest, along the irregular denuded margin already referred to as forming the southeastern limit of the underlying potters' clays. Traced in detail, this northwestern boundary of the greensand formation may be described with sufficient accuracy as commencing at the southern shore of the Raritan Bay, a little to the northwest of the western termination of the Highlands of Nevesink, about the mouth of Compton's creek. Its course from this point, where the underlying strata are seen to rise above the level of the water, is a little south of west, past the small village of Mount Pleasant, to Deep run. From Deep run, the visible limit of the greensand takes a nearly south direction for nearly two miles, and then a westerly one to the Matchaponix creek, which it crosses about two miles southeast of Spotswood. It next crosses the Manalapan, two miles above the mills marked on the map as Mount's, previously sweeping in a somewhat concave line to the southeast. Between the Manalapan and the Millstone streams, it presents a similar curve towards the southeast, appearing on the latter about half a mile above the spot called the Red Tavern. Thence, bending as before, first to the south, and then to the west, it crosses Rocky brook, half a mile below Millford. From this point its course is first south to Empty run, then southwest to Doctor's creek, a little above Allentown, and then west-southwest along the southern side of the same stream to Crosswick's creek, which it passes about half a mile above the little village called Groveville. From Crosswick's creek to Burlington creek the line of the greensand is nearly straight, crossing Black's, Craft's, and Burlington creeks, each at points about one mile and a half from the Delaware. Passing the latter stream, it recedes somewhat from the river, meeting Rancocus creek about four miles above its mouth, near Franklin Park and Pensaukin creek, one mile west of Moorestown. Its course next, is a little more westward, to Cooper's creek, down which the stratum extends, to within four miles of Camden. Sweeping again slightly to the south, the line reaches Timber creek, one mile and a half from the river. Thence its direction is nearly west-southwest as far as Raccoon creek, the line crossing in the interval Woodbury creek near Woodbury, and Mantua creek near Sandtown. Passing Raccoon creek about one mile below Swedesboro, it deflects more to the south, and pursues a nearly straight course to its point of termination near Salem, crossing Oldman's creek at Sculltown, and Salem creek about two miles west of Sharptown.

The undulations of this northwestern boundary of the greensand appear to arise less from any variations in the amount of the southeast dip, which is nowhere more than barely perceptible, than from the inequalities in the denudation of the stratum along its margin, and more especially from the irregular overlapping of the diluvial covering, which, particularly in the eastern side of Middlesex, conceals the true limit of the formation in all the higher tracts of ground between the streams, and gives to the visible boundary the curving outline alluded to. The denuding flood, which has evidently swept along the valley of the Delaware, seems, in curving to the south, to have cut away a large portion of the greensand, which originally extended southwest of Oldman's creek, giving to it a wedge-like form at its termination near Salem. The true strike or direction of the stratum would carry its northwest margin to the Delaware somewhere opposite Newcastle, as shown by the position of this side of the formation, where it reappears in the State of Delaware, in the vicinity of Bowersville. The oblique course of the denudation across the belt is further manifested in the nearly north and south direction of its margin on the western side of the river. In consequence of this, the southwest point of the formation in New Jersey lies opposite the general southeast margin in Delaware; and the northwest termination of the tract in the latter State, is in the prolongation of the general northwest edge already traced across New Jersey as far as Oldman's creek.

From the point where the northwest boundary of the greensand commences, the formation is exposed for a considerable height along the base of the Nevesink Highlands, the whole distance from Compton's creek to the mouth of the Nevesink river. South of this point it appears along both sides of Shrewsbury river, east of the head of which it is seen skirting the sea coast. From about two miles north of Long Branch, southward as far as Shark Inlet, the stratum reaches almost to the ocean beach, being only hidden in places by a superficial covering of white sand, blown for a short distance inland from the shore. We do not find it either at the sea side or for three miles in the interior any where south of the estuary of Shark river. But a little west of the Poor House the edge of the formation crosses Shark river, and takes a gently undulating course towards the southwest.

In consequence of the wooded character of the country along the southeastern side of the greensand, and the irregular and obscure manner in which the white sands overlap this stratum, the southeast boundary is much less capable of being distinctly defined than that on the northwest. Aiming at as close an approximation to accuracy as the structure and condition of the region will permit, I have traced the margin of the formation from Shark river to where it crosses the Manasquan river, about one mile east of Squankum. Its general course thence is nearly westward until it is seen on Tom's river, which it crosses about a mile northeast of Goshen. Assuming in this neighbourhood a nearly southwest direction, and passing near the above village, it ranges about a mile to the southeast of New Egypt, and passes Scrabbletown to Rancocus creek, which intersects it about one mile east of Pemberton. Thence it passes about one mile and a half southeast of Vincentown, and a mile southeast of Medford, reaching Timber creek near Clementon. It lies rather more than a mile to the southeast of Blackwoodtown. On Mantua creek, the limit of the greensand is rather further to the southeast, being visible near a mill-dam about two miles in a direct line from Glassboro. Upon Raccoon creek, its position is nearly two miles to the southeast of Mullica Hill, and upon Salem creek about half a mile east of Woodstown. Pursuing the same general southwest direction, it is seen on Mannington creek, three-fourths of a mile to the southeast of Mannington Hill; beyond which to Salem, where it terminates, it follows very nearly the margin of the meadows of Fenwick's creek.

The belt embraced between the two lines thus delineated, has the form of a long and acutely tapering wedge, the base of which is traced by the coast of the Atlantic Ocean and Sandy Hook bay—the point being marked by the limit of the firm land north of Salem. A slight inclination of the surface of this formation may be shown to exist uniformly from its northeastern towards its southwestern extremity. Independently of proofs derived from the known elevation of the country at various points, we have evidence of the correctness of this statement by merely observing the position which the belt occupies in relation to the streams in the different portions of its range. In Monmouth, where it is widest, it includes the head waters of nearly all the streams which empty either into the Atlantic Ocean, or the Raritan and Delaware rivers. But, crossing Burlington, Gloucester, and Salem counties, its position as we advance southwestward is nearer and nearer to the mouths of the several creeks entering the Delaware. The whole of the strata have been manifestly uplifted to a greater height in Monmouth than elsewhere, which circumstance, in connexion with the less extensive denudation of the northwest side of the belt, readily explains the breadth of the formation in that quarter.

The area here designated as including the whole of the visible greensand formation, embraces also several local, insulated tracts of the other overlying divisions of the upper secondary series. These are obviously but the remnants of strata which at one time spread themselves extensively over the greensand. The general southeast dip of all these deposits, renders their existence beneath the superficial sands of the region to the southeast extremely probable. To the almost universal destruction of the yellow sand and brown sandstone, which form the two upper strata of the series, we are to ascribe, I conceive, the deep and general covering of loose yellowish and white sands which conceal the rest of the formations throughout so large a portion of the region southeast of the greensand belt.

Composition of the Greensand or "Marl" Formation.

The greensand formation comprises, strictly speaking, several subordinate beds, all belonging, however, to two principal varieties. In the first of these, the green granular mineral is the predominant and characteristic ingredient. The second consists, on the other hand, of a dark-blue clay, mingled with more or less siliceous sand. This latter material constitutes the usual floor upon which the true greensand deposit rests; and it occurs, in like manner, especially in the northern and eastern portions of Monmouth county, both above the uppermost visible greensand, and included between its beds in one or more alternations. Appearances would seem also to indicate that these two deposits replace each other in the same bed, when traced for considerable distances. Indications of this passage from the one material to the other are chiefly discoverable in the lower portions of the formation, or along its northwestern margin. As the same dark clay, associated with the greensand, abounds throughout the upper portion of the next inferior division of the series, or that which we have styled the potters' clay formation, it is impossible distinctly to define the lower limit of the true greensand formation. I shall, for convenience sake, however, group all the strata below the lowest bed of greensand, with the division containing the potters' clay.

The external characters, and usual chemical composition of these blue astringent clays lying adjacent to the greensand, have been described in the previous section, when treating of the lower part of the series, to which deposits they more strictly belong than to the greensand. I shall confine myself, therefore, in this section to a description of that part of the present formation which mainly characterizes it, namely, the greensand deposit itself.

Composition of the Greensand.

Description.—The predominant and often the sole ingredient in this bed, is a peculiar mineral occurring always in the form of small dark granules, about the size of grains of gunpowder. their form is roundish, and they are often composed of two or three smaller ones united together, a distinctive feature, by which they may at once be recognised from other dark kinds of sand. Though they contain on the average nearly fifty per cent. of silica, they are not gritty, but may be readily bruised between the teeth, or upon the nail, and some varieties, when moistened, admit of being kneaded into a half plastic mass, like impure clay. The prevailing colour of the grains is a *deep green*, though sometimes the tint is as light as that of verditer. It is often of a dull greenish blue, and not unfrequently of a dark chocolate colour.

Along the eastern side of the marl tract in Monmouth, Burlington, and Gloucester, the stratum comprises very generally two varieties of the greensand, distinct as to colour, and holding generally the same relative position to each other. The uppermost layer, where it appears (for it is not always present), is of a light and glowing green, having very nearly the hue of the green paint called *verditer;* while the lower one is the common dark variety, of a dull bluish-green, or sometimes of a dull blue colour from adhering clay.

In some instances, particularly where the material constitutes the soil, the granules possess a brownish colour, the consequence evidently of the protoxide of iron which they contain, having undergone upon the surface a change to the condition of the peroxide. The dull colour so usual to the surfaces of these grains, when contrasted with the brighter green within the mass, would appear manifestly to proceed from the same cause. Some shade of green may be pronounced to be the colour essential to this mineral, as all the deviations from this tint are attributable either to oxidation, or to a thin coating of clay, which frequently encrusts each grain, and from which the deposit is rarely altogether free. When a mass of the greensand or "marl" is washed, especially with water to which a small quantity of an acid has been added, we invariably find the granules assuming a bright green surface. This colour is also produced in all cases when we mash or bruise a grain, no matter what may be its colour externally. By crushing the grains upon a sheet of white paper, we have an easy and unerring test in the colour of the streak, by which to recognise this material from all other varieties of sand.

Though the green granular mineral here described, constitutes the essential and distinctive ingredient in the greensand stratum, it rarely exists unassociated with several extraneous substances, particularly *clay* and *white siliceous sand.* These constitute sometimes as large a proportion as fifty per cent. of the bed, causing much variety in its external aspect, and influencing materially its properties as an agricultural agent. The sand which is generally white or semitransparent quartz, existing usually in relatively small amount, the clayey matter being ordinarily the most abundant. This latter is of several tints, but is commonly of a light gray or lead-colour. It is also occasionally chocolate-coloured, brown, and even nearly white. Coating frequently the surfaces of the green grains, it conceals their true colour, imparting its own hue to the entire mass. As it is somewhat adhesive when moist, it gives to the stratum where it is abundant the character of a partially plastic clay. Besides the white sand and this clayey material, we often find a minute quantity of finely divided mica mingled with the greensand.

Subjecting the marl in the compound condition in which it occurs in the stratum to analysis, mechanically performed, I have ascertained the relative proportions of its several ingredients for a great number of localities. A large body of results will be presented in the section treating of the economical details of the greensand formation. But in the mean time, with a view to exhibit the prevailing composition of the stratum, the seven following analyses are presented.

Analyses of the "Marl."

A specimen from the pit of William Little, near Middletown Point, Monmouth county.

The material at this locality is of a light stone-gray, inclined to greenish. Closely examined, the green granules are easily distinguishable. At a little distance it has the aspect of a light-coloured clay. The greensand procured from it by washing is of a light green colour.

When separated into its constituents, 100 parts, afford:

Greensand,	-	46·73
Clay,	- -	53·27
Quartzose sand,	-	none.
		100·00

A specimen from Thorp's pits, near Squankum, Monmouth county, (upper part of the bed.)

This marl is of a dark leaden-gray colour, owing to the presence of a large proportion of clay. The greensand when freed from this adhering clay by washing, is of a dark green. Besides the clay, the mass contains a considerable proportion of quartzose sand.

100 parts, afford:

Greensand,	-	58·36
Clay,	- -	27·64
Quartzose sand,	-	14·00
		100·00

A specimen from Horner's pits, near the Bridge, Hornerstown, Monmouth county.

The colour of this marl is a rather light green. After having been washed, its greensand though consisting chiefly of bright green granules, contains, also, some of a brown ferruginous colour. Besides a rather large amount of clay, this marl possesses a small per centage of quartzose sand.

100 parts, afford:

Greensand,	-	75·90
Clay,	- -	20·10
Quartzose sand,	-	4·00
		100·00

A specimen from John Woolston's pit, one-fourth of a mile south of Birmingham, near Rancocus creek, Burlington county.

This marl is but slightly cohesive. Its colour is a leaden-gray. Being washed, the greensand exhibits a clear green colour; it occurs in small granules, with a little quartzose sand admixed.

100 parts, afford:

Greensand,	-	82·60
Clay,	- -	10·40
Quartzose sand,	-	7·00
		100·00

A specimen from the pits of Mr. Hoffman, one mile and a half east of Barnesborough, Gloucester county.

In its native condition, this marl is of a rich green, rather lighter than the medium tint. The greensand which it yields by washing, is of a somewhat darker colour, but uniform. The granules are moderately large, and with very few intermingled grains of common siliceous sand. Minute grains of *carbonate of lime* occur in it, but in trivial proportion.

100 parts, afford:

Greensand,	-	85·58
Clay,	- -	13·42
Quartzose sand,	-	1·00
		100·00

A specimen from Jonathan Riley's pits, at Woodstown, Salem county.

The marl of this locality is of a dark dull greenish gray, with a tint of brown. This colour is owing to the ferruginous character of its clay. It is almost entirely free from quartzose sand, but contains a very small amount of *carbonate of lime* in minute granules. When washed, its greensand is of a very deep tint, nearly black; some of the grains, however, are brownish.

100 parts, afford:

Greensand,	-	88·28
Clay,	- -	11·72
Quartzose sand,	-	none.
Carbonate of lime,		a trace.
		100·00

A specimen from the farm of James Smith, Mannington Hill, Salem county.

This marl has a rather green colour, of the average depth of tint. When washed, the greensand is of a rich dark green.

100 parts, afford:

Greensand,	-	88·80
Clay,	- -	10·20
Quartzose sand,	-	1·00
		100·00

Besides the aluminous and siliceous matters here recorded as usually present with the greensand in the general mass, there occur occasionally several other substances, which, though comparatively minute in quantity, are possessed of active properties. Some of these materials are probably deleterious, while some are undoubtedly beneficial in their action upon vegetation. The substances referred to are *carbonate of lime*, already mentioned, *sulphate of iron, sulphate of alumina, sulphate of lime*, and *sulphate of magnesia;* also, *phosphate of iron.*

They appear to be derived, mainly at least, from constituents in the clay, and only very partially, if at all, from elements in the greensand itself.

The *carbonate of lime*, in most instances, we can trace to fossil shells and other organic remains, imbedded in the stratum. The *sulphate of iron*, obviously proceeds from the action of the atmosphere and moisture on the *sulphuret of iron*, so abundant in the clay; and the sulphate of alumina from the union of a portion of the sul huric acid thus developed, with the argillaceous earth of the clay; while the sulphates of lime and magnesia may result, either from the combination of the same acid with some of the lime and magnesia, sometimes present in a minute share in the green mineral, or more probably from its reaction on the carbonates of lime and magnesia, existing like the sulphuret of iron in an insulated state. The phosphate of iron, is no doubt derived from phosphoric acid, traceable to the animal remains, acting on oxide of iron.

Several of these substances develope themselves upon the mass of the marl after it has been dug and exposed to the atmosphere, in the form of a white efflorescence, encrusting alike the clayey matter and the granules of greensand, with a delicate crystallization resembling a light frost. Collected and carefully examined and analyzed, this efflorescence will be found almost invariably to consist when it is of a pure white, of either the sulphate of magnesia, or sulphate of lime, (gypsum,) the latter predominating; and sometimes, these two occur united. In some instances, we recognise it to contain the sulphate of magnesia, (epsom salts,) in sufficient quantity to be distinguishable by its taste. A yellowish tint and an astringent flavour are apparent when it consists chiefly of the sulphates of alumina and iron. The carbonate of lime more generally shows itself, not in the shape of an efflorescence on the surface like the others, but dispersed in minute granules throughout the body of the marl. Many of these calcareous granules are *grains of dolomite*, analogous in composition to the magnesian variety of the limestone, which overlies the greensand; whence probably the true source of the sulphate of magnesia above referred to. When the traces of shells are very numerous in the bed, and their conversion into the *sulphate of lime* has happened on the large scale, the gypsum forms a conspicuous part of a soft white clayey matter derived from the shells and interspersed among the green grains. The mixed mass of carbonate and sulphate of lime is then usually in a yellowish white *chalky* condition. Sometimes we may detect the gypsum in the marl in the shape of small regular crystals of transparent *selenite*, at times so minute as only to be detected by the magnifier.

Various fossil shells and other marine organic remains, amounting to considerably more than *one hundred species*, are scattered through the greensand. They do not occur very evenly distributed, but lie together in groups or *colonies*, forming layers, often a few feet in thickness, which extend over moderately large spaces. These collections of fossils would seem to be most abundant in those parts of the stratum which consist largely of the greensand.

The water percolating through the overlying sands, and also through the pervious greensand itself, has effected, and is daily effecting, important changes in the condition of the shells and other fossils; sometimes replacing their carbonate of lime with oxide of iron, sometimes removing it altogether, and leaving a mere mould forming either an inner or an outer cast, and sometimes obliterating nearly every trace of their former presence. We can perhaps nowhere meet with a better exemplification of the various alterations induced by the infiltration of water through porous strata, than are to be witnessed in these greensands and their associated deposits, where numerous substitutions of the elements are continually in progress, and where every species of dissolving and cementing action is hourly going forward upon an extensive scale.

The oxide of iron, the chief sources of which, as I have hinted, are the sulphuret of iron in the clays of the greensand and the ferruginous particles of the overlying yellow sands, is frequently so abundantly introduced into the marl stratum, as to act the part extensively performed by it in nature, of a *cement*, binding firmly together into a semi-rocky mass, the materials with which it is in contact. When this occurs, the marl is often rendered too hard to be excavated by the ordinary implements. When indurated or solidified from this cause, it is most commonly in the form of large round concretions, from the size of a bushel to that of a barrel, lying in horizontal layers, generally near the top of the stratum. These masses thrown out and exposed to the frosts of a winter, most usually crumble down into the friable state so essential to form a useful marl; and the material seems to be not in any way impaired in its virtues, from having been united in such firm cohesion. When the cementing action has proceeded farther, a regular stratum of indurated greensand rock exhibits itself. Such may be seen in some portions of the cliffs on the bay side in the Nevesink hills, large blocks of it strewing the beach, and offering some beautiful specimens of a fine brownish-green rock, in which the green granules are dispersed through a cement (or paste), deeply coloured by oxide of iron, giving the whole a pleasing variety of tint.

The above descriptions embrace the principal changes which the materials of the greensand formation seem to have undergone since their original deposition. They claim attention, not merely for the elucidation they afford of some of nature's most important operations, performed in her quiet laboratory by her silent but potent chemistry, but for the valuable practical suggestions they furnish concerning the greensand deposit in its interesting light of a fertilizer of the soil.

The total thickness of the greensand formation, estimating it from the bottom of the lowermost layers abounding in the green granular mineral to the overlying yellow ferruginous sands, or the limestone bed when this is present, may be stated approximately at about one hundred feet. The only place in the whole district where it is practicable to ascertain, with any approach to accuracy, either the depth of the formation, or the relative situation and number of the separate beds which it comprises, is along the shore of Sandy Hook bay in the cliffs of the Nevesink highlands. This, the only coast section of the strata, is still an imperfect one; large masses of the upper beds, fallen from above, covering the lower deposits near the water side. It would appear from what we behold in these cliffs, as well as from evidence collected throughout the "marl region," that the greensand constitutes generally but a *single stratum*, conceived to be continuous beneath the whole district, and to be itself in many places, more than thirty feet in thickness. That it is occasionally divided into two or even more subordinate thinner beds by bands of clay and sand, which are sometimes interpolated, and swell to a thickness of several feet, is obvious enough from the features seen in many excavations. But it should rather be considered as a deposit remarkable for the permanency of its composition, thickness, and external features. Owing to the large amount of water which it usually contains, the greensand is rarely penetrated in the numerous diggings which are made in it for the marl, to a greater depth than about twenty feet, the pits becoming at that limit too wet to be prosecuted deeper.

In one or two instances, wells have been sunk through the stratum, and the depth of the greensand ascertained to be about thirty feet, as already mentioned.

Specific Gravity.—The specific gravity of the green granular mineral, carefully freed from all extraneous adhering matter is, according to several experiments cautiously made, about 2·65. Three different specimens, taken from remote localities, gave for the two lowest each 2·63; for the highest 2·70.

The hardness of this mineral varies materially, being dependent somewhat upon the time elapsed after it has been dug; it is softest when moist and recently uncovered. Freshly extracted, its hardness often does not exceed that of talc; but when long uncovered and dry, it nearly equals that of gypsum.

It would appear by experiment to be entirely insoluble in water, both cold and boiling; but it dissolves with tolerable facility in any of the stronger acids, though different specimens vary materially in this respect.

Chemical Composition of the Green Mineral.

From a number of analyses of the greensand, selected with the greatest care for the purpose, and ascertained to be entirely free from extraneous matter, it would seem that this mineral is not quite uniform in its composition, but exhibits slight variations in the proportions of its principal constituents.

The following results will serve to display its prevailing chemical nature, and the moderate fluctuation of the several ingredients:

Greensand of Thorp's Marl, Squankum.

Description.—Colour, a dark olive-green; granules of a medium size; it composes 58·36 per cent. of the marl of the upper part of the bed, and 72·36 per cent. of the lower.

Composition.—In 100 parts:

Silica, - - - -	51·00
Alumina, - - -	6·50
Protoxide of iron, - -	21·55
Potash, - - - -	10·50
Lime, - - - -	a trace.
Magnesia, - - -	1·08
Water, - - - -	9·00
	99·63

Greensand of Joseph Vanderveer's Marl, Freehold, Monmouth county.

Description.—Colour of the granules, rich green; size, small; composes 70 per cent. of the upper part of the bed, and 92 per cent. of the lower.

Composition.—In 100 parts:

Silica, - - - -	50·00
Alumina, - - -	7·00
Protoxide of iron, - -	22·00
Potash, - - - -	11·00
Lime, - - - -	1·00
Magnesia, - - -	a trace.
Water, - - - -	9·00
	100·00

Greensand of the Marl of Poke Hill, near Plattsburg, Burlington county.

Description.—Colour of the granules, a rich dark olive-green;

their size, rather above the medium; composes 98 per cent. of the marl.

Composition.—In 100 parts:

Silica, - - - -	50·75
Alumina, - - -	6·50
Protoxide of iron, - -	22·14
Potash, - - - -	12·96
Water, - - - -	7·50
	99·85

Greensand of the Marl from the Pits of Thomas Edwards, Burlington county.

Description.—Colour a rather light grayish green; the granules somewhat less than the medium size; it forms 93·51 per cent. of the marl.

Composition.—In 100 parts:

Silica, - - - -	51·00
Alumina, - - -	6·75
Protoxide of iron, - -	22·00
Potash, - - - -	11·00
Lime, - - - -	a trace.
Magnesia, - - -	none.
Water, - - - -	9·00
	99·75

Greensand from the Marl at Evesham, Burlington county.

Description.—Colour of the granules, a medium tint of green; their size rather large; constitutes almost the whole of the marl.

Composition.—In 100 parts:

Silica, - - - -	48·50
Alumina, - - -	7·50
Protoxide of iron, - -	22·80
Potash, - - - -	11·00
Water, - - - -	9·50
	99·30

Greensand from the Marl of Josiah Heritage, two miles and a half east of Barnesborough, Gloucester county.

Description.—Colour of the granules, a very dark olive-green approaching black; size rather large; forms 93·70 per cent. of the marl.

Composition.—In 100 parts:

Silica, - - - -	47·50
Alumina, - - -	7·84
Protoxide of iron, - -	23·78
Potash, - - - -	11·11
Lime, - - - -	0·50
Water, - - - -	9·00
	99·73

Greensand from the Marl of Michael Allen's pits, one mile and a half east of Mullica Hill, Gloucester county.

Description.—Colour of the granules, brownish green; they are of about the medium size; constitute 96·36 per cent. of the marl.

Composition.—In 100 parts:

Silica, - - -	48·50
Alumina, - - -	7·00
Protoxide of iron, - -	21·40
Potash, - - -	12·90
Lime, - - - -	a trace.
Magnesia, - -	1·00
Water, - - -	8·80
	99·60

Greensand from the Marl of Elijah Horner's pits, one mile and a half southwest of Mullica Hill, Gloucester county.

Description.—Colour of the granules, a rich green, rather darker than the average; size, large; forms 90·75 per cent. of the marl.

Composition.—In 100 parts:

Silica, - - - -	51·09
Alumina, - - -	8·23
Protoxide of iron, - -	21·99
Potash, } Magnesia, } - -	14·06
Water, - - - -	5·51
	100·88

Greensand from Marl of Benjamin Coulson's pits, three miles north-east of Woodstown.

Description.—Colour of the granules, a dark rich olive-green; size, rather large; constitues 90 per cent. of the marl.

Composition.—In 100 parts:

Silica, - - - -	48·35
Alumina, - - -	9·35
Protoxide of iron, - -	20·86
Potash, - - -	11·73
Lime, - - - -	0·50
Water, - - - -	9·00
	99·79

Greensand from Marl of Allen Wallace's pits, two miles and a half west-northwest of Woodstown, Salem County.

Description.—Colour of the granules, a dark green; size, rather large; constitutes 90 per cent. of the marl.

Composition.—In 100 parts:

Silica, - - - -	48·40
Alumina, - - -	7·30
Protoxide of iron, - -	23·00
Potash, - - -	11·47
Lime, - - - -	1·20
Water, - - -	8·15
	99·52

Greensand from Marl of Jonathan Cauley's pits, three-fourths of a mile northwest of Woodstown.

Description.—Colour of the granules, a rather dark olive-green; size, large; constitutes 86 per cent. of the marl.

Composition.—In 100 parts:

Silica, - - - -	48·45
Alumina, - - -	6·30
Protoxide of iron, - -	24·31
Potash, - - -	12·01
Lime, - - - -	a trace.
Water, - - -	8·40
	99·47

Greensand from Marl of Samuel White's pits, Woodstown.

Description.—Colour of the granules, the medium tint of green; size, somewhat large; composes 88·26 per cent. of the stratum.

Composition.—In 100 parts:

Silica, - - - -	50·16
Alumina, - - -	6·00
Protoxide of iron, - -	24·74
Potash, - - -	11·70
Lime, - - - -	a trace.
Water, - - -	7·00
	99·60

Greensand from Marl of Paul Scull's pits, three miles northwest of Sculltown, Salem County.

Description.—Colour of the granules, a very dark green; composes 91·5 per cent. of the marl.

Composition.—In 100 parts:

Silica, - - - -	51·50
Alumina, - - -	6·40
Protoxide of iron, - -	24·30
Potash, - - -	9·96
Magnesia, - - -	a trace.
Water, - - -	7·70
	99·86

Greensand from Marl of James Smith's pits, Mannington Hill, near Salem.

Description.—Colour of the granules, a rich dark olive-green; size, rather large; forms 88·8 per cent. of the marl.

Composition.—In 100 parts:

Silica, - - - -	50·00
Alumina, - - -	6·99
Protoxide of iron, - -	20·99
Potash, - - -	10·99
Water, - - -	10·00
	98·97

Comparing the details of these several analyses, we perceive that the greensand even when of the greatest purity is not absolutely constant, either in the nature of the ingredients which enter into its composition, or in their relative proportions. The per-centage of the *silica* is seen to vary from 47·5 to 51·5; that of the *alumina* from 6 to 9·35; that of the *protoxide of iron* from 20·86 to 24·74; that of the *potash* from 9·96 to 12·96; and that of the *water* from 5·5 to 9·5. We find, moreover, that, in some instances, besides these elements, *lime* enters into the constitution of the greensand, in other cases magnesia; while occasionally both occur. The amount of these earths is, however, always inconsiderable.

From the above series of analyses it appears that the mean proportion of the *silica* is approximately 49·5 per cent.; that of the *alumina* 7·3; of the *protoxide of iron* 22·8; of the *potash* 11·5; and of the *water* 7·9 per cent.; while the *lime* when present seldom exceeds *one half per cent.*, and the magnesia is rarely more than a mere trace.

A comparison of the greensand of New Jersey with that of Europe shows no essential difference in their chemical nature. *M. Berthier*, an able French chemist, has analyzed that of the vicinity of *Havre*, in France, and reports the following as its composition.

Greensand of Havre, in France.

Composition.—In 100 parts:

Silica, - - - - -	50
Alumina, - - - - -	7
Protoxide of iron, - -	21
Potash, - - - -	10
Water, - - - -	11
Loss, - - - -	1
	100

The late lamented chemist, Dr. Edward Turner of London, also examined with great care the chemical constitution of the greensand of Kent, in England.

His experiments gave in the 100 parts:

Silica, - - - - -	48·5
Alumina, - - -	17·0
Protoxide of iron, - -	22·0
Potash, - - -	*a trace.*
Magnesia, - - -	3·8
Water, - - - -	7·0
	98·3

The absence of potash in the green granules of the English greensand, and the large proportion of magnesia are facts not a little remarkable.

ECONOMICAL RELATIONS OF THE GREENSAND FORMATION.

Abundant evidence might be adduced to prove that the true fertilizing principle in marl is *not lime* but *potash.* The analyses which have been made, give us in several cases no lime at all, and where a small proportion of lime is present in the green granular mineral, it is in a combined state, chemically united with the other ingredients, and not traceable to the organic remains, which are in many of these instances not present in the stratum. Besides, the quantity of shelly matter, even where the shells are plentiful, is so disproportionately small, and the matter of the shells often so firm and unsusceptible of that easy disintegration, necessary to form a calcareous marl adapted to act speedily upon the crop, that the striking effects witnessed from the marl can in nowise be attributed to the trivial amount of lime which the shells may occasionally furnish to the land. Nevertheless, as some feebly beneficial effects may possibly arise from this source, it may be of service to the agriculturist, in choosing between different fossiliferous marls, to attend to the nature of the particular fossils, and the state of more or less decomposition or change in which they are to be found. It must be borne in mind, that a large portion of the visible marl stratum is immediately overspread by a very porous layer of yellow ferruginous sand, and that this introduces to it a perpetual supply of water, furnished with great regularity as from an *immense filter.* From the upper or *ferruginous sand* it must descend charged often with a considerable amount of the oxide of iron, as may be seen in the abundant ochreous sediment which it almost always deposits as it issues from the surface or upper part of the marl bed. It is ready, therefore, to precipitate this oxide of iron upon any substance capable of displacing it from the water, and meeting with the more soluble carbonate of lime of the shells, an interchange of materials arises, and the calcareous matter of the shells is dissolved and carried away, while the oxide of iron takes its place. Hence we often see the shells of a deep yellow or brown colour, and upon inspection they are found to consist less of carbonate of lime than of oxide of iron. In such case they are to be regarded as wholly inert upon the soil, as, in fact, so much useless matter, usurping the place of a far more serviceable substance, the greensand or marl. But this is not the only change which seems to have been effected in the foreign materials of the marl by this unceasing infiltration of water. I have before alluded to the peculiar composition of the overlying dark-blue astringent clay, and to the fact that it frequently contains a sensible quantity of the sulphate of iron or copperas; and that both this clay and its astringent impregnations are very often mingled through the granular marl itself. Now the water from either of these sources must dissolve in its passage a considerable quantity of the copperas (an easily soluble substance), and where there are shells or other calcareous fossils, it must carry with it a portion of the carbonate of lime derived from them. These two substances coming together in a state of solution, a chemical reaction, of course, ensues, both the sulphate of iron and carbonate of lime are decomposed by the mutual affinities of their ingredients, and the result is a precipitation of the oxide of iron of the former, and a combination of the sulphuric acid and the lime to form sulphate of lime or *gypsum*. That such is the fact is apparent from our finding, in many cases, a sensible amount of gypsum, either in the earthy state or in minute crystals intermixed with the marl; and from our observing besides, that when the gypsum is in greatest plenty, we can most generally discover a strong sulphurous odour, an evidence upon grounds before explained of the existence of sulphuret of iron, undergoing a conversion into the *sulphate of iron*. It will suggest itself to every one, that the existence even in small quantities of so potent a stimulant to vegetation as gypsum, must have a powerful influence in modifying the useful properties of the marl containing it. Yet it must not be inferred from this, that the efficacy of the greensand is owing to the gypsum which I have shown to be frequently present. The comparative inertness of plaster upon the sandy soils of parts of the region where the marl has never been applied, as in several places near Salem, is a fact in itself sufficient to overthrow this notion, even if it were not true that very many marls which do not contain gypsum in any shape, are endowed with the highest fertilizing power.

Directions for Selecting and Analyzing the Greensand.

The valuable fertilizing properties of the greensand, and the extensive use which is made of it in agriculture throughout nearly the whole of the region which it occupies, suggest the propriety of our offering in this place, some practical directions for selecting, analyzing, and applying it.

In seeking for the marl stratum in neighbourhoods where it is likely to occur, but where a covering of any of the superficial deposits obscures it, the primary point to be remembered is, that the true greensand stratum is the lowest accessible deposit of the region. We should find out, therefore, the *deepest depressions* of the land, such as the meadows and natural ravines, and by the use of an auger or other instrument for boring the ground, several feet in length, ascertain whether the stratum lies sufficiently near the surface to be easily and economically uncovered. A rather sure guide to the marl is afforded by the aspect and composition of the earth existing at and near the surface. Should it be at all *greenish*, or contain upon close inspection, any of the green granules, the probability is that the marl lies beneath at a very moderate depth, and the chances augment when we find our borings bring up an increasing proportion of this mineral as we descend. I have repeatedly found the position of the marl stratum indicated by the trickling forth of the water from the foot of a bank, for the water is almost invariably seen to issue along the top of either the dark clay or the true marl.

For judging of the quality of a marl by observation, some familiarity with the multiform aspects which it assumes is indispensable. The leading rule, however, is to bear in mind that the fertilizing efficacy of the compound, resides in the minute round greenish grains which compose most, or sometimes all of it; and that it seems, moreover, to be dependent upon the proportion in these green grains of those powerful alkaline stimulants to vegetation, *potash* and *lime*, but especially potash. The first thing then, is to approximate to the relative quantity of the green grains in the whole mass, and this may be effected with a greater or less degree of accuracy in several ways. The simplest and readiest method is to employ a small pocket magnifying-glass, and to become familiar with the dark-green grains, so as to distinguish them at once from other dark varieties of sand which sometimes occur associated with them. A little practice will very soon enable one to use the glass expertly, and to arrive at a pretty true estimate of the probable per-centage of the green granules. But as these granules cannot sometimes be distinguished from the grains of ordinary white flinty sand, or from other kinds, in consequence of the particles being *all alike coated* with a thin film of the dark cementing clay, it will be useful to adopt some method of bringing out under the magnifier their different characteristics of colour and form. Let the mass be washed in a large glass tumbler, and repeatedly agitated with the water until as much of the clay as possible has been detached from the grains. After pouring off the turbid water by repeated rinsings, and permitting it to settle until clear, we may estimate the comparative quantity of clay in different marls by the relative amount of sediment which subsides. If we wish to be more accurate, we can weigh out a given quantity of the marl, then pursue the above plan, and decant the clear water from the clay; and after thoroughly drying the clay, weigh it to ascertain its amount. Having got away most of the clay, we should spread out the granular matter upon a sheet of paper and dry it, when there will be no farther difficulty in distinguishing, by their colour and lustre, the foreign impurities from the grains of true marl; and also of estimating the relative abundance of each. When the marl to be examined contains much clay, I would recommend the experiments to be made upon a regularly weighed quantity, weighing both the clayey and the granular portions. A delicate apothecary's balance will commonly be found accurate enough. Another more expeditious, though less accurate method, is merely to dry the marl, spread it extremely thin upon a sheet of white paper, and then hold it near a window or in the light, to examine it carefully by the magnifier. The flinty sand, though stained with clay, may then be clearly discerned in consequence of its transparency; whereas when we inspect a solid lump, all the particles upon the surface are nearly alike dark.

A useful suggestion is, to place a portion of the marl upon a hot shovel or on the top of a stove, when all the granules will change from their ordinary green tint to a light red or brick colour, while the other materials of the mass sustain little alteration. This will often render obvious to the naked eye the proportion of the green grains.

When there is a yellowish or whitish incrustation upon the marl after the *moist* surface has remained for some time exposed to the weather, it is indicative of the existence of a portion of either copperas or sulphate of alumina, the hurtful nature of which has already been explained.

An astringent inky *taste* will very often detect the presence of these noxious substances at times when no such efflorescence shows itself. If the quantity be too small to betray them distinctly to the palate, and we are still in doubt as to their presence, other more rigorous tests are within our reach; and as these astringent matters are so unquestionably pernicious in their action, it is of importance to have the means of determining in what proportion they abound in different marls. This can be effected with precision only by a systematic chemical analysis, but their existence can be made to appear by the following simple tests. Put a small portion of the marl in a flask or other thin glass vessel; pour upon it some pure water, and heat it moderately. After causing the water to dissolve in this way as much as possible, remove the heat, and let it settle; then decant the *clear* fluid into some glass vessel, such as a wine-glass. If there is any copperas present, it will be evident upon adding to the fluid a little lime-water, which will produce a milky turbidness that after a little while will become stained of a yellowish-brown colour. The milkiness is owing to the formation of gypsum, and the brown colour to oxide of iron from the copperas. Or in lieu of this, add a solution of oak bark; and if copperas be present, we shall have a dark inky colour at once produced.

A good marl will, upon being squeezed in the hand, fall asunder again rather than bake into a tough doughy mass; and upon being left in heaps to dry, will assume a light grayish green colour and be extremely *crumbly*. It seems to be a very general characteristic of the better class of marls, that they throw out a white efflorescence or crust upon those grains which are most exposed to the air: hence the very light colour externally which some heaps of marl possess. This crust I have already shown to consist usually of the sulphate of lime (gypsum), sulphate of magnesia, and carbonate of lime. A drop or two of strong vinegar, or any strong acid, will produce an effervescence or *frothing* if it be the *carbonate* of lime; and should nothing of this kind take place, we may set it down to be *gypsum*. Of course, from the minuteness of the quantity of the white coating, much care and accuracy of observation are demanded in doing this, in order to avoid erroneous conclusions.

Marls deemed equally good with the kind showing the efflorescence, very frequently occur, exhibiting none of the white incrustation.

It does not seem that any general rule can be given for distinguishing the fertilizing properties of a marl by its mere *colour*, as it must appear from what has been said, that the peculiar shade of colour is frequently owing to the colour of the intermingled *clay*. When the mass, however, is comparatively free from clay or common sand, and consists of little else than the greensand, observations go to show that the rather *dark* green variety is more potent in its effects than the very light green, which sometimes overlies it.

The presence or absence of shells I look upon to be a point of but little moment, for I find that several of the most active marls in the region show no traces of fossils. The whole amount of carbonate of lime in the shape of fossils, and in that of the occasional white incrustation upon the grains, can in very few instances amount to *one per cent.;* while, as analysis shows, the lime chemically combined with the other ingredients in the green grains, is sometimes *one per cent.*, and the potash nearly *twelve per cent.*

There yet remains, however, a more important, and by far more difficult inquiry, namely—into the *exact* constitution of the green grains, in order to determine the per-centage of the several ingredients—or the richness of the marl in *potash* and *lime.* I had entertained hopes that the external aspect of the grains might perhaps depend in part on the presence and proportion of these bodies, and that *mere inspection*, after multiplied analyses were made, might enable any one following certain directions, to inform himself whether a marl abounded in these essentials or not. But, I find that so far from being a mineral of definite and constant proportions, as some mineralogists have regarded it, the greensand is in fact a compound which fluctuates considerably in its external characters, and its chemical composition. The numerous analytical results which I have presented, will abundantly prove this. It is manifest, therefore, that we possess no shorter method to discover the *exact* quantity of the potash, than to subject the marl to a systematic chemical analysis.

Three different plans have been pursued in procuring the composition of the marls described in this work. The *first* consisted in separating, mechanically, that is to say, by washing and selecting the several ingredients, the greensand, the clay, and the quartzose sand, together with any carbonate of lime which may be present. The *second*, in analyzing systematically the green granular mineral, with a view to determine accurately its constitution. The *third*, in partially analyzing the marl for the purpose of ascertaining the proportion of its chiefly efficacious element, the potash. Besides determining the relative quantity of potash by the two latter methods, it has been approximately estimated for a series of specimens too numerous to be subjected to the more operose process of analysis, by ascertaining by the first mode the amount of the green mineral, and then calculating, from the average per-centage of potash, the proportion in which it prevails in the particular marl.

Though it is not presumed that among those engaged in agriculture, more than a very few persons possess the requisite chemical skill, or the facilities for this species of research, yet for the sake of such as may chance to be competent to execute this kind of analysis, I have thought it well to introduce a statement of the method of analyzing the mineral in question. Several plans, modifications of the same general method, have been tried for the purpose of arriving, if possible, at some mode sufficiently simple to make it practicable by those who possess but a limited knowledge of analytical chemistry. But the nature of the compound seems not to admit of either a very direct or expeditious mode of operation.

Method of analyzing the Greensand.

1. Digest the mass in a flask with pretty strong muriatic acid, by a sandbath heat for at least three days, or boil it actively for five or six hours. Every thing is dissolved but the *silica*, which must be filtered, ignited, and weighed.

2. Precipitate the *oxide of iron* and *alumina* by ammonia and estimate them together, and detach the alumina by *caustic potash.*

3. Evaporate the ammoniacal solution to total dryness, and heat the mass to incipient redness, to expel the muriate of ammonia. There remain the chlorides of calcium, magnesium, and potassium, which redissolve in water, dividing the liquor.

4. To one half add oxalate of ammonia, and separate the lime, then by ammonia and phosphate of soda separate the *magnesia.* Subtract the combined weight of these two computed as chlorides, from the original triple chloride, and we have the *chloride of potassium.*

5. Now evaporate the other half again to dryness, and dissolve up all the chlorides of calcium and magnesium by *alcohol,* and dry and weigh the residual chloride of potassium. If further

check is necessary, convert this into chloroplatinate of potassium, and estimate the potash from this.

Suggestions for correcting the Noxious Effects of the Astringent Clay underlying and associated with the Greensand, and for using it as a Marl.

From the descriptions of this stratum already presented, it appears that the action of this astringent mass upon the crop is decidedly pernicious, when the material is employed in any amount beyond the most stinted doses; and the cause of its poisonous property would seem, judging from the chemical analyses made, and from other evidence, to be attributable to the acid reaction of the astringent ingredients which it possesses, namely, the *copperas* and *sulphate of alumina.*

Copperas, though a neutral salt, is well known to chemists to exert an *acid reaction*, and hence we are not to be amazed that a clay containing it in obvious quantities, should burn, or more strictly *poison*, the vegetation. Knowing, as we do, the source of the deleterious properties of the clay, a few simple correctives suggest themselves, and such as any one wishing to use this substance as a substitute for marl may adopt.

My first recommendation to the farmer who is about to make use of this clay upon his soil, is, that he be careful to select, when he has the choice, that variety which contains the green granular material of the true marl, and to avoid altogether the kind which is wholly destitute of this substance. When the green grains are pretty numerous in the mass, as they are near Spotswood, Burlington, Camden, and generally upon the northwest side of the marl tract, I would then advise its use, but guarded by the following precautions. Let the clay be dug several months before it is to be scattered on the land, and let it be spread out in broad, *shallow*, flat heaps, where the rains may soak through it and carry away the copperas and sulphate of alumina, which, from their well known solubility, will be easily dissolved and washed out. The green mineral does not dissolve in water, and hence, while the rains will purify the mass, no loss of its more active portions can happen. Numerous attempts at using this clay as a marl have shown, that though noxious at first, it is often permanently beneficial to the land, after the second, third, or fourth year; a fact which I attribute to the gradual escape of the astringent matter by the rain. Though I do not think that the exposure of even an entire winter will always suffice to rob the clay of all the sulphates (copperas, &c.) which it may contain, yet it bids fair to do much good, and therefore deserves a careful trial.

I have to offer another, and I think, far more promising suggestion, for making the better portions of this stratum beneficial in their effects upon the soil, Chemists are aware that both the sulphate of iron and the sulphate of alumine are decomposed by *caustic lime;* and the antidote I propose is founded upon this fact. My recommendation is, to add to every heap of this spurious astringent marl, a small quantity of *freshly burnt lime*, and to mingle them thoroughly together. The sulphuric acid of the copperas or alum earth, or of both if present, will pass over to the lime and form sulphate of lime (*gypsum* or *plaster*), the value of which, as a stimulant to vegetation, is well understood; the other ingredients, the oxide of iron and clay, will on being liberated, contribute also towards improving the texture of the soil should it be sandy. A bushel of lime to every hundred bushels or five tons of the mass, will in most cases be sufficient to neutralize all the astringent matter present, and to convert it into, or rather replace it by, *gypsum*. The dressing of an acre of such a mixture will contain of the green marl, of gypsum, and of uncombined lime and lime in a state of carbonate, in all probability fully enough to impart to the soil a most decided improvement in point of fertility.

Lastly, I would recommend, for this astringent marly clay, the same course so appropriate also in regard to lime: I mean the practice of making a *compost* of the substance with the common *manure of the farm.*

This, like the former suggestion, is justified by good chemical reasons. In the fermentation of animal manure, *ammonia* always escapes in greater or less quantity; and ammonia, like lime, has the power of decomposing the sulphates of iron and alumina. In this case, however, gypsum is not a product.

From what is here said, it will be obvious, that when a field has been made *sterile* by the indiscreet use of this caustic clay, a ready and certain remedy will be found by spreading upon every acre a few bushels of newly made lime.

Should these hints, which are designed to render useful certain portions of this lower stratum, receive their final corroboration from experience, we may consider that the area of the region susceptible of improvement by marling without the expense of hauling the material from a distance, has been in many districts doubled or tripled in extent. To ascertain whether the clay possesses a sufficient share of the green granules to warrant a trial of it upon the land, it may be necessary to employ the aid of a small *magnifying-glass*, which will be found by every farmer to be of indispensable use in the discrimination of all greensand marls.

SECTION III.

Limestone of Salem, Gloucester, and Burlington counties.

Resting immediately over the greensand formation, we find occasionally the locally developed and thin calcareous rock which we have defined as the *third formation* of the upper secondary series. Though unimportant as regards its thickness and the extent of surface which it occupies, it derives value from its usefulness as a source of lime, in a district having no other calcareous stratum, while considerable interest attaches to it, from the number of its fossils, and its affinity to an extensive and thick formation in the southern States, the *lower* limestone of Alabama.

Geographical Extent.—The general range of the stratum is from a point a little northeast of Salem, past Woodstown, Blackwoodtown, Mullica Hill, Vincentown, and New Egypt to Prospertown; beyond which I have been as yet unable to discover a trace of it. But it is not to be inferred that it exists as a stratum of much extent or importance throughout all of this long line. It has hitherto been detected at distant points only, and nowhere but in Mannington, Salem county, does it cover a wide area, or possess more than a very insignificant thickness. It lies along the southeastern edge of the visible marl tract, and if it dips at all, it is towards the southeast, to underlie the ferruginous sands. At its greatest width, four miles northeast of Salem, it can be traced over a breadth of three-fourths of a mile. Its thickness in the same neighbourhood, as proved by a well sunk through it, is as great in one spot as *twenty feet;* though elsewhere in the same vicinity it is not more than six or eight. Near Vincentown it seems to be still less; and upon the branches of Crosswick's creek, it is reduced to less than one foot. The stratum preserves its prevailing structure and position, at its several localities, leaving us in no uncertainty as to its identity.

Composition and Aspect.—This rock is usually a soft yellowish or straw-coloured limestone, with a structure varying from sub-crystalline to coarsely granular. It is often replete with organic remains, the disintegrated shells and corals, and other fossils, composing a considerable portion of the mass. Much of the rock contains impurities, as sand, clay, and oxide of iron; and its value as a limestone is therefore very variable. At times it is little else than a sandstone, in which the sand is cemented together by a trace of lime. It occurs with this character in loose rounded masses, resting above the marl, at Woodstown. Again it exists as a firm calcareous rock. This is its state in some places near Salem, in Mannington township. In the several accompanying analyses, the composition of the leading varieties of the rock may be accurately seen. This limestone is nowhere to be found in thick massive strata; on the other hand, it occurs only in thin horizontal beds, or irregular layers, not often more than four or six inches thick, and commonly separated by a thin parting of sand and carbonate of lime in small grains, to all appearance an incohering mixture of the same materials that form the rock itself. The more calcareous beds have not unfrequently some resemblance to some of the thin oolitic strata of England, in consequence chiefly of the *granular form* of much of the carbonate of lime; together with the innumerable fragments of fossils which sometimes form almost half of the mass. Unless attentively observed, this rock will appear much more sandy than it actually is, owing to some of the carbonate of lime being in the shape of small round yellow grains, like those of sand. Occasionally, especially near the bottom of the stratum, where it adjoins the marl, it contains a sensible proportion of the green grains, sometimes in such abundance as to unfit it for being burnt into lime, the potash and other ingredients of the green mineral serving to vitrify it and form a kind of slag.

LOCAL DETAILS.

Mannington.—The most southwestern spot at which this limestone appears, is east of Mannington Hill, about three miles from Salem. It occurs in the banks bordering the meadows of Mannington creek, on the farm of Miss Parrot, lying two or three feet beneath the surface. The stratum here is of a light yellowish colour, and consists of minute fragments of shells and other fossils in a chalky state, together with grains of quartzose sand, and a few granules of greensand, all invested by particles of carbonate of lime. The rock is in thinly bedded layers from three to five inches thick, accompanied by a calcareous sand, differing in no respect but in the absence of cohesion from the material of the limestone. This sand rests both above and between the more solid layers.

Analysis of the Limestone from the farm of Miss Parrot, near Mannington Hill, Salem county.

Description.—Colour, straw-yellow, granular, and subcrystaline; fossiliferous.

Composition.—In 100 parts:

Carbonate of lime, - -	81·35
Carbonate of Magnesia, -	1·95
Alumina and oxide of iron,	1·04
Insoluble matter, - -	14·64
Water and loss, - -	1·02
	100·00

On the farm of Mr. W. Petit, in the vicinity of Mannington Hill, the limestone displays itself in considerable thickness, the layers of the rock alternating with the calcareous sand as described above. This locality is about a mile and a half southwestward from the poor-house.

The following analysis exhibits the proportion of carbonate of lime in the limestone of this neighbourhood.

Analysis of the Upper Secondary Limestone of Woodnut Petit, Salem county.

Composition.—In 100 parts:

Carbonate of lime, -	77·80
Carbonate of magnesia, -	1·20
Alumina and oxide of iron,	1·80
Insoluble matter, - -	17·80
Water, - - - -	1·12
	99·72

This stratum is destined to prove of signal service to the agriculture of all the region adjacent to it; for lime is particularly useful upon lands destitute of calcareous matter, like some of the more sandy tracts of New Jersey. The lime from this rock in Salem, is growing rapidly into use. I would recommend—as promising to prove highly beneficial—the soft, friable, unconcreted parts of the stratum which lie between the solid layers, especially near the bottom of the formation. Being already in a pulverulent state, and composed chiefly of carbonate of lime, with occasionally some of the grains of the green marl, the whole must constitute a *calcareous marl*, admirably adapted to ameliorate the lands of the surrounding country.

Both the *limestone* and the *calcareous sand* occur well developed on the farm of Mr. J. Ridgeway, near Mannington Hill. The rock at this place has a subcrystalline texture, being tolerably well cemented; towards the centre of the layers it is of a bluish colour. It is quarried to some extent and burned on the spot, yielding a very good lime. The price of this lime is about nine cents per bushel. The calcareous sand of this place is also growing into demand as a marl, and is vended at the rate of twelve and a half cents per load.

Analysis of Limestone from the farm of Hazleton Stacy, Salem county.

Description.—Colour, straw-yellow, compact, subcrystalline, and granular; consists largely of the fragments of fossils.

Composition.—In 100 parts:

Carbonate of lime, - -	75·56
Carbonate of magnesia, -	1·20
Alumina and oxide of iron,	2·50
Insoluble matter, - -	18·49
Water, - - - -	2·00
	99·75

Salem Creek east of Woodstown.—To the southeast of Woodstown, upon Salem creek, the limestone is visible in two or three places, though rather deeply covered by diluvial sand. I cannot learn that it has attracted attention or been burned for lime. It seems to be of very local extent, though possibly the main portion of the stratum has not yet been exposed.

Near Mullica Hill.—The limestone is found on the small tributaries of Raccoon creek, at two places about a mile and a half southwest of Mullica Hill. Though not as highly calcareous as that near Mannington Hill, it effervesces actively with an acid, and contains a moderate proportion of shells, in a fragmentary condition. It occurs in flat thin layers, separated by more or less of the calcareous sand. Its total thickness has not been ascertained, the stratum having been quarried to a very limited extent for the purpose of procuring lime. By selecting the more compact and crystalline portions of this rock, and observing proper precautions in the burning, it affords a very good lime, for agricultural purposes. This material is exposed in the banks of a meadow on Raccoon creek, on the farm of Charles Batten, where it shows the following beds:

		ft.	in.
1.	Dark micaceous earth, thickness variable.		
2.	Similar bed, abounding in fragments of white friable shells, - - - - - -	1 ft.	6 in.
3.	Soft, porous, fossiliferous *limestone*, - -	0	4
4.	Calcareous sand, with shells, - - -	0	10
5.	Gray, compact, subcrystalline limestone, -	1	0
6.	Calcareous sand, - - - - - -	2	6
7.	Hard subcrystalline limestone only penetrated to the depth of eight inches, it is probably considerably thicker, - - - - -	0	8

The more compact bands of the limestone afford a very good lime.

Near Barnsboro.—Two miles and a half east of Barnsboro, the calcareous stratum occurs near Mantua creek, on the farm of Josiah Heritage. The layers of the rock are between six and eight inches thick. It consists chiefly of comminuted fragments of shells and other fossils, and scattered grains of ordinary siliceous sand, and a few granules of greensand. It is a gray limestone, the interior of the mass having some degree of compactness, and promises with care in the calcination, to yield a lime fit for the purposes of the agriculturist.

Analysis of the Limestone overlying the Marl on the farm of Josiah Heritage, near Blackwoodstown, Gloucester county.

Description.—Yellowish-gray, granular, and subcrystalline, and very fossiliferous.

Composition.—In 100 parts:

Carbonate of lime, -	75·0
Carbonate of magnesia, -	1·8
Alumina and oxide of iron,	2·5
Insoluble matter, - -	18·7
Water, - - - -	1·7
	99·7

Near Blackwoodstown.—Upon the southern branch of Timber creek, the limestone is again met with south of Blackwoodstown. As in the other localities above mentioned, its thin layers are divided by more or less calcareous sand, a bed of which also overlies it at this place. The relative order of the beds commencing with the diluvium, and extending to the surface of the greensand stratum, is as follows:

1.	Diluvial sand and gravel, - - - -	3 feet.
2.	Yellow ferruginous sand, - - - -	1 "
3.	Dark ferruginous clay, very tough, - - -	1 "
4.	Gray siliceo-calcareous sand, containing fossils similar to those of the underlying limestone,	2 "
5.	Yellowish-gray limestone, in thin irregular flaggy layers, contains several species of shells, and the *eschara digitata* in considerable abundance,	2½ "
6.	Greensand marl, at the level of the stream.	

Clementon.—In the vicinity of Clementon, on the north branch of Timber creek, the limestone shows itself in several places, occurring in thin horizontal bands, about six inches in thickness, imbedded between layers of the calcareous sand. These layers are some of them two and a half feet thick, furnishing an abundance of excellent calcareous marl, which is used to a small amount in the neighbourhood, and with striking benefit to the crops. The limestone itself is quarried and converted into lime. The upper surface of the stratum is about twenty-five feet above the level of the stream, and is overlaid by about five feet of diluvial matter.

The stratification here presents a somewhat singular anomaly, the calcareous sand forming in some places tall narrow cones or eminences, rising almost through the overlying stratum, which fills the intervals between them. Some of these cones are *four feet* high and two or three feet in diameter.

Analysis of the Limestone from the Farm of Mr. Isaac Thompson, near Clementon, Gloucester County.

Composition.—In 100 parts:

Carbonate of lime, - -	77·0
Carbonate of magnesia, -	1·5
Alumina and oxide of iron,	2·0
Insoluble matter, - -	18·0
Water, - - - -	1·0
	99·5

The fossils in this limestone are some of them very beautiful and in high preservation. Among them occurs the species *Eschara digitata*, in vast quantities; also, *Spatangus parastatus*, *Ananchytes cinctus*, and *A. fimbriatus*, and an echinus; besides *Anthophyllum Atlanticum*, *Scalaria annulata*, *Gryphea convexa*, *G. Vomer*, *Flustra sagena*, and teredo; together with several more zoophytes and shells.

Medford.—At Charles Haines's mill, two miles below Medford, on the creek, a section is seen exhibiting on the top a greenish siliceous sand; beneath this, a gray sand some feet thick, containing a small proportion of the green granules, and under this again the straw-coloured limestone two feet thick.

These beds hold the same order, and are identical with those above the green marl at New Egypt and elsewhere, towards the eastern side of the "marl tract." One-fourth of a mile from the mill, the beds have been cut through, in digging a well into the greensand stratum underneath. The limestone was reached, between seven and eight feet below the surface. It was in thin irregular beds, separated by incohering sand and calcareous grains, similar to the mixture which composes the rock; its total thickness is about six feet; the organic remains are the same which characterize the limestone at Vincentown.

The limestone belt measured from northwest to southeast, appears as far as exposed to be about one mile wide, and there are pretty good reasons for concluding that it expands still more to the southeast.

Vincentown.—The thin limestone stratum of the vicinity of Vincentown extends to the northeast, as far as Benjamin Peacock's, on the road between Vincentown and Pemberton, and one mile from the limekiln, on the south branch of the Rancocus. To the southwest it extends between Vincentown and Medford, and is seen on the farm of James Lippincott. It occurs at Hosea Moore's, on the Red Lion road, three and a half miles from Lumberton.

I do not think it at all established that Benjamin Peacock's is the extreme northeastern limit of this formation, for there is a thin band of calcareous rock in the marl bank at New Egypt, which is almost identical in character with the rock at the limekiln on the Rancocus; and what is remarkable, the top bed at Egypt is identical with the top or overlying bed at the limekiln, being a thin layer of a *brownish siliceous sand*, tinged here and there with green. This would extend the limits of the limestone much towards the northeast. On the Rancocus it is very thin, consisting of two layers, each only six or eight inches thick, and separated by eighteen inches of sand. It overlies the *marl*, as we know the corresponding stratum does in Mannington, Salem county.

Analysis of the Yellow Limestone, from the neighbourhood of Eayrstown, Burlington County.

Lime, - - - -	49·69
Carbonic acid, - -	38·31
Silica and other impurities,	9·00
Water, - - - -	3·00
	100·00

It is in many places a very pure limestone, containing ninety per cent. of carbonate of lime. It has a structure somewhat resembling certain varieties of the *oolite* of Europe, imparting to it a granular and sandy aspect, which might lead the careless observer to regard it as a more impure limestone than it is.

SECTION IV.

Ferruginous Yellow Sand—Formation IV. Brown Sandstone and Conglomerate—Formation V.

Geographical Range and Extent of the Yellow Ferruginous Sand.—This formation occurs immediately above the greensand, unless where the thin fossiliferous limestone intervenes, and directly beneath the brown sandstone. Its position is usually at the base and in the sides of the outlying hills capped by the sandstone, and it probably spreads extensively to the southeast of the marl region in the district called " the pines."

Geographical Extent and Composition of the Brown Sandstone.—The circumstances under which this stratum occurs, have in the general way been already mentioned. *The brown sandstone* is found high upon the sides, or crowning the tops of all the insulated hills scattered over this district of the State; it lies in masses of all dimensions, from considerable blocks to pebbles the size of gravel, strewing the adjacent portions of the plain, and constituting in fact, in its disintegrated state, an essential part of the surface matter of the district. Being the only native material of the nature of building stone, known or employed throughout the lower section of the State, it becomes a matter of interest to ascertain and trace its numerous detached beds, so as to represent their place and extent upon the map. It is obvious that the topography of the map of the State is not sufficiently minute for such a purpose; and it is equally manifest, that the task, however useful, would far exceed the scope and time allotted to this general survey. Though I am not able therefore to specify all the localities of this rock, which indeed are very numerous, it may be useful to mention that the higher the ground the more likely we are to find it in mass, and that it is by no means confined to the distinctly formed hills, but occurs extensively in the more elevated parts of the intermediate country. We may state, moreover, that the larger and *more angular* are the loose fragments scattered around, the greater is the probability, that the rock exists in a solid stratum near at hand. The rock consists of two varieties, the one a coarse sandstone, the grains of quartz being cemented by brown oxide of iron, which colours the whole mass; and the other a similar sandstone, containing in addition, small white or yellowish pebbles of quartz, giving it the character of a puddingstone. In many instances, I have found the finer grained variety to lie beneath the other, but whether this be a universal rule or not, I cannot say.

The most conspicuous of the detached hills containing the two ferruginous strata before us, are:

The Nevesink range, on the southern shore of Sandy Hook bay; the range south and southeast of Middletown; the two isolated hills near Red Bank; those near Colt's Neck; the Sand Hills, between New Brunswick and Kingston; Mount Holly; Arney's Mount, near Juliustown; the Evesham Mount; the hill at the mouth of Shark river; and the Forked River Hills, near Barnagat.

Besides these localities there are several others where the brown sandstone, the uppermost of the series, occurs at an elevation but little exceeding that of the general surface of the district. One of these points is about four miles from Burlington, on the road to Mount Holly.

The ordinary condition of the yellow ferruginous sand is that of a loose, dry, and rather coarse sand, deeply stained by the hydrated peroxide of iron. This ingredient is sufficiently abundant in some places to act as a cement to the sand, and to form large masses or concretions of a singular ferruginous sandstone of a cellular structure. These occur in many places in the cliffs of the Highlands of Nevesink, especially at their southeast extremity. In the cliffs near the mouth of the Nevesink river the ferruginous sands contain also numerous hollow concretions composed of the same brown mixture of sand and oxide of iron, having the shape of bottles, flasks, and hollow balls or bombs; and what is curious, these are full of white sand, the ferruginous particles seeming to have been withdrawn from the sand within, during the formation of this concretion.

The nearly uniform height at which the yellow ferruginous sand and the overlying brown sandstone occur, wherever they are found in the greensand region and the tract bounding it on the northwest, leads us to infer, that these beds were once continuous over the whole area at present occupied by the lower members of the series.

The denuding currents, which have removed so much of these materials from the surface of the marl tract, have, in their progress towards the ocean, deposited apparently a large portion of the looser particles, in a general diluvial covering, concealing the strata, throughout the whole southeastern side of the southern half of the State.

The superficial sands thus derived occupy the area generally known as *the Pines.* Constituting as they do the debris of strata remarkable for their ferruginous composition, we can readily account for the extensive deposits of *bog iron ore,* which they furnish wherever circumstances favour a sufficient infiltration of water through them.

ORGANIC REMAINS OF THE UPPER SECONDARY STRATA.

It is of little importance to the practical purposes of the present report, to enter into any details respecting the numerous highly curious fossils which abound in the formations, a general description of which I have now given. The most fossiliferous beds are the greensand or marl stratum and the limestone, which so generally reposes immediately upon it. The fossils from these deposits, together with others from some equivalent formations in the Southern States, are described with the requisite details in an interesting work devoted expressly to the subject, by Dr. S. G. Morton, of Philadelphia. This highly esteemed contribution to our geology, is entitled "Synopsis of the Organic Remains of the Cretaceous Group of the United States,"—1834.

To that source I must refer for much specific information respecting the individual fossils of the greensand group. I may be allowed, however, to indulge in a few generalizations calculated to impart more correct notions than commonly prevail respecting the nature of the fossils, and the relative age and origin of the strata in which they are imbedded.

There have been found up to the present time, in the marl and the deposits connected with it, relics of about seventy-five extinct species, chiefly marine; of these, at least seven are of the class of large reptiles, including three species of *crocodile;* two of *fishes;* a *tortoise*, and a wading bird; upwards of sixty-five are remains of shell-fish, corals, and other tribes low in the scale of organised beings. It is a curious fact, that *not one* of the fossils of this catalogue can be traced to belong to any species living in the present day; and it is a scarcely less interesting circumstance that between these fossils and the organic remains of the most nearly related strata of Europe we discover but one species, the *Pecten Quinquecostatus*, common to the deposits of both continents.

The first fact determines the place of the marl group to be somewhere among the secondary rocks, and the generic affinities of the fossils to well known fossils of the greensand and chalk formations of Europe, makes us naturally regard that part of the secondary series as the most probable place to which to refer them. The striking want of identity between the species, renders it, however, a question of much uncertainty, to what precise formation of the secondary series of Europe these deposits strictly correspond.

To refer the production of the marl strata of New Jersey to the same period which produced the greensand rocks of Europe, merely in consequence of their both containing the green granular mineral, and to their having, moreover, a general resemblance in their fossils, is to commit the decision of the question to far too loose a mode of reasoning. Received principles of geological investigation require us rather to consider our own deposits as having originated during a somewhat different epoch from that which produced the European greensand formation.

The following list embraces nearly all the organic remains of the *upper secondary series,* hitherto discovered in New Jersey. It is compiled principally from the *synopsis* of Dr. Morton.

ORGANIC REMAINS OF THE GREENSAND FORMATION.

Reptiles.

Mosasaurus.—Teeth, vertebra, and bones of the extremities of this large massive saurian, have been found at various points in the greensand tract, in the excavations made for marl. They are thought to be identical with those of the Mosasaurus of Europe.

Geosaurus.—Teeth, with a portion of the jaw.

Crocodile.—Teeth and other portions, indicating three species, occur in the greensand.

Saurodon, (*Hays*).—Portions of a jaw of an extinct animal; the relations of which are not very clearly known. It is thought to be analogous to the saurians.

Great saurian, (of *Honfleur*).—I have discovered two vertebræ in the greensand near Big Timber creek, which I regard as either identical with, or very closely allied to bones figured by Cuvier from Honfleur, which he considers to approach nearer to the *plesiosaurus* than to any other genus.

Testudo.—Several bones of a large species of the order *Testudo.*

Coprolites.—These bodies have been occasionally met with, especially in the neighbourhood of Crosswick's creek, near the top of the stratum. In the present instance, they are most probably the fossilized dung of a species of crocodile; some of the bones and teeth of which occur near them.

Fishes.

Squalus.—Teeth and vertebræ of several species, considered formerly to belong to the genus *Squalus*, but lately placed by Agassiz under genera only more or less allied to the shark, are abundant in nearly every part of the greensand formation.

Sphyrœna.—Part of a jaw and several teeth of this curious genus of fishes have been found in the greensand, in Monmouth county.

Birds.

Scalopax (Snipe).—A solitary tibia, apparently belonging to this genus, has been found in the greensand, near Arneytown.

Testacea.

Sepia.—Several remains supposed to be of this genus.
Nautilus Dekayi, (*M.*)
Belemmites Americanus, (*M.*)
Ambiguous, (*M.*)
Ammonites placenta, (*Dekay.*)
Delawarensis, (*M.*)—Chesapeake and Delaware canal.
Vanuxemi, (*M.*)—Chesapeake and Delaware canal.
Scaphites hippocrepis.
reniformis, (*M.*)
Baculites ovatus, (*Say.*)
Bulla lignaria?
Turritella vertebroides, (*M.*)
encrinoides.
Rostellaria arenarum, (*M.*)
undetermined, (*M.*)—Casts, Delaware.
Tornitella bullata, (*M.*)
A small species; casts only found.
Cypræa.—A solitary cast, Delaware.
Patella tentorium, (*M.*)—Arneytown.
Ostrea falcata, (*M.*)—An abundant fossil.
plumosa, (*M.*)—Arneytown.
panda, (*M.*)—Delaware.
torosa, (*M.*)—Mullica Hill.
Gryphea convexa, (*M.*)
matabilis, (*M.*)
vomer, (*M.*)
Exogyra costata, (*Say.*)
Pecten quinquecostatus, (*Sowerby.*)
craticula, (*M.*)—Arneytown.
venustus, (*M.*)
Plagiostoma gregale, (*M.*)—Burlington county.
pelagicum, (*M.*)
Anomia argentaria, (*M.*)—Delaware.
tellinoides, (*M.*)

Placuna scabra, (*M.*)
Plicatula urticosa, (*M.*)
Avicula laripes, (*M.*)
A cast; species undetermined, (*M.*)
Pinna.—Two species not determined, (*M.*)
Pectunculus.—Species undetermined, (*M.*)
Cucullæa vulgaris, (*M.*)
antrosa, (*M.*)
Nucula.—Small casts of an unknown species, (*M.*)
Trigonia thoracica, (*M.*)
Cardium.—Apparently two species.
Cardita? decisa, (*M.*)—Delaware.
Crassatella vadosa, (*M.*)
tellini, (*M.*)
Venilia Conradi, (*M.*)—Arneytown.
Cytherea excavata, (*M.*)—Arneytown.
Lutraria?
Pholodomya occidentalis, (*M.*)—Delaware.
Pholas cithara, (*M.*)—Monmouth county.
Teredo tibialis, (*M.*)
Clavagella armata, (*M.*)—Arneytown.
Terebratula Harlani, (*M.*)—New Egypt.
fragilis, (*M.*)—New Egypt.
Sayi, (*M.*)—Burlington county.
Serpula barbata, (*M.*)—Deal, Monmouth county.
Hamulus onyx, (*M.*)

Crustacea.

Astacus.—A small species, Delaware.
Cancer.—Fragments of several distinct species have been found.

Echinodermata.

Clypeaster florealis, (*M.*)—Delaware.
geometricus, (*M.*)—Delaware.
Spatangus ungula, (*M.*)—Delaware.
Turbinolia inauris, (*M.*)

LOCAL DETAILS OF THE GEOLOGY OF THE MARL REGION.

With a view to exhibit the various aspects which the greensand assumes in different neighbourhoods, and to bring forward many matters of local interest not appropriate in a general account of the formation, I shall here introduce a series of descriptions embracing the principal localities where the marl is at present excavated.

Pursuing the usual order adopted, in tracing the local features of the other formations of the State, that is to say, proceeding from the northeast towards the southwest, I shall commence with the township of Middlesex, in Monmouth county.

Middletown Point.—The lowest portion of the greensand stratum, where it passes into the underlying blue sandy clay, is exposed at several places in the vicinity of Middletown Point, which is a little outside of the boundary designated as the northwestern edge of the formation. The proportion of the green granular mineral in the marl of this neighbourhood, is, therefore, less than where the higher layers of the greensand are most developed, towards the southeast.

On the farm of *Mr. William Little*, not far from Middletown Point, the stratum is of a light ash-gray colour, inclining somewhat to greenish. Though it contains a large excess of clayey matter, the green granules are readily discoverable. These particles after separation from the marl by washing, are of a light clear green.

The composition of this marl is, in 100 parts:

Greensand, - - -	46·73
Clay, - - - -	53·27
Quartzose sand, - -	none.
	100·00

Assuming the proportion of the *potash* in the green grains to be 11·5 per cent., which is the mean of the fifteen systematic analyses given in a preceding chapter, we find the amount of the alkali in this marl to be 7·47 per cent., a quantity capable of imparting very decided fertilizing effects.

Mount Pleasant.—One of the most northern points where the stratum is dug for marl, is upon a farm of J. Morgan, near Mount Pleasant. In the same neighbourhood a marl of very similar quality, is found underlying a part of the farm of Mr. Castlereagh, near the northwestern base of the belt of hills lying south of Middletown. These localities being near the northwestern margin of the formation, where only the lower portion of the greensand, adjacent to the underlying blue clay exists, the material contains, as in nearly every similar locality, but a moderate proportion of the green granular mineral, in which, as we conceive, the chief fertilizing power resides.

The hills here referred to, terminating on the farm of Mr. Conover, near the Dutch Church, consist of the ferruginous yellow sands, immediately overlying the greensand, overlaid by the brown ferruginous conglomerate which constitutes their summits. Greensand, therefore, occurs in places, beneath these hills and around their base. It is generally replete in the green mineral, and is of excellent quality, having been used in the neighbourhood since the first discovery of its fertilizing effects.

At Conover's, near the Dutch Church, we are in the midst of a highly fertile marl tract. The country is rather flat, or gently undulating, and extensively intersected by shallow valleys of denudation, or by meadows which are furrowed out down to the marl stratum, and in some cases twelve feet into it.

Analysis of the Marl, from the farm of Jacob Conover, Freehold township, Monmouth county.

Composition.—In 100 parts:

Greensand, - - -	85
Clay, - - - -	11
Quartzose sand, - - -	4
	100

The amount of *potash* which this marl contains, deducing it from that of the greensand, is 9·7 per cent.

The soil is mostly a loamy clay, sometimes sandy, and not often more than thirty feet above the top of the marl. Upon the marl lies a sandy stratum, containing a trifling share of the green particles and much ferruginous matter, which in some cases, by filtering down, has produced a change on the upper part of the marl bed to the depth of a few feet, dissolving out the shells and replacing them by oxide of iron. The thickness of the marl bed is not known, but perforations twenty feet deep have not penetrated through it. Its general aspect when moist is a deep blue, or black; when dry a light blue, or gray. The lighter kind contains more clay, which is of a dove-colour, and sometimes of a light gray. The tint of the grains is a dark olive-green, almost black, and in this quarter rarely a light green. Sometimes the clay exceeds in quantity the green grains, and this in marls which are regarded as being very active. Those varieties which possess the lowest reputation are found invariably to contain either a quantity of siliceous sand or mica.

The fossils are Exogyra costata, Gryphea convexa, G. mutabilis, Ostrea falcata, Belemnites Americanus, Terebratula, Spines of Cidaris, Teeth of Shark, and Vertebræ of Crocodile.

When the marl dries, the surface is sometimes covered with a white or gray incrustation. When moist, the black marl often exhales a sulphurous odour, and the white efflorescence has an astringent sweetish taste, indicating it to be in part at least, a *sulphate of alumina*.

The marl in this quarter has been known and used as a fertilizing agent for forty years. It is applied very profusely; one hundred loads to the acre, or even more, being no unusual dressing. The improvement to the soil is very permanent, changing the natural growth from *Indian grass* and *five finger*, (or cinquefoil,) to fine white clover. *White alder* and other plants of rich soils abound in the meadows.

The natural *timber* of this, as of most other parts of the marl tract, consists of several varieties of Oak, also Chestnut, Locust, Beech, Maple, Dogwood, Hickory, Liriodendron or Tulip Poplar, &c.

The following analyses exhibit the composition of the marl in this vicinity:

Analysis of a Marl, (the upper stratum,) from the farm of John Smock, Freehold township, Monmouth county.

Composition.—In 100 parts:

Greensand, - - -	90·00
Coarse siliceous sand, -	2·00
Ash-coloured clay, - -	8·00
	100·00

Analysis of the Greensand.

Composition.—In 100 parts:

Silica, - - - .	51·00
Protox. Iron, - - -	25·10
Alumina, - - -	7·50
Potash, - - - -	9·30
Lime, - - - -	a trace.
Water, - - - -	6·50
	99·40

Marl from the farm of Dr. Conover Thompson, two and a half miles northwest of Freehold, on the head waters of South river.

Description.—Colour, light-gray, with a very little tinge of green; is adhesive, and has much the character of clay.

Composition.—In 100 parts:

Greensand, - - -	50
Clay, - - - -	40
Quartzose sand, - - -	10
	100

The proportion of *potash* in this marl, deduced from that in the greensand, is 5·7 per cent.

Marl from the farm of William T. Sutpham, on the head branches of South river, two and a half miles northwest of Freehold.

Description.—Colour, earthy-gray, with but little tinge of green, mottled and coloured with oxide of iron.

Composition.—In 100 parts:

Greensand, - - -	40
Clay, - - - -	52
Quartzose, - - - -	8
	100

The *potash* in this marl, deduced from that of the greensand, is 4·6 per cent.

Mr. Joseph Vandeveer has opened pretty extensive pits, about half a mile to the north and west of Bucks. The marl is much like that of Mr. Smock's. The following analyses will show the composition in 100 parts, of the upper and lower strata, the last of which is the best.

Upper stratum:

Greensand, - - -	70
Clay, - - - -	27
Quartzose sand, - - -	3
	100

Lower stratum:

Greensand, - - - -	92
Clay, - - - - -	5
Quartzose sand, - - -	3
	100

The amount of *potash*, as deduced from that of the greensand, is, in the upper bed, 8 per cent., in the lower 10·5. The washed grains of the above marl are of a rich green, and small in size.

Large excavations have been made to the north and east of Bucks, by Mr. Charles Hendrickson, and a marl obtained corresponding in character to the preceding.

The above specimens furnish fair examples of the character of the marl in the vicinity of Swimming river.

Few exposures of marl are noticed in the tract between Bucks and Bloomdel. One and a half miles west from the latter place, it has been quite extensively worked by Elisha Holmes and Mr. Ely. A specimen taken at a point one-fourth of a mile from Bloomdel, where the road approaches to the side of Swimming river, will furnish an example of the marl of this neighbourhood.

This marl is greenish-brown in colour, and somewhat argillaceous in texture. When washed, its granules become more distinctly green, they are of small dimensions.

Composition.—In 100 parts:

Greensand, - - -	83
Clay, - - - -	13
Quartzose sand, - - -	04
	100

By direct analysis, this marl yields 8·5 per cent. *potash.*

At *Ely's mill* the marl is very impure, being almost entirely composed of siliceous sand; and doubts may exist whether it belongs to the marl bed, or the overlying clay.

At Mr. John Johnson's, *Nut Swamp*, the marl consists, towards the top, of the usual ferruginous yellow clayey bed, containing a small portion of the dark grains. This is not used, but is pared off to a depth of two or three feet. Next to this comes the dark marl, nearly black when wet, and rather hard in the bed, from the quantity of ferruginous matter which cements it. It crumbles on exposure, and becomes gray or even white, from the efflorescence which collects upon it. In it are large roundish masses of the marl cemented into firm stone by the oxide of iron. These, however, crumble down in time by exposure. In these beds the siliceous sand is very little in quantity. The top of the bed is the richest in greensand; lower down there is more of the dove-coloured clay, resembling precisely the clayey marl at Conover's. The vertebræ of a species of crocodile have been found here.

On *Porricy brook*, upon the road to Middletown, there occurs a fine exposure of the marl. It seems to be very thick and is covered by the yellow ferruginous sandy marl which is seen again half a mile south of Middletown, in the meadows. The black marl lies beneath.

At *Middletown* and its immediate vicinity, the upper yellowish, or ferruginous bed is chiefly seen; while the greensand marl has been reached in only a few points, though there can be no doubt of its existence at a small depth every where in the neighbourhood.

This upper portion of the marl stratum contains a considerable amount of the green grains, but mixed with much ferruginous clay and sand of an orange and variegated yellow hue. This orange and many-coloured clay is distributed in streaks and blotches.

The upper stratum is inferior to the green marl in fertilizing power, though it is used with excellent effect in many places near Middletown.

Marl from the Farm of Captain Edward Taylor, at Middletown.

Description.—Colour dull green; texture clayey, grains of small size. After being washed and freed from clay, the colour is more distinctly green.

Composition.—In 100 parts.

Greensand, - - -	80
Clay, - - - -	14
Quartzose sand, - -	6
	100

The proportion of the *potash*, ascertained by direct experiment, is 8 per cent.

The marl from the lower portion of the bed at Captain Taylor's, is richer in greensand than that from the upper, as will be seen by the following analysis:

Composition.—In 100 parts:

Greensand, - - -	90
Clay, - - - -	5
Quartzose sand, - -	5
	100

The amount of *potash* which it contains, is 9.9 per cent.

Between Middletown and Chapel, Jonathan Tunis has penetrated into the lower greensand marl, and uses it in preference to the yellow top bed, and with great advantage to the crop.

Near to Chapel, and about two miles east of Middletown, Mr. Daniel G. Conover, after penetrating the overlying soil and ferruginous layer, has obtained a marl of a singular mottled appearance; consisting of a mixture of light-coloured clay and greensand, looking when freshly cut somewhat like a decomposing granite. The lower portion of this marl has for its

Composition.—In 100 parts:

Greensand, - - -	84
Clay, - - - -	10
Quartzose sand, - -	6
	100

The proportion of *potash* deduced from that of the greensand, is 9·6 per cent.

The colour of the green mineral, after washing, is but little changed.

The upper portion of the marl bed of Mr. Conover is less valuable in greensand, as will be seen by the following analysis:

Composition.—In 100 parts:

Greensand, - - - -	67
Clay, - - - -	30
Quartzose sand, - -	3
	100

The amount of *potash* which it contains, is 7·3 per cent.

Chapel is upon a flat hill or table land; and a well near this place dug seventy-four feet through the upper strata, did not reach the marl, though it shows itself, near the surface, in all the surrounding low grounds, where it is of very good quality.

The hills are sandy and strewed with fragments of the conglomerate, which is also in place, being quarried half a mile south of Chapel.

The timber growth on the hills contains a pretty large mixture of cedar.

The marl extends from Chapel north towards the Bay shore, as far as the permanent land itself. Richard Wallin has reached it in digging a well; it was seven feet below the surface, and was penetrated fourteen feet. Mr. Anderson, within half a mile of the shore, also has a marl pit. The dark green grains abound in the sands of the beach, and every where as we pass along the road from Chapel to the Bay shore, towards the east.

Bay Shore and Cliffs of Nevesink Hills.—The marl appears to extend to within a short distance of the Bay shore near Compton creek. The first cliffs which we meet with on going along the shore to the east, exhibit a dark stratum, chiefly clay and siliceous sand, with mica, containing very little of the marl, and often a considerable share of copperas, which shows itself upon the surface, in the state of a yellow efflorescence. Tracing the base of the cliffs, we see this stratum slowly rising and forming the lowest bed visible along the beach, nearly the whole way to the termination of the highlands at the Telegraph hill.

In some places the cliffs have a height of fifty or sixty feet, composed of several different beds, all containing more or less of the marl; but some of the layers are chiefly made up of siliceous sand, and clay, and ferruginous matter. Over the dark lead-coloured siliceous clay, a stratum of the sand is seen, often green, though for the most part gray and quartzose. High above this the true marl is seen in many places, and may be known by its *white* efflorescence.

The marl taken from the cliffs about two miles northwest of the Telegraph Tavern, exhibits the following,

Composition.—In 100 parts:

Greensand, - - -	92·2
Clay, - - - -	5·8
Quartzose sand, - -	2·0
	100

The proportion of *potash*, deduced from that of the greensand, is 10·6 per cent. The appearance of this marl is a dull or dirty green, and is little changed by washing.

Where the cliffs are high, the conglomerate is seen in its natural place, over the top of all. Near the upper surface of the marl bed may be seen large globular masses of indurated and cemented marl, like that found before at Nut Swamp. They here possess the hardness of a true rock and do not crumble. The freshly fractured surface is often very beautiful, showing the green grains of marl distributed through a cement of argillaceous red oxide of iron. The globular masses are seen in horizontal layers in the marl, and they strew the beach pretty thickly. The blocks of the horizontal iron stone are often several feet in diameter. Sometimes the consolidated ferruginous masses of the cemented sand are the size of a small apartment.

In several places beneath these cliffs of the Highlands, vast masses of the strata have subsided by the undermining action of the water passing through the lower beds, and they form an *under-cliff* or landslip with a steep pitch toward the land, bringing down into nearer view the top strata, the upper ferruginous sands of which, owing to the condition of their oxide of iron, are of a most beautiful reddish colour.

At the shore beneath the Telegraph hill on the ocean side, the lower dark astringent stratum is seen at the water's edge, the piles in the foundation of the wharf, in front of the Telegraph Tavern being driven into it. Some portion of this bed is said to be marl, and the green grains abound every where *among the sands of the beach*, as they do at Long Branch, a few miles more to the south, and indeed the whole way from the commencement of the Nevesinks along the bay shore, and along the sea-shore to Deal.

Tracing the cliffs round the Telegraph Point to the mouth of the Nevesink river, the lower or marl-bearing strata, are covered by a steep talus or inclined bank of fallen matter at the base of the cliff, reaching thirty or forty feet up. Above, are the yellow sands covered by a layer of the cellular iron stone several feet in thickness, being beautifully displayed at the Devil's Chimney. Above this there is a very ferruginous, brownish, consolidated sandstone, full of impressions or casts of shells, especially *ostrea falcata.* It seems to be a more ferruginous portion of the stratum. A little above this, at the height of eighty or ninety feet, is a bed a few feet thick, of a bright *green clay*, consisting apparently of the same material as the light green variety of the marl, but not in a granular condition; it includes a few indistinct light green grains. Over this again and towards the top of the hill, the fragments of the conglomerate abound, and there is every reason to believe that all the hills near the mouth of Nevesink river, are capped by the conglomerate in place.

Along the north bank of the Nevesink river, at Mr. Hartshorn's, the stratum which is on a level with the beach is the copperas-bearing dark clay and sand. It has been found by him to be hurtful to the soil when applied thick, but as it contains a very considerable share of the green grains, it is probable that applied in lighter dressings, it might prove somewhat beneficial.

There is no good marl from the mouth of Nevesink river up as high as *Claypit creek*, above which as far as its head, the marl extends on the north side and is generally very good. The other or astringent stratum below the marl, sometimes takes its place in the banks on the water's edge.

Ascending the Nevesink river, no good marl occurs below the west side of Burgis's or Claypit creek, where it is of excellent quality; from thence to the next, or Redneck creek, the impure astringent kind prevails; on the west of the creek, the bed at the water's edge is again the true marl, being like Burgis's. The deleterious bed contains much ordinary sand and mica, abounding also in oxide and sulphuret of iron, and seems to be in fact the same stratum as that upon the bay shore under the Greenland banks, in the Nevesinks.

We may trace the marl to Crow's creek; approaching which it becomes very green and good. Here and farther east it lies below the layer of nodular indurated marl seen on the bay shore, on the top of which is the micaceous sandy bed containing copperas. In one place on the very beach, the marl has been dug and exported to Barnegat, for sixty-eight cents for the load of twenty bushels.

On drying this marl, it assumes a light-green colour. The spurious bed almost invariably presents the yellow astringent efflorescence, and is evidently a different layer from the good marl; and there seems to be no good reason to doubt that this shore if examined, would every where display *both* beds; the astringent clay above, the nodules next, and below all, the pure greensand marl.

The reason that the banks of the Nevesink river display sometimes the true marl, and at others the dark astringent clay, seems to be, that there occurs a slight undulation of the strata. Some have thought them portions of the same stratum, shading into each other upon the same level. The above view is the correct one, and is important, as it indicates the possibility of reaching marl almost *any where* by sinking to a very small depth.

Red Bank.—In this neighbourhood the banks of the river vary in elevation from ten to twenty feet and upwards. On the north side, near the bridge, on the land of Mr. Tylee Conover, the bank presents a bed of diluvium four feet thick, the lower part of which is tinged with oxide of iron. Beneath this lies the upper layer of the marl, eight feet in thickness, consisting of a mixture of very tenacious clay and greensand. Resting directly below this, and nearly on a level with the tide, occurs the main bed of marl, forming the beach of the river. It is composed almost entirely of the greensand, the extraneous matter being merely a little white siliceous sand and clay. Excavations to the depth of several feet are made at the retiring of the tide, and the marl thus procured is much preferred to that of the overlying layer in the bank. Its colour is a dirty green; that of the washed greensand is brighter; the granules are rather larger.

That portion of the stratum which is below the level of high water at Mr. Tylee Conover's, gives the following:

Composition.—In 100 parts:

Greensand, - - -	93·85
Clay, - - - -	6·15
Quartzose sand, - -	none.
	100·00

The amount of *potash* in the whole marl, as obtained by direct analysis, is 9.5 per cent. Though the marl throughout this neighbourhood is generally rich in the greensand, the good effects of this are sometimes impaired by the presence of decomposing sulphuret of iron, which it derives especially from the overlying ferruginous bed.

At Judge Patterson's we have a convincing proof of the hurtful influence of the copperas, in a marl otherwise excellent; his being extremely rich in the fertilizing green grains. The bank for a few feet up from the level of the water, is composed of the marl stratum, abounding in the yellow astringent efflorescence. Tried upon the land, it has been found injurious to the crops for at least the first year or two, unless when applied in great moderation.

Where the poisonous impurity is abundant, it is not safe to employ more than five loads of the marl upon an acre; nor do I see any good reason why five loads of a rich marl is not enough, in nearly all cases, for a single dressing.

The entire material of the beach beneath the bank, consists of the dark greensand, from which nearly the whole of the astringent matter appears to be removed by the washing of the waves, as the caving of the bank from time to time, brings down the matter upon the beach, and within the dissolving action of the water.

This washed marl is pure, and may be used, as some experiments made by Judge Patterson have fairly proved, in any proportion, even at the rate of one or two hundred loads to the acre, without showing any caustic action upon the vegetation. This among other facts induces me to recommend to the farmers, to expose their *caustic* or astringent marls to the rain for a season, before attempting to employ them.

On the south side of the river, one-fourth of a mile below Red Bank, the shore, which is rather steep and about twenty-five feet high, displays a bed of dark micaceous sandy clay, overlaid by a mass of diluvial sand and gravel twelve feet in thickness—the line of separation between these being very obvious. The dark micaceous clay and sand on this side of the river seems to replace the upper impure layer of marl of the opposite or north shore. From the surface of the water to its upper edge it is about twelve feet in thickness, and it extends down along the water's side as far as Jeffries' Point.

The stratum of pure greensand lying immediately below this layer, corresponds to the lower bed on the north side of the river. It consists almost entirely of the green granules. The marl is penetrated to the depth of about twenty feet at several spots along the beach. Though Jeffries' Point seems to be the termination of the dark micaceous clay and the underlying greensand on the south side of the river, yet there are good reasons for inferring that the marl extends along the opposite side at an accessible level the whole way to the extremity of the peninsula dividing the Nevesink and Shrewsbury rivers.

The marl at Jeffries' Point is of a lighter green than any in this immediate quarter. Very few organic remains occur in the greensand formation in this vicinity, either in the cliffs of the Nevesink Hills or in the banks of the river.

The marl of Jeffries' Point gives by analysis the following:

Composition.—In 100 parts:

Greensand, - - -	92·5
Clay, - - - -	7·5
Quartzose sand, - -	none.
	100·0

The proportion of *potash* in this marl, deduced from the average quantity in the greensand, is 10 per cent.

When washed, the granules are large and of a dark green colour.

A marl taken from the beach near Red Bank, belonging to Jonathan M'Lane, exhibited the following

Composition.—In 100 parts:

Greensand, - - -	91·4
Clay, - - - - -	8·6
Quartzose sand, - -	none.
	100·0

The *potash* in this marl, by calculation, is very nearly 10 per cent.

The ordinary aspect of the marl is a dull green; that of the washed greensand is a brighter, purer green. The granules are rather large.

Marl of good quality displays itself in several places between Red Bank and Shrewsbury, and around Eatontown. That at the farm of Mr. Lafetrea near Eatontown affords by analysis the following

Composition.—In 100 parts:

Greensand, - - -	79
Clay, - - - -	13
Quartzose sand, - -	8
	100

The *potash* in this marl, by estimation from the amount of the greensand, is 9.1 per cent.

About one mile southeast of Eatontown, in a low swampy tract of ground, Dr. John P. Lewis has uncovered a stratum of somewhat peculiar marl, composed of fragmentary shells, a little greensand, and much quartzose sand intermixed. From several trials which have been made, it would appear to be endowed with decidedly fertilizing properties.

Between Eatontown and Long Branch, and about three miles from the sea-shore and two from Eatontown, at a mill called Turtle Mill, there occurs a variety of marl somewhat analogous to the above. It consists of hardly any thing but shells in a fragmentary condition, very friable and purely calcareous, and contains but a very small share of the green particles; its colour is yellowish, owing to a small portion of common sand. The shells are in a very broken condition, but we may recognise them to belong to the well known secondary fossils of the marl. The large shell called *Terebratula Harlani* seems to constitute a large portion of the mass. Something similar is seen farther to the south, on the farm of Mr. Field, about one and a half miles from Eatontown. This deposit deserves to be traced more minutely, as it is probably a new variety of marl fit for the agriculture of the neighbourhood, containing much more lime than the greensand formation usually possesses.

Long Branch.—Along the cliffs facing the ocean in front of the boarding-houses at Long Branch, appearances in several places show that the true marl stratum meets the sea-coast in this quarter, and that it cannot lie at any considerable depth below the beach. About half a mile north of Renshaw's, at apparently the highest point in the cliff, the astringent clay bed which so generally accompanies the marl as an overlying stratum is exposed, rising four or five feet above the average level of the beach. This itself is strongly indicative of the existence of the marl at no great distance beneath. The probability of this is manifested, however, in another way. The sand of the beach contains a very notable proportion, often *five per cent.* or more, of the green granules of the marl, which examination assures me cannot be derived from any of the strata in this part of the bank, and which therefore, can only come from a bed extending into the sea below the ocean level, or at least lying as low as the base of the cliff. This mixture of the green granules among the sand of the beach is observable along the whole of the bay shore, from near *Chapel* to the Telegraph Hill, and thence along the ocean side from the mouth of the Shrewsbury river past Long Branch to Deal, and somewhat further. It has been discovered somewhat recently, that the beach sand throughout this line is endowed with active fertilizing powers, attributed heretofore to salt and other supposed marine substances in the beach. But the well known properties of the green grains, coupled with the fact that in every place along the shore further south than Deal, where the marl does not reach the coast, the sand of the beach contains none of the dark granules, prove conclusively that the benefits so distinctly perceived, are attributable to the source which I suppose. The good effects of the beach sand are strikingly exhibited upon Wardell's farm, a little north of Long Branch: no less decided results are also witnessed on the farm of Jacob Curlis, at Deal. The most sterile patches of sandy soil are made to yield very abundant crops of corn by the use of this powerful agent. The quantity of the beach sand applied, is often as great as two hundred loads to the acre; but the facilities for procuring and spreading it are very great. It is obviously a point of importance to discover those portions of the beach where the green matter is most abundant; for there are spots which are much darker than the rest from this cause. Experience has already taught that the sand gathered after the heavy storms of the winter, is the most efficient, a fact countenancing the notion that the green grains are cast up by the beating of the surf. The high degree of fertilizing power possessed by the beach sand, upon both the clayey and dry sandy soils of this portion of the sea-board, goes far towards establishing several very essential points in the doctrine previously advanced concerning the cause of the enriching qualities of the greensand. It clearly demonstrates, in the first place, that the efficacy of the marl lies mainly in these green granules, and not, as many imagine, in the shells and other foreign substances discovered occasionally in the bed. It moreover decides the point, that the more essential and permanent properties of this mineral are in no way connected with the gypsum, or with the carbonate of lime, which so frequently form a coating upon the green grains. Both of these incrusting matters, should they exist in the stratum from which the granules are derived, are too easily dissolved by the water which incessantly washes the shore, to remain in the sand in the smallest appreciable quantity.

We are forced, therefore, to ascribe the usefulness of the green mineral to its *potash*, the only ingredient of an alkaline action which is always present and which is essential to its composition.

Another important consideration is, that the marl or green mineral loses nothing of its potency by a long exposure, even of years, to water and the atmosphere; in other words, that it is not dissolved, or decomposed, or changed, by the ordinary atmospheric agents which react so powerfully upon many other minerals. We are to regard it, therefore, as nearly unchangeable until the roots of the plants come in contact with it, cause its decomposition, and by the *vital* powers of their organs, imbibe a portion of some of its constituents.

When we behold a luxuriant harvest, gathered from fields in which the original soil is of a kind least of all congenial to vegetation; when we find that all this fertility, contrasting so strikingly with the barrenness around it, proceeds from a few granules of a substance sparsely distributed through the enormous and counteracting excess of sea-beach sand, more arid than the soil to which it is applied, are we not led to look with admiration on the potent properties of this curiously constituted mineral? The developements of geology are full of instances like this, showing in how many unlooked-for ways, the mineral world may be made subservient to the good of mankind.

This striking proof of the fertilizing power of the marl ought to encourage those districts not directly within the tract, where some of the strata possess the green granules in a sensible proportion. It expands most materially the limits of the territory where marling may be attempted, and points us to many beds as fertilizing, which otherwise would be deemed wholly inefficacious.

There can be no doubt that the agriculture of our seaboard States is destined to derive essential benefit from the remarkably wide distribution of this green granular mineral under various geological relationships, besides those in which it presents itself in New Jersey.

Thus the tertiary shell marls of Delaware, Maryland, and Virginia, and I might add of other States still farther south, contain not unfrequently as high a per centage of the greensand, as does the sea-beach sand upon the coast of Monmouth county in New Jersey; and I may mention that my brother, Professor William B. Rogers, of the University of Virginia, charged with the geological survey of that State, has already done important service to the agriculture of some districts, by discovering, and calling attention to the existence of the greensand in the tertiary strata of Virginia.

Between Long Branch and Deal, the marl stratum has been penetrated thirty feet. The upper two feet consist of a green clay, seemingly derived from the disintegration of the green grains, intermixed with a large proportion of yellowish white clay. The main marl bed having a thickness of about twenty-six feet, contains several subordinate layers, but all contain a large share of the green granules. Beneath the whole there is a gray-yellowish clay, in which the grains abound; they are remarkably large, and are associated with numerous casts of shells. A similar layer is seen in Jacob Curlis's pits, where it contains beautiful casts of the *nautilus* and several univalve shells, and also shark's teeth. The marl stratum, composed of nearly the same layer, is exposed again between Jacob Curlis's and the Whale Pond Mill, at John Curlis's. At all these points, the bed contains a considerable share of astringent matter, sulphate of iron, which, wherever it shows itself in excess, may be counteracted by following the suggestions proposed in this report.

Elisha West's, near Long Branch.—A very interesting and rather extensive exposure of the marl stratum may be seen on the farm of Elisha West, about one mile south of the boarding-houses at Long Branch, and in a direct line, not more than a fourth of a mile from the sea. The pit is dry, a rather unusual circumstance, and occurs near the head of a gently sloping hollow or small valley, which circumstance in connexion with the obvious outline of the ground between it and the shore, leads the observer to believe that the top of the stratum is not as low, by several feet, as the sea-beach. It follows, if this be correct, either that the marl bed runs horizontally and meets the cliffs at the sea-side, above their base, where the inclined pile of fallen matter may conceal it, or else that it descends with a gentle eastward dip until it merges beneath the ocean at a lower level than the tide. This question is of some consequence to the neighbourhood, for a good marl pit opened directly on the shore would benefit no inconsiderable line of coast.

The section in the pit is about twenty feet deep, being almost entirely in the marl stratum. The top layer, one foot thick, consists of an indurated marl, somewhat similar to that at the top of the marl at Ely's, on Shark river. It contains but a trivial proportion of the granules, which are imbedded in a paste of a grayish-white calcareous clay, identical in aspect and composition with certain waterworn rocky masses which strew the beach in front of the boarding-houses. This apparent identity in all respects except hardness, furnishes a farther proof that the marl stratum is prolonged to the sea-side, and rests either at the level of the beach or at so small a depth beneath the surface, as to be within the action of the surf, which may, I conceive, disturb and bring to shore not only portions of this upper bed, but likewise of the softer marl below.

Beneath this upper bed in the pit at Elisha West's, there occurs a hard, somewhat firmly cemented mass, consisting of light green grains and a little ordinary sand, the whole being eight feet thick. In it is a very thin layer of white clay. Lower down we meet a gray and afterwards a yellowish ferruginous marl, both rather sandy, and in aggregate thickness about three feet.

Still lower and throughout the rest of the vertical section we find a layer of yellowish ferruginous sand, containing a very moderate proportion of the green grains. Few or no shells are visible in the perpendicular wall or section disclosed in this pit, but numerous traces of casts occur, showing that they have once been there, and intimating the nature of the change which they have undergone, and the possibility that they may have furnished to parts of the stratum a small amount of diffused carbonate of lime and perhaps gypsum.

The marl from the pit of Elisha West displays by analysis the following

Composition.—In 100 parts:

Greensand, - - -	73·2
Clay, - - - -	22·8
Quartzose sand, - -	04·0
	100·0

The amount of *potash*, deduced from the above proportion of greensand is about 8·4 per cent.

This marl is a light yellowish green; adhesive; the admixed clay giving it a mottled appearance. The washed material is darker and more distinctly green; the granules are small.

Tinton Falls.—The stratum here is a dark brown and greenish friable sandstone, which forms a horizontal ledge across the creek, causing, by its abrupt termination, a sudden fall of about sixteen feet. It seems to be nothing more than a very sandy and highly ferruginous marl, consolidated by the cementing action of the oxide of iron into a moderately compact sandstone. It abounds in the usual characteristic shells of the marl series, but these are almost invariably in the state of casts. The amount of the green grains in the rock is not very considerable, though sufficient, in some of the layers, to impart a decidedly green or dark olive hue to the otherwise brown mass. Three layers of nearly similar aspect, all differing somewhat in their hardness and the proportion of oxide of iron and of the green granules, are to be observed here.

Whether this rocky stratum at Tinton Falls may not be the equivalent of the brownish ferruginous sandstone with casts, which overlies the friable marl in the Nevesinks, near the mouth of Shrewsbury river, or whether it is the true marl stratum rather more than usually cemented, and ferruginous, are questions which it is of some importance to determine, in order to form a just opinion as to the probability of meeting, at a moderate depth, the valuable bed of loose greensand itself.

Nearly upon the same horizontal line with the top of this rock, and at a less distance than a fourth of a mile, a bed of sandy green marl, not consolidated, shows itself very near the surface of the fields upon the Monmouth road. The somewhat clayey texture and greenish hue of the road itself between this point and Eatontown, is strongly indicative of the proximity of the marl stratum to the soil.

Poplar Swamp.—At Jacob Woolley's, Poplar Swamp, the section of the marl stratum which is exposed, exhibits three separate layers. The top bed is about three feet thick; the granules are of a light green, and mixed with them, is a small quantity of common siliceous sand. The next, or middle layer, is four feet thick, of a much darker green; and the bottom bed is of a dull greenish ash colour, and contains rather less than fifty per cent. of the green granules, the rest being clay and ordinary sand. Very few shells occur at this locality, though bones of the fossil crocodile and shark's teeth are occasionally met with.

The middle stratum gives indications, from its darker green colour and greater freedom from foreign matter of being the most efficacious of the three as a marl. Astonishing results have been produced by it when applied in the proportion of from seven to ten loads to the acre.

This marl lies on Poplar Brook, the source of which is about a mile west of Mr. Woolley's, its entrance to the ocean being at Deal. There is marl in the banks of the meadows and adjacent ravines throughout nearly the whole length of the stream.

Mr. Woolley manured a piece of land in the proportion of two hundred loads of good stable manure to the acre, applying upon an adjacent tract of the same soil his marl in the ratio of about twenty loads per acre. The crops, which were timothy and clover, were much heavier upon the section which had received the marl: and there was this additional fact greatly in favour of the fossil manure over the putrescent one, that the soil was also entirely *free from weeds,* while the stable manure had rendered its own crop very foul.

This greensand stratum at Poplar Swamp seems to be almost entirely free from any sulphate of iron or other astringent material, and, as a consequence, the crops seem not to be scorched by an extra dose, however lavishly applied.

There can be no doubt that twenty loads of marl per acre must be regarded as an unnecessarily bountiful dressing, but computing the relative cost of the two manures, when employed in the ratio above stated, we find a considerable disparity in favour of the greensand. Placing the home value of farm-yard manure at one hundred cents for each two-horse load, and that of the marl at twenty-five cents per load, we have the expense of manuring one acre, *two hundred dollars;* of marling the same, *five dollars.*

This being an *experiment,* an extravagantly large dressing of manure was employed, but not exceeding the usual average application more than the twenty loads of marl surpassed what was necessary.

Experience has already shown that land once amply marled retains its fertility with little diminution for at least ten or twelve years, if care be had not to crop it too severely; while with all practicable precautions, the stable manure must be renewed at least three times in that interval to maintain in the soil a corresponding degree of vigour.

Marl from Mr. Woolley's middle bed possesses this

Composition.—In 100 parts:

Greensand, - - -	86
Clay, - - - -	12
Quartzose sand, - -	2
	100

The amount of *potash* by experiment in this marl, is 7·5 per cent.

I present here the analysis of another marl from the same neighbourhood. It is that of Mr. John Howland, of Poplar Swamp. Its colour is grayish-green, owing to a coating of carbonate of lime on some of the particles. The washed material is a light and rather rich green.

Composition.—In 100 parts:

Greensand, - - - - - - -	88·5
Clay with a little carbonate of lime, -	6·5
Quartzose sand, - - - - - -	5·0
	100·0

The amount of *potash* deduced from that of the greensand, is 9·7 per cent.

Shark River.—Ely's marl pits, on Shark river, present the following layers in the descending series:

1st. A dark-brown or amber-coloured mixture of sand, clay, and mica; reminding one strongly, both from smell and aspect, of an ooze of the ocean. It sometimes contains thin seams of very coarse sand, completely water-worn and rounded. This bed is between seven and eight feet in thickness, and is seen resting immediately on an indurated or cemented marl. It is visible elsewhere in the neighbourhood, and always has the astringent character of the corresponding bluish sandy clay already so often mentioned, with which, in fact, I hold it to be identical as a stratum.

2d. A hard cemented marl, being a paste of a yellowish white clay, perhaps containing gypsum, with a moderate sprinkling of the marl grains. Except in its being a cemented mass it differs but little from the bed of friable marl which underlies it. It is two feet thick.

3d. This lower stratum yields the well known marl so much in request in this part of Monmouth. When moist, the mass possesses a dark, dull, grayish hue, from the colour of the clay which coats the granules. When dry the colour is a very dark plumbago (black-lead) tint, or sometimes a deep olive-green tinge. It consists of little else than the dark granules, the small quantity of clay present occurring only as a thin coating upon the grains. The lower part of this layer has a more yellowish hue from a greater excess of the clay, which is here rather ferruginous. The thickness of the bed is not known, though it has been penetrated sixteen or seventeen feet.

I have witnessed its action on some very poor light soils, which were rendered highly fertile from the use of this marl in a first dressing of five loads to the acre, and an equal quantity at the next rotation of the crops.

The best marl of Ely's bed exhibits the following

Composition.—In 100 parts:

Greensand, - - -	80
Clay, - - - - -	20
Quartzose sand, - - -	none.
	100

The amount of *potash* in this marl, by calculation, is 9·2 per cent.

The following analysis shows the composition of another marl of this neighbourhood, that from the pit of Mr. John Shaft, of Shark river.

The specimen was taken from near the mill, and is the best of the several samples procured.

Composition.—In 100 parts:

Greensand, - - -	87
Clay, - - - - -	11
Quartzose sand, - - -	2
	100

The amount of *potash* ascertained by analysis, is 9.5 per cent.

Squankum.—Thorp's marl, near Squankum, presents the following varieties:

1st. On the top, a bed of diluvial sand and gravel, and in certain places a coarse, ferruginous sandstone, sometimes two feet thick.

2d. A light greenish-blue clay, the upper part of which sometimes shades into a brown sandy clay, like the corresponding bed at Shark river. One portion of this contains a small mixture of the green granules. This portion appears, in fact, to graduate into the upper part of the marl bed, in which there is not unfrequently as much as fifty per cent. of the clay itself.

3d. The inferior layer is the true marl stratum, consisting of little else than the green granules. When dry, the colour of the mass is a tolerably light grayish green, but not uniform, light specks occurring throughout the marl.

When the heaps have dried, the external grains are coated, in some degree, with a white efflorescence. The upper portion of the bed, in consequence of containing much of the astringent clay, presents a good deal of the yellowish efflorescence ascribed to copperas. The depth which has been reached in the pits is about twenty feet, and hitherto the bottom of the marl has not been struck. The lower part of the stratum is conceived to contain the best marl. It is not free from decomposing sulphuret of iron, judging from the strong odour of sulphur which every pile of it exhales, and which it does not lose even after being conveyed to a distance, and long exposed to the weather. It probably, therefore, contains a slight impregnation of sulphate of iron or copperas, but not enough to injure it, if we are to infer from the reputation which this marl possesses.

At the pits, which are very extensive, the marl is sold at the rate of 37½ cents the load, the purchasers having to dig it. It is transported by wagons to a distance, in some directions, of twenty miles, and retailed, when hauled that far, at the rate of 10 or even 12½ cents per bushel, being very profitably spread upon the soil in the small proportion of twenty-five or even twenty bushels to the acre.

In its external aspect this marl does not differ from many others in the State, nor am I convinced that it surpasses a numerous list in point of efficacy as a fertilizing agent. The amount of *potash* which it contains is materially less than belongs to a large proportion of the better marls of the region.

Marl from the upper part of the bed at Squankum.

Composition.—In 100 parts:

Greensand, - - -	58·36
Clay, - - - -	27·64
Quartzose sand, - -	14·00
	100·00

The amount of *potash* in this marl, deduced from an analysis of the greensand of this locality, is 6·1 per cent.

Marl from the middle part of the bed at Squankum.

Composition.—In 100 parts:

Greensand, - - -	35·72
Clay, - - - -	54·28
Quartzose sand, - -	10·00
	100·00

The amount of *potash* in this marl, deduced from that of the greensand, is 3·7 per cent.

Marl from the lower part of the bed at Squankum.

Composition.—In 100 parts:

Greensand, - - -	68·29
Clay, - - - -	27·71
Quartzose sand, - -	4·00
	100·00

The amount of *potash* which this marl contains, derived from an analysis of the selected grains, is 7·1 per cent.

In the neighbourhood of Mount's Mills or Berkelue's, at Mr. Rue's, half a mile south of Spotswood, there is a black clay like that of Middletown Point, containing a considerable quantity of the marl. It has been thought to be somewhat beneficial to the land. It is near Mr. Berkelue's mill-pond, and not in the lowest ground. There is a considerable undulation of the surface in this quarter, though the denudation would seem not to have reached a low level. The superficial stratum is sandy, containing also some of the loose materials characteristic of the marl region.

At the pits of William Johnson, one mile east of the former, the supposed marl stratum exhibits a small proportion of the greensand with much siliceous sand, some clay and mica, and has a decidedly sulphurous odour; it also tastes of copperas, and has a yellow crust. These pits lie in the side of a hill, on the road from the mills to Johnson's house. Around this neighbourhood the land is rather high, and hence perhaps the true marl has not yet been reached. The proximity of this impure marl to the railroad, makes it desirable, if possible, to learn whether the true greensand bed does not lie below it at an accessible depth.

Three miles from Englishtown, on the Matchaponix creek, at John Perrine's saw-mill, the same stratum is seen as at Rue's. It is not so destitute of the grains of marl as to be entirely unfit for use. It occupies the bed of the creek for some distance below the saw-mill. It is sandy and micaceous, with small irregular concretions of clay cemented by oxide of iron, and a few grains of marl.

In many parts of this section there is a stratum of a mottled bluish clay with blotches of yellow ferruginous clay. This lies over the spurious marl stratum, and looks not unlike the upper marl bed at Middletown and its vicinity.

Around the parsonage, two and a half miles from Englishtown, on the road to Freehold, the marl is pretty good, though a little impure from containing some sand and clay. At no great depth it contains shells and other fossils. The soil is sandy, but grows better to the northwest. All the indications of the marl region are present here.

In and around the farm of Mr. Hunt, one mile from Bloomsburg tavern, the marl lies extensively denuded in the meadows. It is pretty good, consisting mainly of greenish grains, with a good deal of clay. These meadows are very ferruginous, and contain bog iron ore.

Marl from the farm of Mr. Hunt.

Composition.—In 100 parts:

Greensand, - - -	75·0
Clay, - - - -	19·5
Quartzose sand, - -	5·5
	100·0

The proportion of *potash* which this marl contains, deduced from that in the greensand, is 8·6 per cent.

The marl seems not to be known much farther to the northwest, in which direction there is a low range of hills of denudation.

Below the dam at Bargain's mill, on the Millstone creek, the spurious marl stratum is visible again. At Lewis Perrine's, half way between this and the Presbyterian church, the marl is found, but not very good; it lies rather high in the fields. The true marl is known here as far west as Mr. Van's, two miles farther towards the railroad on Rocky brook, one mile below Imlay's mills. The quality is not known, but it is supposed to be the inferior sort.

At Willow Tavern or Clarksburg, a thin layer occurs in the roadside, being a light-green marl with yellow specks. Beneath this there is a whitish bed of siliceous sand with white clay and a very few yellow and green specks.

The ochrey olive hue, so common in the clay of the marl region further to the southwest, is seen here upon the road, and though no marl has been dug, I do not doubt its existing in this quarter. Marl, declared to be good, has been found two miles to the northwest of Willow Tavern.

The country between this and Allentown is, for a certain distance, somewhat hilly, then flat and very sandy. Hills occur of some magnitude near the head waters of Rocky brook, and range from east to west. The highest is called Pine Hill, and is the same which is seen so conspicuously from Hendrick Conover's insulated hill, as before noticed. We pass through a gap in this range, in coming from the northeast to the Willow Tavern.

Two ranges of high grounds seem to extend in parallel directions to the southwest, one on each side of the road going to Wrightsville, before reaching which place, however, the western one is crossed. To the east is Cream Ridge.

At the head of Montgomery's mill-pond, near Allentown, Mr. Burden has dug in search of marl. It is very poor (of the spurious kind), no green grains being visible, and it tastes strongly of copperas. At the rate of twenty loads to the acre it destroys the crop. A very slight dressing, however, was thought to be beneficial to potatoes. The stratum is the blue sandy clay usually so astringent.

At Crosswick's, Gideon Middleton has a marl pit near the mill, in which the layers are as follows:

1. A micaceous tough clay on the top.
2. A rather greenish gray marl, somewhat micaceous, but pretty rich. Beneath this, one foot of ferruginous marly concretions, each about the size of a man's head.
3. A dark blue marl.
4. A black sand and marl.

In sinking a well at his house, many years ago, the beds traversed were ten feet of yellow sand, then twenty-seven feet of marl, and below all a white sand. Low down in the pit just spoken of, shells, belemnites, &c. occur. Fossil wood, with much pyrites attached, is sometimes seen in the marl pit near the bottom.

This marl is highly fertilizing, as Mr. Middleton's fields show. Mr. M. has *mixed it with lime with very beneficial results.* In the upper stratum, yellow incrustations of efflorescent sulphate of iron abound.

Marl from the farm of Gideon Middleton.

Composition.—In 100 parts:

Greensand, - - -	68·00
Clay, - - - -	29.00
Quartzose sand, - -	3·00
	100·00

The proportion of *potash* which this marl contains, deduced from that in the greensand, is 7·8 per cent.

The marl is very good one mile lower down upon Crosswick's creek, at David Killey's. It lies in a bank on the side of the meadows along the creek, and has a top layer of the black astringent clayey or spurious marl. There is a good marl on Crosswick's creek, half a mile above Hogsback landing, and I am told it extends still lower down. This proximity to the railroad is a matter of much importance to the adjacent region.

Near the Sand Hills, and in places between these and Bordentown, the lower or spúrious marl stratum is visible in the sections of the railroad, and I am now firmly of the opinion, that the clay with lignite at Bordentown landing and below, is the lower bed of the marl formation, and identical with the astringent blue clay bed beneath the true marl or greensand at the base of Nevesink Hills and elsewhere in Monmouth county, and throughout a great portion of the whole marl region.

Shelltown.—Howard's marl is near this place on the south side of Crosswick's creek, and presents both the true marl stratum and the astringent clay. The marl is dark, friable, smells of sulphur, and is found to be very efficacious. The overlying lead-coloured clay is somewhat micaceous, and contains a trivial quantity of the greensand, being in all respects like the underlying bed which shows itself at Wall's mill near Burlington. It resembles very much the character of the bed where it caps the marl at Crosswick's and in the neighbourhood.

On the road from Shelltown to James S. Lawrence's, which is one mile southwest from Varmington; the same overlying bed is exposed in numerous places in the banks of the meadows.

All these cases are adduced to show that the true marl overlies and alternates with the dark astringent clay along nearly the whole northwestern edge of the marl tract, as, for example, near Burlington and Camden.

Fine exposures of the marl offer themselves to view in the vicinity of the residence of Mr. Lawrence. The soil itself is a brown ferruginous loam, being a portion of a narrow tract of red clayey soil, which extends a considerable distance northeast and southwest, passing by Arneystown, and exibiting wherever it is seen, every evidence, from its texture and the minute water-worn grains of quartz, of its having resulted from the breaking up of an overlying stratum of brown sandstone. In some of Mr. Lawrence's fields, it contains a very sensible quantity of the green granules. The upper part of the marl stratum here differs materially in aspect from the lower. For a thickness of several feet, it is little else than a mass of decomposed shells almost invariably in the state of casts, the shells replaced by oxide of iron. An inconsiderable proportion of the green grains is mingled with a yellowish white pasty matter, which is a mixture principally of sulphate and carbonate of lime, derived no doubt from the shells, and which imparts many valuable qualities to the marl.

The lower stratum is a mass of dark greensand, in which we witness few traces of the changes noticed in the materials of the mass above. The quantity of oxide of iron in the free state mixed with the marl causes it to be rather hard to dig; this is the case with nearly all the more ferruginous kinds, but a brief exposure to the air renders it friable, when it is found to be a very powerfully fertilizing marl. Striking benefits result from the use of this marl when it is applied in the ratio of about ten loads to the acre. In this bed have been found teeth of the *mosasaurus* and several bones apparently of the fossil crocodile. Mr. Lawrence states that his lower or dark green marl, which is very full of the astringent matter or sulphate of iron, will not admit of being lavishly employed, for it then invariably *poisons the crop.* If as much as twenty-five loads be used, the growth of the corn is seriously checked; nor does it recruit until late in the season, after which the vegetation is wonderfully quickened. The upper stratum, on the other hand, will admit of being applied in any excess, one hundred loads or even more, producing no deleterious effects upon the crop. Where the banks of the meadows are high, a different stratum from either of the previous two is seen, and to all appearance occupying a higher place in the series. This is the calcareous sandy stratum which in another part of this Report I alluded to as being in all probability a deposit of the same date with the limestone of Vincentown and Mannington. It is here a yellow calcareous sand with scattered grains of marl, and with a multitude of solid casts of various fossils, some of which do not show themselves in the green marl beneath. In this bed I have procured *coprolites.** All the casts in question consist chiefly of carbonate of lime in an earthy state mixed with a little clay and sand.

The stratum in some places is more than twenty feet in thickness. Being the upper bed, it is in many instances the only accessible one, in which case I think it deserves to be employed as a substitute for marl, not merely for the amount of calcareous matter in it, but for the quantity of the greensand. Bones of some reptile, the *crocodile* apparently, are found in this stratum, and we may hence form a conjecture of the source of the coprolites. From the same bed we may procure solid internal casts

* *Coprolites*, are the fossilized dung of extinct animals.

of *claws* of a *fossil crab*, two species of *baculites*, teeth of the crocodile, and many interesting species of bivalve and univalve shells.

In a deep ravine on the opposite or west side of Crosswick's creek, and a little lower down than where the previous beds are seen, and very near the line of an ancient Indian path, we have an exhibition of a very different group of beds.

The upper layer is a yellow sand. A little beneath this, there occurs a brownish, ferruginous, sandy rock, characterized by casts of the *ostrea falcata*, identical in all its features with the stratum containing ostrea falcata, and resting high up in the cliffs of the Nevesinks. Next beneath is a dark siliceous sand, with casts of shells, and masses which appear to have been lignite or fossil-wood, replaced by a sandy clay. This bed is very astringent, the surface in many places being coated with the yellow efflorescence. Lower still there exists a mottled gray and yellow sand, and beneath all a gray sand with lumps of what was once lignite but is now clay, having all the markings and occupying the place of the woody matter now removed.

At John Miers, two miles south of the localities above described, excellent marl is seen in two layers, the top one being a light green, with little or no white incrustation upon the grains, and this graduating into the inferior, or dark green marl, which seems to be rather less friable and considerably more ferruginous. The grains in the lower part of the stratum acquire, when drying in the heap, the white tasteless incrustation or efflorescence so common to the marls of the region, and which chemical experiment establishes to be the sulphate of lime or gypsum.

Marl from the farm of John Miers, on Lahaway creek, near Hornerstown, Upper Freehold township, Monmouth county.

Upper part of the bed.

Description.—Colour, light green, clayey and adhesive. The washed granules, which are small, are of the same bright green colour.

Composition.—In 100 parts:

Greensand, - - -	84·5
Clay, - - - -	14·5
Quartzose sand, - -	1·0
	100·0

The proportion of *potash* which this marl contains, deduced from that of the green grains, is 9·7.

Lower portion of the stratum.

Description.—Colour, bluish-gray, texture clayey and tenacious. The washed granules dark, almost black, and very large.

Composition.—In 100 parts:

Greensand, - - -	77·45
Clay, - - - -	22·55
Quartzose sand, - -	none.
	100·00

The proportion of *potash*, by analysis, is 9 per cent.

It is an observation made in this neighbourhood, and one in complete accordance with my observations throughout the marl tract, in its range from hence through Burlington and Gloucester counties, and even Salem, that when the *light green* shows itself it is usually along the eastern side of the marl belt, and invariably occupying a position on the top of the dark greensand. The latter, I find in many districts to be esteemed the most efficient of the two varieties.

At *Snuff Mill*, on a small tributary of Crosswick's creek, about one mile north of New Egypt, we witness the same limestone bed which appears lower down the State, at Vincentown, and in Salem county. It holds the same position on the top of the green marl, is a stratum of about a foot in thickness, and contains the same corals or zoophytes—for example, the same alcyonia, and the same shells seen in the districts where this stratum of rock is of more important thickness.

At *Fuller Horner's*, on Crosswick's creek, about a third of a mile below New Egypt, there is a bank exposing the strata, where, during the last twenty years, enormous quantities of marl have been procured for the use of the neighbourhood. The section is between twenty and twenty-five feet high. Near the top of the bank, the upper layer is a greenish siliceous and slightly calcareous sand, and beneath this occurs the rubbly, straw-coloured, and somewhat sandy limestone, the frequent capping to the marl. Both these layers are represented in precisely the same order near Vincentown. In the bank before us the limestone is rarely more than one foot thick, and reposes upon the greensand, or marl bed, which consists of a series of thin layers of different tints, and various degrees of purity, occupying a depth of at least twenty feet.

This is a locality containing some very interesting fossils, but the present is not the place to treat of them. The marl has the very usual odour of sulphur, and exhibits, when dry, the gray or white efflorescence. It enjoys a high reputation as a manure. Most of the shells in it show that the carbonate of lime has been nearly all supplanted by oxide of iron, and here, as in the instance of many other greensand marls, the virtues of the mass are not to be attributed to the lime, but to the specific power of the constituents of the dark granules, chiefly the potash.

Marl from the farm of Fuller Horner, New Egypt.
Upper part of the bed.

Description.—Colour dark olive-green; washed granules very dark green, size large.

Composition.—In 100 parts:

Greensand, - - -	100
Clay, - - - -	none.
Quartzose sand, - -	none.
	100

The proportion of *potash* which this marl contains by analysis, is 11 per cent.

Marl from the bridge at Hornerstown, Monmouth county.

Description.—Colour, a rather light green. The washed grains quite small, and of a richer green.

Composition.—In 100 parts:

Greensand, - - -	75·90
Clay, - - - -	20·10
Quartzose, - - -	4·00
	100·00

The proportion of *potash* in this marl by direct analysis, is 9.1 per cent.

Near *Arneystown*, the marl is to be met with in nearly all the meadows and low grounds. The soil is the red or brown loam, derived from the destruction of the brown ferruginous sandstone, one of the principal upper beds of the secondary strata of the region.

The underlying marl does not, to my knowledge, offer either the overlying light-green layer, or the still superior seam of limestone, a fact corroborating what has been said, that these lie chiefly upon the eastern or ocean side of the marl tract. The dark marl here is highly effective upon the crops.

Between Arneystown and Hornerstown, we meet the same superior thick mass of calcareous sand full of organic remains; these are usually in the state of solid casts of the *interior* of the shells. The whole corresponds to what we see nearer to Varmintown, at Mr. Lawrence's. The spot where this bed best shows itself is on the hill side overlooking the meadows at Crosswick's creek, and it is thought that we may behold here, as at Lawrence's a slight dip of the strata to the southeast. Upon the other side of the valley, on a level with the meadows, we meet with a gray loose sandstone full of *ostrea falcata*, in an undissolved and beautifully pearly condition.

At *Cookestown*, a rock, equivalent to the Vincentown seam of limestone, is seen lying near the level of the stream.

At *Imlay's*, where the Monmouth road crosses Crosswick's creek, and about half a mile below Fuller Horner's beds, the marl series is exposed at a considerable elevation above the creek. Gray sand shows itself on the top, then follows a yellow sand, with ferruginous bands of cemented shells, and then sand with green grains, through a thickness of several feet, down to the top of the pure greensand stratum.

A light-green marl, four feet thick, full of casts of shells succeeds; below which lies the dark-green marl, rather coherent or slightly cemented by oxide of iron, and a few shells.

The top of this is many feet above the meadows, and I can well comprehend how, by the descent of the meadows to Lawrence's, space enough may exist for the siliceous beds, characterized by ostrea falcata, to occupy a yet lower place in the series.

Marl from the farm of William Imlay, between Plattsburg and Arneytown, Burlington county.

Description.—Colour, dark olive-green; washed granules, dark clear green, and of large size.

Composition.—In 100 parts:

Greensand, - - -	91·85
Clay, - - - -	6·65
Quartzose sand, - -	1·50
	100·00

The proportion of *potash* in this marl, deduced from that of the greensand, is 10·5 per cent.

Marl from Crosswicks creek, at its intersection with the Mount Holly and Monmouth road.

Description.—Colour, dark earthy green.

Composition.—In 100 parts:

Greensand, - - -	82·22
Clay, - - - -	13·58
Quartzose sand, - -	4·20
	100·00

The proportion of *potash* in this marl, as deduced from the greensand, is 9·6 per cent.

Plattsburg, or *Sykesville.*—Marl of excellent quality is procured at several places in this neighbourhood, as the following analyses will show.

Marl from Poke Hill, near Plattsburg, Burlington county.

Description.—Colour, a greenish olive-gray; washed granules, a rich dark olive-green, rather above the medium size.

Composition.—In 100 parts:

Greensand, - - -	98.0
Clay, - - - -	2·0
Quartzose sand, - -	none.
	100·0

The proportion of *potash* in this marl, by analysis, is 10·7 per cent.

Marl from the farm of Sarah Willis, half a mile northwest of Plattsburg.

Description.—Colour, a rich green; the washed granules have a still richer tint; they are of medium size.

Composition.—In 100 parts:

Greensand, - - - -	69·1
Clay, - - - - -	28·9
Quartzose sand, - -	2·0
	100·00

The proportion of *potash* in this marl, deduced from that in the greensand, is 7·9 per cent.

Marl from the farm of John Pancoast, half a mile northwest of Plattsburg, Burlington county.

Description.—Colour, light verdigris-green; the washed granules even lighter in colour; size, small.

Composition.—In 100 parts:

Greensand, - - - -	76·50
Clay, - - - - -	22·00
Quartzose sand, - -	1·50
	100·00

The proportion of *potash* in this marl, deduced from that in greensand, is 8·7 per cent.

Marl from the farm of Thomas Earl, three quarters of a mile northwest of Plattsburg.

Description.—Colour, earthy pea-green; the washed grains, small in size and of a dark sea-green colour.

Composition.—In 100 parts:

Greensand, - - - -	56
Clay, - - - - -	36
Quartzose sand, - -	8
	100

The proportion of *potash* in this marl, deduced from that in the greensand, is 6·4 per cent.

Marl from the farm of Caleb Newbold, two miles southwest of Plattsburg, west side of Lowland road.

Description.—Colour, pea-green; the washed grains small in size, and of a sea-green colour.

Composition.—In 100 parts:

Greensand, - - -	84·10
Clay, - - - - -	15·90
Quartzose sand, - -	none.
	100·00

The proportion of *potash* in this marl, by direct analysis, is 9·2 per cent.

Marl from the farm of Thomas Black, two miles west of Plattsburg.

Description.—Colour, dark dull green, but little changed by washing; granules large.

Composition.—In 100 parts:

Greensand, - - -	90·50
Clay, - - - - -	9.50
Quartzose sand, - -	none.
	100·00

The proportion of *potash* which this marl contains, ascertained by direct analysis, is 10·8.

Arney's Mount is a considerable hill at the Friends' meeting-house, one and a half miles southwest from Juliustown. The sandy soil of the neighbourhood, even that of the road, is mixed with the greensand, so that its colour is sensibly influenced by it. Eastward from the meeting-house, a few hundred yards, there is a small opening on the road, where the ferruginous conglomerate has been quarried. Most of the cemented particles in this rock are grains of coarse siliceous sand, but some of them are *felspar.* It is very hard and durable, and shows no departure from the horizontal position.

On the top of Arney's Mount, there lies a pretty thick bed of this sandstone; it is largely quarried, dipping very gently to the east. This mount is distinctly visible from *Mount Holly*, from which there is a rather extensive view. The whole surrounding landscape is extremely flat, the eastern horizon, more especially, being perfectly uniform. Marl occurs, near the surface of the fields, to the southeast; its existence being shown by the water oozing forth along the base of the hill or mount.

Marl from the farm of Thomas Coats, half a mile southwest of Juliustown, Burlington county.

Description.—Colour, a very rich verdigris-green; the washed grains of a darker colour and very small.

Composition.—In 100 parts:

Greensand, - - -	77·25
Clay, - - - -	12·75
Quartzose sand, - -	10·00
	100·00

The proportion of *potash* in this marl, deduced from that in the greensand, is 8·8 per cent.

On the Assiscunk (Barker's branch) a little above Slabtown, marl has recently been opened. It is not good, owing to its containing too much of the ordinary impurities. The opening is on the side of the road. It is said to contain fossils.

Higher up, on the same branch, the marl seems to be considerably better, yet it is too siliceous to be ranked as the best kind.

Burlington.—The nearest place to the river where marl occurs in this vicinity, appears to be at the mill-pond near Wall's mill, one mile south of the town. The pit is not deep, owing to the stratum being wet. It is exposed in a spot where the dam some time since gave way, and its top is very little below the level of the original water course. The top of the stratum is covered by a thin, hard, ferruginous crust. The marl is highly siliceous and micaceous, yet contains a very sensible proportion of the green particles. No fossils appear in it. It has a strong sulphurous odour, and presents the yellow efflorescence and astringent taste of copperas, and resembles pretty closely that at Johnson's, near Mount's mills.

This material manifestly underlies the true greensand, which here and at Bordentown, and indeed generally throughout the belt of country bordering the Delaware, has been extensively swept away along the northwestern margin of the formation by denuding currents.

At *Costill's mill* the marl is pretty much of the same character, containing perhaps rather more of the black clay and siliceous sand. *Sulphuret of iron* also occurs in it, in little nodular lumps. It smells strongly of sulphur. When applied in light dressings to the land, it has been found useful. It is said to contain shells and shark's teeth.

On the *Rancocus*, near Franklin Park, the good marl lies at the level of the tide, being covered by the yellow ferruginous sand, and has much clay mixed with it. It has been found very beneficial, but is regarded as inferior to that which lies higher up the Rancocus. It contains fossils.

Higher up the Rancocus, the marl extends to Pemberton and Vincentown, and, it would appear, almost to the vicinity of the Pine Cottage.

Marl from Pemberton Mills.—Upper part of the Stratum.

Description.—Colour, yellowish pea-green; the washed grains of a darker green and of small size.

Composition.—In 100 parts:

Greensand, - - -	54·13
Clay, - - - -	20·47
Quartzose sand, - -	25.40
	100·00

The proportion of *potash* in this marl, by direct analysis, is 6·5 per cent.

Lower part of the Stratum.

Description.—Colour, very light greenish-gray ; highly clayey and adhesive.

Composition.—In 100 parts:

Greensand, - - -	38·05
Clay, - - - -	26·95
Quartzose sand, - -	35·00
	100·00

The proportion of *potash* which this marl contains, deduced from that in the greensand, is 4·3 per cent.

On the Haybridge run, a mile and a half north of Pemberton, there is very good green marl which is dug near the road. Over this is a thin layer, containing much of the copperas earth in a state of efflorescence.

At Forsyth's, north of the road between Pemberton and Lisbon, and one and a half miles from the former place, there is very good dark-green marl, lying on the surface of the meadow. It contains numerous fossils. On the edge of the meadow, and near the top of the marl, there were found, some years ago, the principal portions of the head of a *mastodon*, and also a tusk, pieces of the tibia, ribs, &c. It would seem, from the state of the bones, and the unworn condition of the teeth, to have been a young one. The head was exposed to the air, lying only eighteen inches below the surface of the meadow, and was much decayed.

In a ravine, on the edge of the meadow, and lying in the yellow sand which covers the marl, there was found a mass having all the external characteristics of *retinasphaltum.*

Shark's teeth, phosphate of iron, &c. occur in the marl of this vicinity.

Birmingham.—The marl is generally of a superior quality along the north branch of the Rancocus, both above and below Birmingham. On the north side of the stream, it is extensively opened on the farm of Jacob Gaskill, where the greensand may be penetrated to a depth of twenty-five feet without serious inconvenience from the infiltration of water into the pits.

Marl from the farm of Jacob Gaskill, near Birmingham, Burlington county.—Lower part of the bed.

Description.—Colour, dark greenish-gray; washed granules, dark olive-green; rather large.

Composition.—In 100 parts:

Greensand, - - -	92·9
Clay, - - - -	6·1
Quartzose sand, - -	1·0
	100·0

The proportion of *potash* which this marl contains, by analysis, is 10·8 per cent.

Marl from the farm of John Woolston, a fourth of a mile south of Birmingham, Rancocus creek.

Description.—Colour, dull grayish-green; the washed grains of a light green colour, and rather small size.

Composition.—In 100 parts:

Greensand, - - -	82·60
Clay, - - - -	10·40
Quartzose sand, - -	7·00
	100·00

The proportion of *potash*, deduced from that of the greensand, is 9·5 per cent.

Marl from the farm of John Dobbins, a fourth of a mile south of Birmingham, Rancocus creek.

Description.—Colour, dark olive-green; texture, granular, granules of a medium size; when washed of a deep full green.

Composition.—In 100 parts:

Greensand, - - -	92·75
Clay, - - - -	6·25
Quartzose sand - -	1·00
	100·00

The *potash*, by direct analysis, in this marl is 10·02 per cent.

Marl from the farm of Mr. Charles Euen, one-fourth of a mile south of Birmingham, on Rancocus creek.

Description.—Colour, sea-green; the washed grains of rather large size, and of a very rich green colour.

Composition.—In 100 parts:

Greensand, - - -	91·35
Clay, - - - -	8·65
Quartzose sand, - -	none.
	100·00

The proportion of *potash* in this marl, by analysis, is 10 per cent.

Vincentown.—The proportion of greensand in the marls of the vicinity of Vincentown, though such as to confer decidedly active properties, is yet somewhat inferior to that of some preceding localities. In other respects these marls are of ordinary purity.

Marl from the farm of Mr. Job Frick, near Vincentown.

Description.—Colour, dull greenish-gray; washed granules of a dark rich green, and of medium size.

Composition.—In 100 parts:

Greensand, - - -	77·55
Clay, - - - -	20·45
Quartzose sand, - -	2·00
	100·00

The proportion of *potash* in this marl, by analysis, is 8·3 per cent.

Marl from the farm of Mr. Benjamin Peacock, near Vincentown.

Description.—Colour, dark grayish-green; the washed grains of a deeper green and small size.

Composition.—In 100 parts:

Greensand, - - -	76·13
Clay, - - - -	15·45
Quartzose sand, - -	8·42
	100·00

The proportion of *potash*, as deduced from that of the greensand, is 8·7 per cent.

Marl from the farm of Edward Hilliard, half a mile south of Vincentown.—Lower portion of the stratum.

Description.—Colour, verdigris-green; the washed grains of a darker colour, and very small.

Composition.—In 100 parts:

Greensand, - - -	72·58
Clay, - - - -	19·92
Quartzose sand, - -	7·50
	100·00

The proportion of *potash* in this marl, by analysis, is 7·9 per cent.

Eayrstown.—The marl in the meadow midway between Eayrstown and Newbold's Corner, presents something unusual. The grains are generally coarse and dark green, while some are very light, almost white, and seem to be decomposing. These owe their whiteness to an incrustation of *carbonate of lime*, their interior being of a very light green.

I here submit the analyses of two marls from the vicinity of Eayrstown, by which it will appear that the greensand formation exists here in considerable purity.

Marl from the farm of Thomas Edwards, half a mile southwest of Eayrstown.

Description.—Colour, lead-gray; contains a few particles of carbonate of lime, adhesive; the washed granules are light grayish-green, and of medium size.

Composition.—In 100 parts:

Greensand, - - -	93.5
Clay, - - - -	6·5
Quartzose sand, - -	none.
	100·0

The proportion of *potash* which this marl contains, is 10·1 per cent.

Marl from the farm of Messrs. Thomas and William Edwards, near Eayrstown.

Description.—Colour, dark verdigris green; the washed grains, quite small and of a very rich green.

Composition.—In 100 parts:

Greensand, - - -	81·59
Clay, - - - - -	18·41
Quartzose sand, - -	none.
	100·00

The proportion of *potash* in this marl, deduced from that of the greensand, is 9·30 per cent.

Points south of the Rancocus.—On Haines's creek, or the main south branch of the Rancocus, one mile and a half below Haines's place, the banks exhibit the black micaceous and astringent clay, ascertained to rest throughout a considerable area *beneath* the true green marl. In a meadow half a mile to the north of Joseph Haines's the two beds are seen in contact.

At Charles Haines's mill, two miles below Medford, on the creek, a section is seen, exhibiting on the top a greenish siliceous sand; beneath this, a gray sand some feet thick, containing a small proportion of the green granules; and under this, the straw-coloured limestone two feet thick.

These beds hold the same order, and are identical in composition with those above the green marl at New Egypt and elsewhere, towards the eastern side of the "marl tract." One-fourth of a mile from the mill, the beds have been cut through, in digging a well, into the greensand underneath. The limestone was reached between seven and eight feet below the surface. It was in thin irregular beds, separated by incohering sand and calcareous grains, similar to the mixture which composes the rock; its total thickness is about six feet; the organic remains are the same which characterize the limestone at Vincentown. The marl stratum here possesses when dry, a dark, slightly greenish-gray hue, the granules being coated with a very copious efflorescence; it resembles the marl at Inskeep's. In the upper part of the bed there is a layer four feet thick, of decomposed shells, (Gryphea, &c.) mingled with the green grains, in a dark friable brownish mass; the efficacy of this upon the soil is found to be very great. Capping this upper layer, the diluvium contains a bottom band of very ferruginous cemented sand and gravel, a foot and more in thickness.

The extensive range of meadows in which these exposures of the strata occur, meets the meadows of the Rancocus about two miles above the limit of the tide, at Joseph Haines's. They contain marl along their banks almost to the source of the stream. None of the overlying limestone seems to occur nearer the Delaware than this point, for the marl here is the uppermost stratum.

The limestone belt measured from northwest to southeast, appears, as far as exposed, to be about one mile wide, and there are pretty good reasons for concluding that it expands still more to the southeast. In the marl at J. Haines's, shells, shark's teeth and bones are occasionally found.

The marl is traceable as far to the southeast as Pricket's, upon the edge of the sandy tract, denominated from the prevailing timber, *the Pines.* It is here very similar to the upper and moderately pure variety seen in the stratum at Medford.

Near Medford, which is about two miles from the edge of the pines, pretty good marl abounds in all the ravines or meadows adjacent to the town.

Evesham.—Some of the marl in this vicinity is remarkably pure, as the following analysis will show:

Marl from Evesham, Burlington county.

Description.—Colour, a medium tint of green; granules of rather large size.

Composition.—In 100 parts:

Greensand, - - - -	100
Clay, - - - -	none.
Quartzose sand, - -	none.

The proportion of *potash*, by direct analysis, is 11 per cent.

On the north branch of Cooper's creek, and about one and a half miles south by west from Swain's, the marl is very extensively laid bare in the banks bordering the meadows. The marl pits of Mr. Buck, J. P. Rogers and others, are very extensive. At the former, which are low, the marl is of a pretty light bright green; upon drying, it does not become covered with much efflorescence. The excavations enter the stratum about ten feet; no shells or other fossils are seen. The sand of the overlying diluvium contains some of the green granules, and a layer which has somewhat the aspect of a green clay, derived perhaps from the granular marl below. That this overlying bed is certainly diluvium, is proved by the fact of its occasionally filling *troughs* or undulations in the top of the marl, which seems to have been furrowed at some time by rapid currents sweeping over its surface.

At J. P. Rogers', the colour of the marl is darker, being a deep dull bluish green. These varieties in colour are due more often to small admixtures of differently coloured clays than to an intrinsic difference in the tints of the granules themselves. The marl now before us exhibits a copious white efflorescence on drying. It is certainly a curious fact, but is true, as far as I have yet observed, that the darker marls have more of this than the light ones. The dark and light green varieties in this quarter, seem not to be, as in many places elsewhere, distinct beds. At the depth of about ten feet numerous fossils occur. Besides the ordinary shells, there have been found sharks' teeth, and a portion of the jaw of a crocodile, containing three of the teeth in their sockets. A small mass of a black bituminous substance possessing all the characters which belong to *retinasphaltum*, was procured two feet beneath the top of the marl. It is identical in all respects with the mass found near the top of the marl at Forsyth's.

At Cooperstown, upon Cooper's creek, five miles from Camden, there is a marl much in use throughout the neighbourhood; it lies near the surface, being covered by a yellowish mottled bluish clay, apparently the same with the *brick earth* upon which Philadelphia stands.

It has been penetrated in pits which are dry, to the depth of twenty-four feet. It is a tough unctuous bluish clayey stratum, with only a moderate per-centage of the green granules, and a considerable amount of the astringent matters, (copperas, &c.) It contains numerous shells, some of them of great size, an *oxygra costata* found in it weighing upwards of *nine pounds.*

Marl from the farm of William Skinner, near Cooperstown, Gloucester county.

Description.—Colour, dark dull green; the washed granules more distinctly green; these are of large size.

Composition.—In 100 parts:

Greensand, - - -	85·63
Clay, - - - -	14·37
Quartzose sand, - -	none.
	100·00

The proportion of *potash* in this marl, deduced from that in the greensand, is 9·8 per cent.

Within one mile of the Delaware, to the north of Cooper's creek, a bed is reached having all the characteristics of that at Burlington and near Spotswood. It is highly astringent, though when used in moderation it has been found to be serviceable upon the potato crop. Shells and shark's teeth are said to have been found in it, though of this I have not been able to get distinct information.

LOCALITIES BETWEEN CAMDEN AND SALEM.

Good marl abounds on Big Timber, Woodbury, and Mantua creeks, within the limits already designated. In the vicinity of Barnesborough, the proportion of greensand in the stratum gives it a high degree of fertilizing power. The following analyses will serve to show its composition in this portion of the tract.

Marl from the farm of Thomas Bee, Esq., Union Cross-Roads, about five miles southwest of Woodbury, Deptford township, Gloucester county.

Description.—Colour, rich verdigris green; the washed grains of a deeper green.

Composition.—In 100 parts:

Greensand, - - -	92·48
Clay, - - - -	7·52
Quartzose sand, - -	none.
	100·00

The amount of *potash* in this marl by absolute analysis, is 10·35 per cent.

Marl from the farm of Josiah Heritage, two and a half miles east of Barnesborough, Gloucester county.

Description.—Colour, dark olive-green; washed granules still darker, approaching to black; size, rather large.

Composition.—In 100 parts:

Greensand, - - -	93·70
Clay, - - - -	6·30
Quartzose sand, - -	none.
	100·00

The proportion of *potash* in this marl, by analysis, is 10·4 per cent.

Marl from the farm of Joseph Clarke, three quarters of a mile east of Barnesborough.

Description.—Colour, very dark greenish gray; the washed grains, quite coarse and of a dark sea-green colour.

Composition.—In 100 parts:

Greensand, - - -	84·31
Clay, - - -	14·69
Quartzose sand, - -	1·00
	100·00

The proportion of *potash* in this marl, by direct analysis, is 9·8 per cent.

Marl from the farm of Mr. Hoffman, one mile and a half from Barnesborough.

Description.—Colour, rich verdigris green, granular; washed grains unchanged.

Composition.—In 100 parts:

Greensand, - - -	85·58
Clay, - - - -	13·42
Quartzose sand, - -	1·00
	100·00

The proportion of *potash* in this marl derived by direct analysis, is 9·5 per cent.

Marl from the farm of John Gaunt, one mile and a quarter west of Barnesborough.

Description.—Colour, dark gray, somewhat tinged with oxide of iron; granules large, and when washed of a dull earthy colour.

Composition.—In 100 parts:

Greensand, - - -	82·45
Clay, - - - -	17·55
Quartzose sand, - -	none.
	100·00

The proportion of *potash* deduced from that of the greensand, is 9·4 per cent.

Marl from the farm of James Jehnes, one mile and a quarter west of Barnesborough.

Description.—Colour, pale yellowish green, somewhat clayey and cohesive in texture; the washed grains are dark green and of medium size.

Composition.—In 100 parts:

Greensand, - - -	90·22
Clay, - - - -	8·78
Quartzose sand, - -	1·00
	100·00

The proportion of *potash* which this marl contains as deduced from that in the greensand, is 10·1 per cent.

At Carpenter's Landing, and about one hundred yards north of Mantua creek, the blue clay, containing a small proportion of the green granules and much siliceous sand, displays itself upon the road where the top of the stratum holds up and discharges the water. It is seen very generally upon the side of the marl tract next the river, and may, in nearly every instance, be known by the water which it throws out, and the astringent impregnations contained in it.

A pretty deep section of the beds belonging to this portion of the marl region, is beheld in Richard's Hill, about two miles north of Mullica Hill. A loose yellowish sand containing a few of the green grains, and having the depth of about five feet, occurs on top, being underlaid by about seven feet thickness of ferruginous sand full of disintegrating shells, casts, and concretions, intermingled with a small amount of the greensand or marl grains. Below this there occurs a brown ferruginous sand, containing a few of the granules, indistinct casts, and cemented lumps or concretions of the same with the calcareous matter of the shells. Beneath all, and nearly at the base of the hill, is a bed of unmixed ochreous ferruginous sand, very yellow. It has been dug by the meadow side, and applied to the soil, but with what good results I know not. By adverting to the section at Mullica Hill, to be given next, it will be seen, that this last bed is in all probability the same which lies at the base of the series there, and that to search, therefore, lower in the earth at this place for a purer marl than that half way up the hill, would be to experiment without hope of success, or at least any that could be justified by our present knowledge of the marl stratum in this quarter.

About four miles northeast of Mullica Hill, a marl is dug in a ravine near the road which leads to Woodbury, which is of a dark green colour, and found to be extremely beneficial upon the land.

Analysis shows it to possess the following

Composition.—In 100 parts:

Silica, - - - -	52·05
Protoxide of iron, - -	23·20
Alumina, - - -	7·50
Potash, - - - -	11·20
Water, - - - -	5·25
Lime, - - - -	a trace.
	99·20

Mullica Hill.—At the village of this name, a fine escarpment, formed by the valley of Raccoon creek, exposes an interesting series of beds through a height of about forty feet. The uppermost deposit of all, is about six or eight feet of diluvial sand and gravel. In the descending order the beds are:

1. A light-coloured bright *greensand*, very free from any foreign substance, if we except a moderate share of greenish clay. It has all the aspect of the light-green or upper marl of many other localities, the efficacy of which has been proved in some cases to be equal to that of the darker stratum which lies beneath; notwithstanding which, the farmers of the vicinity deem it to be quite inert, and therefore erroneously call it a clay. It is admitted that very imperfect attempts have been made in using this material as a manure, and I cannot but believe that a too precipitate judgment has been passed upon it; for, as the following exhibition of its chemical constitution shows, it differs but little from many marls of long acknowledged efficacy. Its composition, it will be seen, does display a less than ordinary proportion of potash.

Analysis of the light-green Greensand of Mullica Hill.

Composition.—In 100 parts:

Silica, - - - - -	52·32
Protoxide of iron, - -	27·56
Alumina, - - -	8·94
Potash, - - - -	5·50
Water, - - - - -	5·42
	99·74

2. A chocolate-coloured bed, in which about one half is the green granular matter and one half a fine clay of a light purple or chocolate tint. This also has all the features of a good marl, though it is not reputed to have any power.

3. A thin seam, not more than a foot in thickness, of a dark bluish-green marl, *unquestionably* very good.

4. A bed consisting of dark greensand and shells in the state of casts; the shelly matter being all replaced by oxide of iron.

5. A dark yellow ferruginous sand, with casts of shells and ferruginous concretions, and a small proportion of the green granules.

6. A dark yellow ferruginous sand, almost entirely free from the grains of marl, and containing no trace of organic remains.

In the meadows east of Mullica Hill about half a mile, excellent marl is dug from a level many feet higher than the bed of the stream. As far as the general aspect of the surface enables us to judge, the position of this bed is lower than the green stratum in Mullica Hill; but whether they are different horizontal beds, or one and the same stratum connected by a slight dip to the east, are points demanding additional research to settle.

The width of the visible marl tract in the neighbourhood of Mullica Hill, is about three miles.

The several beds seen at Mullica Hill are discernible in the same relative positions in various places more to the southwest. At Colston's, four and a half miles off, the marl is very good.

The analyses which follow will exhibit the character of the marl in the neighbourhood of Mullica Hill.

Marl from the farm of Isaac Sherman, one mile east of Mullica Hill.

Description.—Colour, dark-green; the washed grains, small and of a deeper tint.

Composition.—In 100 parts:

Greensand, - - -	90·37
Clay, - - - - -	7·63
Quartzose sand, - -	2·00
	100·00

The proportion of *potash* in this marl by analysis, is 9·9 per cent.

Marl from the farm of Michael Allen, half a mile north-east of Mullica Hill.

Description.—Colour, light pea-green; the washed grains, medium size and of a darker green colour.

Composition.—In 100 parts:

Greensand, - - -	96·36
Clay, - - - -	3·64
Quartzose sand, - -	none.
	100·00

The proportion of *potash* which this marl contains, as obtained by analysis, is 12 per cent.

Marl from the estate of William Howe, Mullica Hill.

Description.—Colour, dull verdigris green; the washed grains of a richer green, and small in size.

Composition.—In 100 parts:

Greensand, - - - -	91·95
Clay, - - - - -	8·05
Quartzose sand, - -	none.
	100·00

The proportion of *potash* in this marl by actual analysis, is 10·2 per cent.

Marl from the farm of Mr. Jonathan Coulson, one mile from Mullica Hill.

Description.—Colour, dark grayish-green; the washed grains, large in size, and of a deeper green colour.

Composition.—In 100 parts:

Greensand, - - -	86
Clay, - - - -	11
Quartzose sand, - - -	3
	100·00

The proportion of *potash* in this marl deduced from that in the greensand, is 9·8 per cent.

Marl from the farm of Josiah Lippincot, one mile south-southwest of Mullica Hill.

Description.—Colour, dull grayish-green, owing to the presence of clay; the washed granules dark green, and of medium size.

Composition.—In 100 parts.

Greensand, - - -	89·52
Clay, - - - - -	7·88
Quartzose sand, - -	2·60
	100·00

The proportion of *potash* deduced from that in the greensand, is 10·2 per cent.

Marl from the farm of Elijah Horner, one mile and a half southwest of Mullica Hill, Gloucester county.

Description.—Colour, rich green, of medium tint; washed granules dark, and of large size.

Composition.—In 100 parts:

Greensand, - - -	90·75
Clay, - - - - -	8·25
Quartzose sand, - -	1·00
	100·00

The proportion of *potash* shown in this marl by direct analysis, is 10·8 per cent.

Marl from the farm of John Doull, between Woodstown and Mullica Hill, three miles from the former.

Description.—Colour, dull earthy green; the washed grains of a dark green and very small in size.

Composition.—In 100 parts:

Greensand, - - -	89·55
Clay, - - - -	10·45
Quartzose sand, - -	none.
	100·00

The proportion of *potash* in this marl, deduced from that in the greensand, is 10·2 per cent.

Woodstown.—The exposed portion of the marl tract opposite Woodstown is of inconsiderable width, extending from a little east of the village to about one mile and a half northwest of Sharptown. In this neighbourhood, the streams cut rather deeply into the bed, and reveal very nearly the same varieties of the marl or greensand as at Mullica Hill. Upon Old Man's creek, the marl is found as far towards the Delaware as Skulltown, which indicates a wider expansion of the deposit than might be inferred from confining our observations to the exposure upon Salem creek. The marl of Skulltown resembles closely that which is seen in many other places as we approach the Delaware.

The excavations at Woodstown are very extensive in consequence of the excellent quality of the material and the circumstance that this is near the extreme southwestern termination of the marl tract, or at least of that portion of it which lies at a sufficient elevation to be of easy access. The features of the stratum where it is opened in the eastern bank of Salem creek, are such as belong to a great number of other localities, more particularly within the southern half of the marl region.

The beds in the descending order are as follows:

First, the usual covering of diluvium, in which there abounds a considerable quantity of white quartzose gravel, and near to the top of the subjacent marl a number of large rounded blocks of a yellowish sandstone, scarcely calcareous. It is close grained, and often excessively tough. It has been derived evidently from a stratum once in place upon the upper surface of the marl, a portion, I have no doubt, of the bed which still occupies that position in many places not remote. I see every reason to consider it as representing the stratum known as the siliceous limestone of Mannington, Vincentown, and other points. It seems to differ from this rock in the relative proportion of the sand and lime, containing but very little of the latter. At the bridge over Salem creek about a fourth of a mile to the west of the marl pits where these rounded blocks occur, there exists in an undisturbed condition a stratum of rock in the very position here assumed, and of a composition and aspect strictly intermediate between the almost pure limestone, and the above mentioned almost perfect sandstone. It lies close to the water's edge, and has therefore been little noticed. It effervesces pretty actively with an acid, and has been found when burned in the small way to yield a lime capable of slaking. It possesses a yellowish-gray hue, showing the ordinary flinty sand which is its main ingredient, and in addition, a trivial per centage of the green granules.

The next deposit is the light-green marl, which does not overlie the dark green in all parts of the bed, being absent in all the excavations nearest the town. In the banks lower down the creek, as at Mr. White's, the section exhibits a layer of the light green or upper marl four or five feet thick, resting upon the dark green, which is here called *blue marl*, and from which it is occasionally separated by a crust of cemented ferruginous matter an inch or two in thickness. Mr. White has applied the material of this upper stratum to a portion of his soil without any apparent benefit to the crops, and his sentiment is, that it is destitute of fertilizing powers. In the pits farther up the creek, where a thin stratum of it occurs, it is dug and use is made of it, though the farmers prefer the marl from the darker bed below.

In the banks nearest the town, we behold only the lower marl penetrated in some places to the depth of fourteen feet, and resting under the gravelly diluvium, from which it is parted by a thin cemented ferruginous crust, a proof of the imperviousness of the stratum, and the facility with which the water penetrates the diluvium, and brings down the oxide of iron which it contains. As the covering of diluvial sand and gravel increases in thickness in receding from the creek, it is becoming a daily augmenting obstacle to the uncovering of the marl, rendered more serious by the copious ingress of water from the marl itself. I take this place to recommend attention to the advantages to be derived from the application of some simple machinery, for the purpose of more effectually elevating the marl and draining the pit, that it may not be necessary to abandon each excavation at the trivial depth of ten or twelve feet, and to incur the labour of uncovering fresh surfaces of the marl bed.

Marl from the farm of Michael Nulls, three miles from Woodstown.

Description.—Colour, dull green; the washed grains, very fine and of a very rich sea-green colour.

Composition.—In 100 parts:

Greensand, - - -	83·5
Clay, - - - - -	14·5
Quartzose sand, - -	2·00
	100·00

The proportion of *potash* in this marl deduced from that of the greensand, is 9·6 per cent.

Marl from the farm of Mr. Benjamin Coulson, three miles from Woodstown, on the road to Mullica Hill.

Description.—Colour, very rich verdigris green; washed granules, dark rich olive-green, rather large in size.

Composition.—In 100 parts:

Greensand, - - -	90
Clay, - - - -	10
Quartzose sand, - -	none.
	100

The proportion of *potash* in this marl by analysis, is 10·1 per cent.

Marl from the farm of John Dickinson, two miles from Woodstown.

Description.—Colour, light sea-green; the washed grains, differing from the original only in their deeper colour.

Composition.—In 100 parts:

Greensand, - - -	92·59
Clay, - - - -	7·41
Quartzose, - - -	none.
	100·00

The proportion of *potash* in this marl by direct analysis, is 10·4 per cent.

Marl from the farm of Mr. Allen Wallace, two miles from Woodstown.

Description.—Colour, dark sea-green; washed granules, still darker, size rather large.

Composition.—In 100 parts:

Greensand, - - -	90·00
Clay, - - - -	8·00
Quartzose, - - -	2·00
	100·00

The proportion of *potash* which this marl contains by analysis, is 10·2 per cent.

Marl from the farm of Jonathan Cauley, three quarters of a mile from Woodstown.

Description.—Colour, a clear light-green; washed granules, a little darker; size, large.

Composition.—In 100 parts:

Greensand, - - -	86
Clay, - - - -	14
Quartzose sand, - - -	none.
	100

The proportion of *potash* which analysis shows in this marl, is 10·3 per cent.

Marl from the farm of Elizabeth Borton, two miles north-east of Woodstown, Gloucester county.

Description.—Colour, dark grayish green; washed granules, dark-green, of medium size.

Composition.—In 100 parts:

Greensand, - - -	90·13
Clay, - - - -	9·87
Quartzose sand, - -	none.
	100·00

The *potash* in this marl deduced from that in the greensand, is 10·3 per cent.

Marl from the farm of Mr. Jonathan Riley, Woodstown.

Description.—Colour, dull greenish gray; the washed grains of a very rich sea-green colour and very small in size.

Composition.—In 100 parts:

Greensand, - - -	88·28
Clay, - - - -	11·72
Quartzose sand, - -	none.
Carbonate of lime, -	a trace.
	100·00

The proportion of *potash*, as deduced from the greensand, is 10·1 per cent.

Marl from the farm of Mr. Samuel White, Woodstown.

Description.—Colour, light sea-green; the washed grains coarse and of a dark sea-green colour.

Composition.—In 100 parts:

Greensand, - - -	88·26
Clay, - - - -	8·74
Quartzose sand, - -	3·00
	100·00

The proportion of *potash* in this marl, by direct analysis, is 10·3 per cent.

Marl from the farm of Mr. Henry Guest, near Skulltown.

Description.—Colour, dull sea-green; the washed grains small in size and of a dark sea-green colour.

Composition.—In 100 parts:

Greensand, - - -	48·30
Clay, - - - -	21·47
Quartzose sand, - -	30·23
	100·00

The proportion of *potash* in this marl, as deduced from the greensand, is 5·5 per cent.

Marl from the farm of Paul Skull, three miles northeast of Skulltown, Salem county.

Description.—Colour, dull grayish-green; the washed grains rather large in size and of a deeper green colour.

Composition.—In 100 parts:

Greensand, - - -	91·5
Clay, - - - -	7·5
Quartzose sand, - -	1·0
	100·0

The proportion of *potash* contained in this marl, shown by analysis, is 9 per cent.

In the vicinity of Sharptown, and in two places near Dr. Swing's, upon the road from thence to Salem, the marl stratum is pretty fully exposed, and seems to present almost precisely the same succession of beds as seen at Mullica Hill. The upper stratum invariably consists of little else than the green granules, their colour being a light verditer green, and on drying rarely presents the white crust upon the grains seen in the darker sort. The dark green bed possesses a larger share of dark clay intermingled with the grains, which, according to its hue, imparts different tints to the stratum. The grains themselves are not of a very deep green. In Dr. Swing's neighbourhood, the lower bed alone is used, under the impression, not based upon experience, however, that the other is inert. This lower marl has proved to be highly beneficial, the evidences of which may be seen upon Dr. Swing's farm. Yet this lower bed is apparently identical in all respects with the lower stratum at Mullica Hill, where it is pronounced equally inefficient with the upper. This fact ought to show us how many experiments remain to be made before we can pass a final judgment upon the non-existence of fertilizing properties in any of these marls. The lower bed here contains but few shells. At Woodstown there is one layer containing a prodigious abundance of the *gryphea convexa*, and a less proportion of one or two other species. Sharks' teeth, and the bones of the fossil crocodile are not uncommon. The shells possess but a small amount of lime, much of it having been dissolved away, and its place supplied by oxide of iron, from which they derive their brown ferruginous colour. Their presence is therefore of little or no benefit to the marl.

Marl from the farm of Dr. Swing, near Sharptown.

Description.—Colour, dark earthy-green; the washed grains of the same colour, and large in size.

Composition.—In 100 parts:

Greensand, - - -	91·20
Clay, - - - - -	8·80
Quartzose sand, - -	none.
	100·00

Potash, by direct examination, 10 per cent.

Four miles to the southwest of Sharptown, the surface of the country suddenly drops twenty-five feet, or more, to a lower level forming an extensive plain, characterized by a clayey soil, and noted in this section of the State for its greater relative fertility. The same tract borders, in a belt a few miles in width, the Delaware river and bay, to Cape May. Throughout the whole of this area, in consequence of the very small elevation of the surface above the tide, the marl stratum is scarcely once intersected by ravines or streams; though I entertain but little doubt that it spreads itself in the southwest direction to the Delaware. At Joseph Bassett's, about four miles from Salem, the marl may be seen at a small depth beneath the surface. It resembles in all respects that which is generally the lower stratum; containing the same mixture of clay, the same shells, and having the same white efflorescence. The principal fossils are *gryphea convexa, exogyra costata, ostrea falcata*, and several spiral univalves in the state of casts, finely preserved, from which we may justly infer that the stratum is not very wet. Teeth and bones also occur.

Marl from the farm of Joseph Bassett, north side of Branch.

Description.—Colour, dirty-green, unchanged by washing.

Composition.—In 100 parts:

Greensand, - - -	89·81
Clay, - - - -	5·19
Quartzose sand, - -	5·00
	100.00

The proportion of *potash* in this marl, deduced from that in the greensand, is 10·3 per cent.

Marl from the farm of James Smith, Mannington Hill, Salem county.

Description.—Colour, rather green, of average depth of tint; the washed greensand is of a rich dark green.

Composition.—In 100 parts:

Greensand, - - -	88·80
Clay, - - - -	10·20
Quartzose sand, - -	1·00
	100·00

The proportion of *potash* which this marl contains, by direct analysis, is 9·5 per cent.

Marl from the farm of Woodnut Petit, near Mannington Hill, Salem county.

Description.—Colour, light yellowish-green; washed granules dark-green, of medium size.

Composition.—In 100 parts:

Greensand, - - -	77·15
Clay, - - - - -	18·35
Quartzose sand, - -	4·50
	100·00

The proportion of *potash* in this marl, deduced from that in the greensand, is 8·8 per cent.

I have thus brought my observations as far to the southwest as any traces of the marl stratum show themselves. The chief object of the numerous details here given is to furnish hints, possibly of some future advantage to the several neighbourhoods specified, and moreover to awaken in each district a spirit of *inquiry* and *experiment*, which, should it ever be aroused to vigorous activity, must sooner or later be productive of the greatest benefits to the whole marl region, and to the State at large.

CHAPTER II.

DISTRICT SOUTHEAST OF THE MARL TRACT.

The physical features of the extensive sandy plain which reaches from the southeastern margin of the greensand, almost to the seacoast, have already been described. It only remains for me to detail a few points in its geology of a chiefly practical bearing. These are some small tracts of *tertiary calcareous marl*, its numerous deposits of *bog iron ore*, and the extensive stratum of white *glass-maker's sand*, with which its surface is covered.

SECTION I.

Tertiary Calcareous Marls.

These are highly interesting in a twofold point of view: first, in reference to our agriculture, as occurring in the midst of a region of sandy soils where the greensand marl, lime, and other like sources of fertility are remote; and secondly, in reference to the progress of our scientific geology, from being the only *tertiary formations* yet discovered in the State, and at the same time the extreme northeastern limit of the very extensive range of the tertiary deposits of the Atlantic border of the middle and southern States.

The geology of these beds is at present somewhat obscure, though the few fossils found prove that they belong to one of the oldest periods of our tertiary formations. Their range is very circumscribed, the only locality of much importance being near the western corner of Cumberland county. Nevertheless, the deposit demands a brief description from its economical value to the neighbourhood where it occurs, and the clew which it may furnish to corresponding strata in other sections of the sea-board region of the State.

These small insulated patches of tertiary, are evidently referable by their fossils to the *miocene* epoch, notwithstanding the disproportion of extinct over recent species. We can at present enumerate only about thirteen clearly recognized species; twelve of which are no longer in existence. Though this proportion might rather imply an *eocene* date for the deposit, the number of discovered fossils is too few to justify us in concluding this to be the actual relation of the extinct to the recent shells; while on the other hand, all the species are either identical with those of the *miocene* of Maryland and Virginia, or exhibit a close analogy of form.

The position of the principal known tracts of tertiary in the State, will be seen by consulting the geological map.

The principal deposit of these tertiary marls occurs in Cumberland county, upon the upper part of Stow creek and its tributaries, but whether it extends farther through the country, concealed by the superficial sands, or, what is rather more likely, occupies what was originally a *cove* or *bay* in the midst of the adjacent *secondary* strata, are points still obscure. At Elwell's pits, about two miles northwest of Roadstown, the deposit shows the following features:

The superficial stratum of the neighbourhood is a rather coarse yellow sand, five or six feet thick in the bank where the marl is excavated. Beneath this, there is a layer four or five feet thick, of a reddish-yellow clay, abounding in traces more or less obscure of fossil shells in an extremely rotten and decayed condition. Beneath this there is a bluish-green clay containing a multitude of the same fossils in a somewhat less decomposed state, though very soft and tender. These two fossiliferous beds are in some places twelve feet thick, and rest upon a dark greenish-blue adhesive sand, bearing a close resemblance to the tenacious sandy clay of the greensand formation. In the adjacent bank it has the prevailing colour of that bed, and the same *astringent* substances (copperas, &c.) which characterize it so generally. The mass of loose friable clay, both yellow and green, exhibits a very considerable proportion of *carbonate of lime* derived from the decomposition of the shells, and the calcareous matter of these fossils themselves. It is a marl calculated to be especially beneficial upon the very sandy land of the vicinity. It will be found valuable as a fertilizer in proportion to the lime which it contains, the crumbly state of the shells, and its freedom from sand.

The description here given of Elwell's marl, will apply pretty well to the other marls excavated upon the same streams, with this reservation however, that the shells in some localities are less rotten and in their nature less destructible, which is the case with those of the oyster. These occur in one part of the deposit at Davis's bank; and also in the greater number of the openings higher up the stream, where the clay seems to possess a rather larger share of sand.

Another stratum of the same geological age, occurs about a mile and a half southeast of Fairton, and near the Rattlesnake run. It is a very thin bed of a similar bluish clay, containing a small proportion of decomposed shells, and resting, like the Stow creek marl, upon the same astringent argillaceous sand. It also is of two varieties, one containing only oyster shells and much sand: the other being more clayey, and possessing a larger amount of calcareous matter, and the fossils in a very decayed state. The deposit here has not been much developed, though it obviously deserves to be zealously explored.

Much of the value of a marl of this description depends upon the condition of the shells which furnish the lime. These may be very indestructible, the case most generally with the oyster; or on the contrary so easily decomposed, as to be found generally in that chalky and decayed state necessary to constitute a good marl. The largest, and at the same time one of the most abundant fossils in the Stow creek marl, is the *Perna maxillata*, a thick, flat, pearly shell, dividing into numerous thin scales, and valuable from the readiness with which it decays and distributes its calcareous particles.

In excavating marl in this neighbourhood, it is all important to avoid mixing with the calcareous stratum any of the *astringent* matter which lies immediately beneath. This is noxious to the crop and seriously detrimental to the soil. It will be known by its *taste*, and its rarely containing fossils.

I have accompanied this account with the following analyses of these marls, for the purpose of ascertaining for the inhabitants of the quarter interested, the relative efficacy of different specimens from several localities.

1. A specimen of average richness from the marl pits of Mr. Elwell, yielded

Lime, - - - -	25·5	Carbonate of lime 45·5 per cent.
Carbonic acid, - -	20·0	
Greenish residue, chiefly clay, with some oxide of iron,	54·0	
Loss, - - - - -	00·5	
	100·0	

The shells in a very rotten chalky state, principally *Pernas*, and a good many small turrited univalves.

2. A specimen of the better variety in Mr. Davis's pits, afforded

Lime, - - - -	20·6	Carbonate of lime 36·8 per cent.
Carbonic acid, - -	16·2	
Greenish residue, clay and sand containing some oxide of iron,	63·0	
Loss, - - - -	00·2	
	100·0	

The shelly matter much decayed, consisting chiefly of *Pernas* and *Turritella.*

3. The Fairton marl affords from the best variety

Lime, - - - -	19·0	Carbonate of lime 34 per cent.
Carbonic acid, - -	15·0	
Greenish residue of clay and sand, - - - -	65·5	
Loss, - - - -	00·5	
	100·0	

The shelly matter fragments of *Perna.*

The inferior variety, consisting of sand with a little clay and shells belonging to a species of oyster in an undecayed condition, contained, in two examinations made, not more than *four per cent.* of carbonate of lime, after the shells were picked out.

Bog Iron Ores.—This district is characterized by an abundant supply of bog iron ore, which sustains in fact a principal part of its manufacturing industry.

The origin of the deposits of bog ore of the region before us, we can readily understand, by adverting to the very ferruginous nature of nearly all the strata, both the greensand and the beds overlying it. The water, not only in the marl region proper, but throughout the adjacent tracts, contains very generally a considerable quantity of the oxide of iron, which it procures in its passage through the upper strata. Upon coming into the open air it parts with the carbonic acid, the agent by which it is enabled to retain the oxide of iron in the dissolved state; this it quickly precipitates, and hence the accumulations of bog ore in all situations where the low grounds are entered by springs passing out of the more ferruginous beds of sand and clay. As some of these, the marl stratum for instance, contain a notable proportion of the phosphate of iron, we discover whence the bog ore is contaminated with phosphoric acid, producing a cold short iron. The source of the ore accounts for the interesting fact that, after being dug, the deposit is again renewed after a series of years. In some places, the requisite period does not exceed twenty years. It is essential to the continual deposition of the ore, that the soil in which it is precipitated should not be drained, but that it should be incessantly washed by the ferruginous springs. Where the water from these is enabled readily to escape, and the surface of the ore laid bare and exposed to the rains, the oxide of iron vanishes almost as rapidly as it before accumulated. The lumps retain, it is true, the cellular structure of bog ore, but the matter left consists almost entirely of the more earthy portions, from the solvent power of rain water for oxide of iron in the loosely cohering state in which it exists in the ore. The rain water seems to owe its capacity of dissolving the iron in the ore to the small quantity of carbonic acid which it collects in its passage through the atmosphere.

We derive one important hint from these facts: namely, that those who make use of this variety of ore, should avoid keeping large accumulations exposed to the weather as we so frequently witness at the furnaces in the section of the State where the bog ore abounds. It should be dug, in fact, only as it is needed.

The map accompanying this report, will exhibit the general limits of the several tracts of bog ore, both those confined to the greensand region, and those of far greater extent which occur in the wide sandy country lying between it and the ocean. While the areas represented on the map embrace all the deposits of magnitude and importance, they are not to be regarded as containing the bog ore throughout every portion of their surface. On the contrary, the mineral lies principally along the borders of the main streams and their tributaries, and in the beds of those extensive swamps and wet meadows, with which, owing to the sluggishness of their waters, they are generally surrounded.

Two great deposits, incomparably the largest in the State, border the principal tributaries of the Little Egg Harbour river. The most western of these is connected with the waters of

Atsion river and most of its branches, extending from near the sources of these streams in a tolerably wide belt southeastward to Landing creek. The length of the tract within which the bog ore is found on nearly all the tributaries, is about twenty miles, while we may state its average breadth at three miles. The other, or eastern tract, lies along the Tulpehaukin or Wading river, and its several branches. It covers an area quite as extensive as the former, but the deposit of ore in this latter district is greatly inferior in abundance to that on the Atsion river, particularly in the neighbourhood of Atsion iron works.

The several minor deposits of bog ore are confined to the limits of the marl region.

One of these occurs on Talman's creek, a small tributary to the Rancocus; another is found upon the south branch of the Rancocus near its junction with the north branch; and another lies on the Manasquan river, near the little village called Georgia, in Monmouth county. Other similar deposits are met with on the Manalapan and Machaponix creeks, in Monmouth county, two small tributaries of the South river, which flows into the Raritan.

The usual features of the beds of bog ore, their probable origin, and the peculiarities in the structure of the ore itself, will be understood by the following description of those which occur in the vicinity of Atsion iron works, which may be regarded as representing those deposits generally.

The Atsion river takes its origin within a mile of Longacoming. In the greater part of its course, it flows through extensive flats or cedar swamps, the water becoming in its passage through these, highly tinged with vegetable matter.

Near to the source of this stream, and at numerous other places along its course, the sand, though of a snowy whiteness on the surface, presents a ferruginous tinge wherever the inferior layers are to be seen. The water oozing from these sands, carries with it more or less of the oxide of iron, derived evidently from the upper and more exposed parts of the stratum, depositing it as it reaches the air.

Within two miles of the source of the Atsion, bog ore is found, though not in very considerable quantity.

The ores which are used at the Atsion works, are obtained from above the furnace, the present excavations are chiefly at about three or four miles above the pond or dam which supplies the water power. Great quantities of the ore are also taken from the bed of the pond during the winter, when the furnace is out of blast and the water is drained off. The ores which are used at this furnace are, the *loam ore*, the *seed ore*, and the *massive ore*. The swamps of the river (which is rather sluggish) are extensive, and form numerous shallow coves, some of which are covered with water to the depth of about a foot, while others contain a very spongy peat, which is always found on the edges. The ore is chiefly taken from these coves when the water is not too deep, especially along their wet margins. Excavations eight or ten feet square are made, between each of these a thin dike is left, so as to prevent the water from one flowing in upon the workmen in the others. The three kinds of ores are generally found in each hole; the loam ore nearest the surface, the seed ore under this, and the massive ore at the bottom. In some positions, however, only one of these kinds occurs, unaccompanied by the others. In other positions, the several varieties may be seen in their various stages of maturity. The loam ore is that which appears to form first, being in reality merely the infiltration of ferruginous sediment into the soil of the bog. This, which is at first quite soft, becomes by the accumulation of oxide of iron, heavier and more compact. In the centre of many lumps, the mass has a crystalline or regular ore-like character. This structure would pervade the whole deposit, could it be exposed for a sufficient length of time to the correcting action. The loam is thus in time completely replaced by the oxide of iron, which is seldom solid, but of a honeycomb structure, the cavities being more or less filled with yellow aluminous matter. These ores are obtained in various conditions of compactness. That which is partly concreted, partly pulverulent or loamy, is called *young ore*, a variety which experience shows to be better adapted for easy fusion, than the more concretionary harder kinds.

Great quantities of woody matter, such as stumps and trunks of trees, abound in these ore beds, completely converted into oxide of iron. The curious process of replacement which has taken place, has preserved the precise form and structure of the bark and woody fibre, down to the most delicate lines and markings.

Analyses.—The following analyses will display the composition of the bog ore, in its ordinary varieties.

Bog Ore.—Atsion Iron Works.

Description.—Variety called seed ore.
Composition.—In 100 parts:

Peroxide of iron, - -	66·10
Alumina, - - -	·66
Insoluble matter, - -	20·53
Water, - - -	12·54
	99·83

The *metallic iron* in this ore amounts to 45·83 per cent.

Bog Ore.—Atsion.

Description.—Concreted, cellular; taken freshly from the bog.
Composition.—In 100 parts:

Peroxide of iron, - -	68·90
Alumina, - - -	2·37
Insoluble matter, - -	13·99
Water, - - -	14·04
	99·30

The *metallic iron* amounts to 47·71 per cent.

Bog Ore.—Upper Squankum.

Description.—Concreted, cellular.
Composition.—In 100 parts:

Peroxide of iron, - -	76·35
Alumina, - - -	0·23
Insoluble matter, - -	9·29
Water, - - -	12·76
	98·63

The amount of *metallic iron* is 52·94 per cent.

Bog Ore.—Shrewsbury river, near Eatontown.

Description.—Concreted, cellular.

Composition.—In 100 parts:

Peroxide of iron, - -	67·78
Alumina, - - -	a trace.
Insoluble matter, - -	18·54
Water, - - -	8·69
Organic matter and loss,	4·99
	100·00

The amount of *metallic iron* in this ore is 46·98 per cent.

White Sand for Glass Making.

Upon the Maurice river, about three miles below Millville, in Cumberland county, an important locality occurs, which furnishes this valuable material in great abundance. This deposit of sand presents a number of layers, more or less approximating to absolute purity; but previous to its being employed in the glass-house, it is always necessary to submit it to a careful washing, in order to discharge a small quantity of yellowish and slightly ferruginous clay, with which it is intermingled in the bank. After the washing it is a pure transparent quartzose sand, the grains of which are small and of very uniform size. There are five glass-houses in the vicinity of Millville, besides many at a distance, which are supplied with sand from this spot. Numerous other places throughout the very sandy district before us, yield a material equally good, but scarcely any other point yet explored offers the same readiness of access.

In the neighbourhood of Mount Hope much good sand is found; it is used at the Windslow and several other glass works. The sand used at the Waterford glass works is procured in the vicinity of that establishment.

Within two miles of the Brooklin glass works good sand is procured, and is employed both in these and in the Squankum works.

The neighbourhood of Jackson's glass works furnishes a sand well adapted for the manufacture of both window and bottle glass.

FINIS.