rock are superimposed, bringing the total thickness of this sand-rock deposit to 30 or 35 feet. West of Flat Rock Point, the cliffs are interrupted, and at the base of the massive ledges, thin-bedded, more finely grained, sandy flagstones, partly of red, partly of greenish color, come to the surface. Some distance further on, at the mouth of a small creek, lower beds of a micaceous greenish sand rock, rich in calcareous cement, and partly conglomeratic, barely emerge from the water, and in seams are very fossiliferous. The fossils are Nucula Hubbardi, Solen quadrangularis, Goniatites Marshallensis, Orthoceras, Rhynchonella, Productus, and other forms identical with those found in the sandstones of Marshall. Toward the mouth of Pinegog River, west of the creek, the rocks disappear, but Hat Point, 3 miles from that spot, is again formed of rock cliffs, 15 or 18 feet high, composed of the same coarse-grained sand rock as the cliffs of Flat Rock Point. One of the rock masses forms a small island in the shape of an inverted cone, resting on a slender base, and expanded above into a discoid platform overgrown with trees. This, bearing a general resemblance to a hat, gave the point its name. At the foot of the cliffs, the greenish, micaceous sand-rock ledges come out, but show no fossils. The cliffs of Hat Point recede some distance from the shore in a southeast direction, forming the margin of a terrace; westward, bluffs of drift sand take their place; only at intervals does the sand rock show itself on the surface, in small, circumscribed spots—as, for instance, on the roadside near Mr. Smalley's farm-house. On Mr. Klump's farm, southeast of Oak Point, the sand rock is covered by fossiliferous limestone ledges, which represent the basal part of the next higher group of rocks. South of Port Crescent, on the branches of Pinegog River, the water frequently flows over denuded ledges of a sand rock, and through this whole district only a thin coating of drift, rarely more than 20 feet in thickness, is spread over the rock, which resembles the finer-grained beds below the cliffs of Flat Rock, but contains no fossils in the localities examined by me. Further south, toward Badaxe and Verona, the drift is much deeper, and the rock beds are not within reach by well-excavations of ordinary depth. Very large metamorphic boulders are strewn over the surface of some fields, but the soil of this vicinity is generally good.

On the east side of Port Austin, we find the cliffs of Point of Barques composed of the same coarse-grained sand rock as Flat Rock Point; they rise vertically from the lake to a height of about 20 feet; the rock is harder and more greenish than at Flat Rock, more like the cliffs of Hat Point. An impression of a Goniatite and casts of a Rhynchonella are the only fossils I observed in it. The strata at the base of the cliffs are of a darker greenish tint and of finer grain, and are so undermined by the water that large masses have tumbled over into the lake, or stand like inverted conical masses, as at Hat Point, resembling at a distance barks at anchor. It is from this that the name of the point is derived.

In the drift masses covering the cliffs, slabs of a calcareo-ferruginous sandstone are quite abundant, which are almost totally composed of casts and shells of Rhynchonella camerifera and Centronella Julia, together with a few other shells and stems of bryozoa. These fossiliferous, loose rock fragments were long since discovered, but their exact position in the series was not known. By following the sand beach east of Point of Barques, toward Burnt Cabin Point, quantities of similar fossiliferous slabs, but evidently freshly broken from the ledges, are thrown out by the lake; the stratum, consequently, must be denuded under the water-level, and have a position only a few feet below the base of the cliffs. The reddish, thin-bedded flagstones next below the cliffs of Flat Rock are probably representatives of the same horizon. I found in them, sparingly however, specimens of Rhynchonella camerifera. The cliffs of Point of Barques, at the old mill erected there, recede from the immediate vicinity of the shore, and continue southeastwardly, as a terrace-like bluff of about 30 feet elevation, at some distance from the lake, passing the grindstone quarries and extending to Willow Creek. The low shore belt in front of the bluffs is underlaid by the grindstones which have frequent exposures between Burnt Cabin Point and the grindstone quarries, and beyond them to Willow Creek, with some interruption by sand beaches.

The grindstone quarries are opened in a part of this shore belt where the rock faces the lake in vertical bluffs of from 5 to 15 feet elevation. A thin coating of boulder drift covers the surface of the level ground extending to the foot of the terrace formed by the cliff rock of Point of Barques, half a mile back from the shore. The layers found next under the drift are thin-bedded, brittle

slabs of chocolate-brown color; below them is usually found a band of conglomerate not over a foot in thickness, composed of pebbles of sizes ranging from that of a pea to that of a hazle-nut. Then comes a fine-grained, micaceous, greenish-colored sand rock, and a few feet below the upper conglomerate another seam of it often follows; but these conglomerate bands are not regular; they wedge out on both sides, while, in places, no such seam is developed. The conglomerates contain a large proportion of calcareous cement, and are usually very hard. The sand-rock beds between the conglomerates often contain single pebbles scattered through them, and globular concretions from the size of an egg to that of a man's fist, of extremely hard, calcareous sand-rock mass, which, split open, are nearly always found to inclose some kind of a fossil, bones of fish, or Goniatites, etc.; the same fossils are found in the conglomerate seams. The sand-rock ledges inferior to the conglomerates represent the useful quarry rock, having a total thickness of about 16 feet. It is a middling, fine-grained sandstone, micaceous, of bluish or greenish color, in places very regularly stratified, and all through homogeneous, splitting in even beds, with sometimes ripple-marked surface. In some parts of the quarries, however, the bedding is discordant, as it is found in every sandstone formation, involving a greater proportion of waste. Sometimes also layers are damaged by single quartz pebbles scattered through them, which unfit them for use as grindstones. The rock is split into plates of any desirable thickness, dressed roughly with the hammer, and is then finished by a steam-turning machine; portions also are sawed into strips for use as whetstones. Grindstones of 6 and 7 feet in diameter can be easily obtained. The blocks not well suited for grindstones are either dressed on the spot as building material, or are shipped in the rough, to be used for the same purpose.

I have already mentioned the occurrence of Goniatites and Fish remains in the conglomerate beds and in the calcareous concretions; the same fossils, although more rarely, are also found in the other parts of the rock series. Teeth and spines of various fishes of the shark family are found in great perfection; among these I may mention a tooth of an Orodus $4\frac{1}{2}$ inches long. This specimen, besides a number of others, I gave into the hands of Prof. Newberry for description, the study of fossil fishes being a specialty

of his. Of Goniatites, I collected three different species. Some seams contain also numerous casts of bivalve shells, most of them identical with forms found in the sandstones of Marshall and Battle Creek. Carbonaceous vegetable fragments, among them Calamites and Lepidodendron, are of common occurrence. The lower beds of the sand rock are largely intermingled with shale fragments, and the underlying shales being eroded on the surface, the sand rock resting on them fills out their furrows.

In the bluffs on the lake shore, below the solid body of sand rock which is designated as the *grindstone*, a series of blue shales, interlaminated with seams of sandstone, is exposed, emerging about 5 or 6 feet above the water-level. Similar shaly beds are noticed in the bed of Willow Creek, under the mill at Huron City. At that locality the sand-rock ledges much prevail over the shaly material, certain seams of this sand rock being completely filled with the casts of a Rhynchonella, intermingled with a species of Productus and a few other shells. The surface of some layers is often covered with relief forms resembling Fucoides caudagalli. On the south side of Willow Creek, the hill over which the road to Port Hope leads is again capped by the grindstones. The hill forms toward the lake a steep escarpment about 50 feet high, which continues southward about a mile beyond Point of Barques Lighthouse. Twenty feet of the top part are solid sandstone ledges, containing irregular seams of conglomeratic structure; the lower portion of the escarpment, down to the level on which the lighthouse stands, is made up by arenaceous shales, alternating with seams of sand rock. The shales contain casts of bivalves and other fossils, similar or identical with those found in a bed of calcareous sand rock below them, the same on which the lighthouse is built.

This sand-rock ledge, having a thickness of from 2 to 3 feet, is even with the water-level a few hundred yards north of the lighthouse; at the lighthouse it has risen about 5 feet, and further south it may be seen in the bluffs 8 or 10 feet higher than the level of the lake. The shale bluffs above the sand-rock ledge are at a distance from shore at the lighthouse and north of it; a quarter of a mile south of the lighthouse, however, they come up close to the shore line, and cover the ledge from above, while below it, as basal part of the same bluffs, shale beds similar to the upper ones make an outcrop. These bluffs continue for about half a

mile, when they again recede from the shore, which further south is a low sand beach.

The sand rock of Point of Barques Lighthouse is coarse-grained, partly conglomeratic, full of nodules and granular crystals of iron pyrites. In undecomposed condition, it is rich in calcareous cement, and very hard; its color is partly dark bluish, or, in weathered condition, ferruginous brown; much weathered portions which have lost nearly all their cement are softer and often whitish. The bed is quite fossiliferous. The surface of the ledge is rugose by fucoid-like ramifications spread over it, and seams of it are often densely crowded with casts of a Rhynchonella; of other Brachiopods, a species of Orthis, a Productus, a Syringothyris, a Spirifer of a large kind, Streptorhynchus, Rhynchospira, Spiriferina, Terebratula, are generally plainly recognizable, but are too imperfect for specific determination or identification with forms of other remote localities.

In addition to the Brachiopods, several Lamellibranches of the genera Cypricardella, Schizodus, Aviculopecten, and of Gasteropods a large Pleurotomaria (Huronensis Winchelli), were found, as well as a species of Goniatites, and a large form of an annulated Orthoceras. A Prœtus, the head of a Cyathocrinus, and stems of other Crinoids, together with traces of Bryozoa, complete the list of fossils found there by me.

The order of sequence of the strata composing the section from Port Austin to Point of Barques Lighthouse, is differently represented in Prof. Winchell's report of 1861, in which the same locality is described. It will be remembered that I consider the rocks of Flat Rock Point, Hat Point, and Point of Barques as identical, and occupying the highest position in the series; next below them are thin-bedded ledges of sandstone with a fossiliferous seam containing Centronella Julia and Rhynchonella camerifera. A band of conglomerate rock follows, and then we come upon the grindstones, which in their fossils are identical with the sandstones of Marshall; to the latter, shales, with seams of sandstone, are subjacent, and last and lowest in the section is the sand-rock ledge of Point of Barques Lighthouse.

Prof. Winchell commences his section with the calcareous sand-rock ledges west of Flat Rock Point, which he correctly identifies with the sandstones of Marshall, but places as the highest of the exposed strata, and, under a preconceived theoretical opinion on

the general dip of the strata, he believes that he descends to lower beds, when, moving eastward, he really ascends to the cliffs of Flat Rock; proceeding on to Point of Barques, he still is under the impression that he descends to lower horizons. From Point of Barques toward the Lighthouse, the section is actually changed into a descending one, which is considered by him as a direct downward continuation of the former. Unfortunately, this section is laid across a synclinal undulation of the formation, and begins at one end with the same rock beds (Marshall sandstone) which on the other end are found very near the base (grindstone ledges). Under the impression that he has all the while descended, he stands again on the horizon from which he started. An almost uninterrupted section through all the above-described rock beds can be seen in Willow Creek, 5 miles above its mouth; the layers between the coarse-grained upper sandstone and the grindstone series are particularly well denuded there in the bed and banks of the creek.

The sand-rock ledge of Point of Barques Lighthouse, whose fossils I have enumerated, is designated by Prof. Winchell as the dividing stratum between his Huron shales and his Marshall group; the sand-rock bed is pretended to represent the Devonian fauna, the shales above it, the fauna of carboniferous character. He enumerates 19 species of fossils found in the sand rock to prove its Devonian character. Six of them are identified with Hamilton species, identifications which must be questioned, and 13 species are newly described by the Professor, which, as new forms, can have no great value in the instituting of comparisons, their generic types being as much at home in the Devonian as in the carboniferous rocks. The shales above this sand rock contain a majority of all the species in common with it. The conformity of rock material and stratification in this part of the formation, above and below the imaginary division line between the Devonian and carboniferous deposits, is so perfect that no one could accept this stratum as the terminal deposit of the Devonian ocean, even if the fact were ignored that at least 500 feet of rock beds below this horizon present the faunal characters of the Cuyahoga shales of Ohio, which form the upper division of the Waverly group.

From Lighthouse Point southward, as far as Forestville, in the north part of Sanilac County, rock beds approximately of the

same horizon with the grindstones of Huron City are near the surface along the shore line. The outcrops are insignificant compared with the stretch of sand and gravel beach interrupting them, but it rarely requires the removal of very deep drift masses in order to uncover the rock beds.

At Port Hope, the grindstones crop out in the lake bed close to the docks. More extensive denudations are to be seen one mile and a half north of the village, at the shore; the land behind it rises in several terraces formed of coarse boulder drift with metamorphic and crystalline blocks and of Niagara and Helderberg or Hamilton limestones, besides a large proportion of fragments from the underlying sand rock, some of which are rich in the shells usually found in the Marshall and Battle Creek sandstones. The boring of a salt well at Port Hope, to a depth of 787 feet, is recorded as follows:

Drift	16 ft.
Greenish micaceous sandstone	6 "
Blue arenaceous shale, with occasional seams of sand rock	510 "
Very hard rock (not more particularly specified)	1 "
Dark blue shales	154 "
Arenaceous shales	29 "
Coarse, whitish sandstone, saturated with strong salt brine	71 "

Further south, in the creek near Sand Beach, greenish and bluish micaceous sand-rock ledges interstratified with shales are exposed in seams filled with a species of Chonetes. The same beds, with Chonetes and impressions of Goniatites, are well exposed at Rock Falls, the ripple-marked surface of the ledges in the latter place being covered with Caudagalli fucoids in relief, as well as other singularly-shaped prominences of organic origin.

At White Rock, south of the village, the arenaceous shale beds below the horizon of the grindstones ascend in steep bluffs of 25 feet elevation from the lake bed, for the distance of about a mile. Indistinct casts of fossils, amongst which Goniatites is recognizable, are found on the surface of the arenaceous flags; this is the last rock exposure on the shore of Lake Huron, which washes upon a drift beach for the remainder of the distance down to

Port Huron. Mr. Thompson sunk two artesian wells at White Rock—one to the depth of 555 feet, the other to 700. In both, blue shales, alternating with arenaceous layers containing much iron pyrites, extended to the depth of about 450 feet below the surface, when a porous gray sand rock was struck, saturated with a strong and very pure salt brine. The thickness of the sand rock was about 100 feet, and below it blue shales were found again, which were penetrated to a depth of 50 feet. Mr. Thompson had saved specimens of his deeper drill hole, representing almost every interval of 5 feet, which he kindly presented to me, and by which I could form a more correct idea of the character of the rock beds than could be obtained from any descriptive record.

Of other deep borings made within the district under consideration, I may mention the salt well at New River, only two miles south of the grindstone quarries, bored to a depth of 1029 feet.

It begins in the grindstone, which is there 15 feet in thickness, underlaid by soft blue shales 30 feet thick; to them follow alternately shale and sand-rock ledges to the depth of 800 feet. There, as the record says, a rotten, bad-smelling, soft rock was penetrated, and then 100 feet of a porous, coarse-grained, whitish sand rock was found, saturated with brine, below which the boring was continued for a few feet into blue shales. Salt brine was already found at a depth of 90 feet below the surface, but it continued to increase in strength as a greater depth was reached. In the sand rock at the bottom of the well, it has a strength of 85 salinometer degrees.

At Port Austin, one of the oldest salt wells was bored to a depth of 1200 feet, but the boring record has been lost. Lately, Mr. Skene made a new boring to the depth of 1225 feet in a locality one mile west of the village and about 200 yards from the shore line of the bay. The boring, after the penetration of a few feet of drift, begins in the conglomerate band of the grindstone series, following which are greenish-blue micaceous, fine-grained sand-rock ledges. Another conglomerate bed is found 125 feet below the surface, and from that a strong current of sweet water rises to the surface. From there to 163 feet are arenaceous shales; at 204 feet is a gray sandstone, and the first signs of brine were observed at from 204 to 315 feet, shales with arenaceous seams occur at 317 feet, and a conglomeratic sand rock 20 feet thick. There was a strong discharge of sweet water from the bore hole, from 336 to 1100 feet (764 feet),

all of which was through bluish shale, with only a few intermediate strata of sandstone. At 1120 feet are bright-red and chocolate-colored shales 40 feet thick, while from there to 1225 feet is white sand rock saturated with brine; underneath lie shales again.

Inland from the shore line, whose geological structure has been described in previous pages, we find the greatest part of the surface of Huron County covered by deep drift deposits. The upper coarse-grained sand rock comes to the surface in Bingham township, near the head-waters of Cass River. Similar outcrops are found in the northwestern towns of Sanilac County, in Greenleaf and Argyle, and in Tuskola County, in the towns of Elkland and Novesta, where the bed of Cass River is formed by the upper coarse-grained sand rock inclosing vegetable remains, Lepidodendron. Further up the river, at Indian Rapids, in Town. 13, R. 12, Sect. 7, some lower beds of finer-grained sand rock interlaminated with shale form vertical bluffs about 20 feet high on both sides of the river. One of the interlaminated seams is soft, almost entirely composed of mica scales and carbonaceous vegetable substance. The sand rock is mostly thin-bedded, and without fossils as far as observed.

On the north side of Saginaw Bay an outcrop of the upper sandstones of the Waverly group forms the bed of Rifle River for the distance of a mile. The locality is in Town. 21, R. 3, Sect. 16. The rock is coarse-grained, whitish or greenish, with ferruginous spots, moderately soft and irregularly stratified in discordant bedding. Its thickness can not well be estimated, but 30 or 40 feet of the strata are distinctly seen successively rising to the surface. No fossils were observed in it. The hills on both sides of the river are all composed of drift. The strata dip southward, and a few miles lower down calcareous beds of the next higher formation, having the same southern dip, form rapids in the river, but the immediate contact between the Waverly rock and these limestones is not seen.

In this upper portion of the peninsula, no other natural outcrops of the Waverly group are known to me, but the formation has been found in several deep borings made for salt; two made in Tawas City and one lately at Sable City. Of the latter boring I have no details, being only informed of their success in finding a good supply of brine. Of one of the borings at Tawas, in the

establishment of Grant and Sons, I copied an accurate record from the books of the firm, which reads as follows:

Sand	30 ft.	drift.
Clay, yellow	20 "	
Sandstone, whitish	60 "	
Sandstone, red	15 "	
Sandstone, gray	5 "	
Sandstone, red	40 "	
Shale, light-colored	10 "	
Shale, arenaceous red	30 "	
Shale, light-colored	5 "	
Shale, arenaceous red	88 "	
Shale, blue	35 "	
Sandstone, red	40 "	
Shale, hard, light-colored	60 "	
Sandstone, red	5 "	
Shale, white	15 "	
Sandstone, red	5 "	
Shale, hard, light-colored	40 "	
Sandstone, red	5 "	
Shale, white	3 "	
Shale, arenaceous, light-colored	3 "	
First indications of brine.		
Shale, white, hard	164 "	
Sandstone, gray	195 "	
Abundant supply of strong brine.		
Shale, blue	10 "	
Total	905 ft.	

A few years later, another company bored a well at Tawas with the same success, but I did not find out the particulars of the boring.

In the south part of the State, natural exposures of the Waverly group are found in the counties of Jackson, Hillsdale, Branch, and Calhoun. In the west part an outcrop is known at Brown's Station, in Lake township, Berrien County, and other exposures are near Holland, in the south part of Ottawa County. At Napoleon village, in Jackson County, sandstones of the Waverly group have been quarried as a building-stone since the first settlement of the

State. The quarries are about half a mile south of the village, with the rock beds close under the surface, on the summit level of a slight undulation.

The sandstone is of middling coarse grain, greenish-yellow, intermingled intimately with kaolin-like granules, by which the firmness of the rock is impaired. For ordinary uses, however, it is durable enough, and selected blocks are used for ornamentally-cut door and window sills, etc. The beds are not very thick, often irregular through discordant stratification, and alternation with shaly seams. The thickness of all the rock beds uncovered in the quarries may be 50 feet. Fossils have never been found.

Southwest of Napoleon, at Stony Point, a station on the Jackson and Hillsdale Railroad, sandstones entirely similar to the Napoleon rock are quarried. The quarries were first opened in an uptilted mass of sand-rock ledges in vertical position, in all probability an effect caused by forces of the drift period, by an underwashing of the strata, and consequent disruption from the main body of the deposits, which were found behind the loose portion in regular horizontal position. The bottom of the valley on the side of which the quarries and rock escarpments are, presents no rock ledges; it is deeply eroded, and the erosion is filled up with drift material. In the quarries, about 35 or 40 feet of strata are exposed; the highest beds are thin-bedded, soft flagstones of discordant stratification, the lower strata being in beds of from 1 to 4 feet in thickness. The vertical clefts dividing the beds are rather irregular, oblique, or curved, which causes considerable waste in shaping the blocks. The rock is moderately coarse-grained, light, drab-colored, and sufficiently compact to make a valuable building-stone. Fossils are generally rare, but abound locally in certain seams; the species are all identical with the forms found in the sandstones of Marshall and Battle Creek. I collected in the quarry: Nucula Hubbardi, Nucula stella, Solen quadrangularis, Solen scalpriformis, Sanguinolaria similis, Myalina Michiganensis, Allorisma, Bellerophon galericulatus, Chonetes Illinoisensis, Orthoceras, Goniatites, and others. The same rock beds are laid open in many localities in the vicinity of Jonesville, of Hillsdale, Osseo, and Moscow, but the quality of the rock is not always so well adapted for use as a building-stone, its general character and the fossils inclosed proving, however, the identity of all the outcrops. Every locality has

certain species of fossils for itself or more abundant than in others, nearly all as casts, but sometimes with the shell, with all its delicate surface decorations, most perfectly preserved. Other exposures of the Waverly sandstone are near Homer, and near Condit Station, south of Albion. At the latter place a quarry is opened in a sand rock exactly similar to the Napoleon sandstone, and like it perfectly destitute of fossils. The beds of the quarry amount to about 20 feet; below them are a bluish-colored micaceous sandstone alternating with shale beds, and from this seam issue copious springs. Besides that afforded by the superficial outcrops of the district, something is added to our knowledge of its geological structure by deep artesian borings. In the Court-house square of Hillsdale two artesian wells have been drilled, one to the depth of 1350 feet, and another to that of 1550. No register of the borings was kept; however, from some attentive citizens, who watched the progress of the boring, I have received the following general statements, drawn from memory: Under a cover of several feet of drift, a soft, thinly laminated, micaceous, bluish sand rock, 20 feet in thickness, was first penetrated; under it, to a depth of 1120 feet, the principal rock found was shale of bluish color, interlaminated with arenaceous seams, and sometimes with harder ledges, believed to be of calcareous nature; the color of the shales became dark bituminous in the lower portion of the section. Next to the shale a hard, red-colored rock containing much iron pyrites was found, and the water was strongly saline. In the deeper of the two borings, below the hard red rock, a white limestone 50 feet in thickness was penetrated, and below it a softer, likewise calcareous rock continued downward as far as the drilling went. The lime rock in the bottom part of the drill hole very probably represents the Helderberg limestone, which, according to the record, is in that locality about 1400 feet below the surface. The dark bituminous shales above, equivalent to the black shales, can not be distinguished from the incumbent shales of the Waverly group, but we can see the considerable aggregate thickness of these formations.

In the city of Albion, several borings were made to a depth of 300 or 400 feet. Near the flour mill at Albion, a flowing well of slightly mineral, palatable drinking-water was opened by boring to a depth of 281 feet, all through solid sand rock, with the exception of 10 feet of

drift on the surface. Below the sand rock the boring was continued for 100 feet through blue shales, without reaching their limit. At Marengo, 6 miles west of Albion, a boring went through 60 feet of drift before striking the sand rock, which was found 200 feet thick. Below it shales were penetrated through a thickness of 200 feet.

From Albion westward the valley of Kalamazoo River offers frequent exposures of the upper sandstones of the Waverly group, as far as Battle Creek, and for some distance further. The sandstones of Marshall and Battle Creek have become famous through the abundance of their fossils. Prof. Winchell has described a large number of species from these localities, some of which are in good preservation and easily recognized; but a great proportion of those described, the originals of which are deposited in the University Museum of Michigan, are mere fragments offering so few species characteristic, that it would have been better to omit all description until additions to the collected material should justify it. The most common forms of fossils in this rock are casts of bivalves, their shells being rarely preserved. I enumerate Nucula Hubbardi, Nucula stella, Nucula Iowensis, Nucula bellastria, Myalina Michiganensis, Solen quadrangularis, Solen scalpriformis, Sanguinolaria similis, Edmondia equimaryinalis; likewise various forms of Orthonota, Cyrtodonta, Allorisma, Avicula, and Aviculopecten. Several forms of Productus, Spirifer, Spiriferina, Rhynchonella, Bellerophon galericulatus, Bellerophon rugosiusculus, Goniatites Allei, Goniatites Marshallensis, Nautilus of various kinds (Trematodiscus), also different forms of Orthoceras, fish remains of the shark tribe, and vegetable remains (Lepidodendron), as well as traces of corals and Bryozoa, are observed. Formerly a number of quarries were worked at Marshall along the bed of Kalamazoo River, which are now abandoned. The superficial rock ledges are a micaceous soft sand rock of yellowish-brown color, splintered into thin, uneven slabs by exposure; the deeper, more protected rock beds are harder, of bluish color, and rich in calcareous cement. Interlaminated with them are seams of a blue arenaceous shale. The harder rock answers a good purpose as a building material. The fossils are confined to certain seams, or at least rarely are found in other parts of the rock. Within the city of Marshall, a great number of artesian wells have been opened by boring through the

sand rock to a depth of from 60 to 100 feet, a copious stream of sweet water, rising several feet above the surface, being found in all the borings without exception.

The west part of the city of Battle Creek is built on rock ledges of the Waverly group. The upper strata, opened by digging out cellars, and seen on the slope of the banks of the river, are a middling, coarse-grained, yellowish sand rock, resembling the sand rock of Napoleon or Condit Station. Some beds are of moderate thickness, and are used for foundation walls; others are thinly laminated, of discordant stratification, and worthless. Some vegetable stems and concretions of iron pyrites are inclosed within them. Their total thickness is about 30 or 40 feet.

Below these strata, in the bed of Kalamazoo River, and emerging a few feet above it, are micaceous sand-rock ledges, thinly laminated, alternating with harder calcareous sand-rock ledges crowded with fossils of the same kinds as enumerated from the sandstones of Marshall, with additional forms peculiar to the locality. The higher elevations surrounding Battle Creek are all composed of heavy drift accumulations, partly well stratified sand and gravel beds, partly coarse, non-stratified boulder drift in a position above the stratified deposits. In the northeast part of the city the rock beds are covered by 70 feet of drift. An artesian well bored in that part of the city went below the drift stratum through 43 feet of sand rock, when the drill struck a cavity, sinking at once 3 feet, and a copious stream of water rose in the bore-hole to within 16 feet of the surface. The boring was continued through 326 feet of blue shales, until at 440 feet it was given up.

Twelve miles north of New Buffalo at Brown's Station, on the Lake Michigan shore road, and about 1½ mile east from the shore line, a brownish or violet-colored sand rock is found under a drift cover only a few feet in thickness. By exploring ditches, about 4 or 5 feet of the rock ledges have been laid open, which contain some of the most characteristic forms of the sand rock at Marshall: Nucula Hubbardi, Allorisma, etc.; but this is all that I could observe—the flat, level shore belt presenting no larger denudation or deeper sections into the rock. Hard, thin-bedded flagstones resembling the rock at Brown's Station are frequently thrown out by the lake, all along the beach from Michigan City northward; similar flagstones are also largely intermingled with

the lower unstratified clayey boulder drift of this vicinity, which induces me to believe that this rock series underlies the whole southwestern corner of the State; but the drift is generally too deep to allow of denudation of the rock beds by natural erosions, or by the ordinary excavations in well-digging, etc.

The next known outcrop of the Waverly group on the west shore is on Black River, near Holland, in Ottawa County, and some miles further north, near Grand River, it is seen for the last time. The outcrops at Holland are about 4 miles north of the village, in the flats bordering Black River. They comprise only a limited vertical series of beds, some of which are thinly laminated, while others are in thick, regular ledges, which are quarried for building uses. Their lithological character is nearly the same as that of the grindstones in the quarries on the Lake Huron shore, a greenish, middling, fine-grained, micaceous sand rock. In seams, a great number of the usual fossils of the Marshal sandstone are found; other parts of the rock are almost destitute of them. I found in the quarry, Nucula Hubbardi, Nucula stella, Nucula Iowensis, Solen quadrangularis, Solen scalpriformis, and other bivalves; also Bellerophon, Nautilus, Orthoceras, Goniatites, etc. North of Ottawa County, nearly all the land west of the Grand Rapids and Indiana Railroad line is supposed to be underlaid by the Waverly group as far as the head of Big Traverse Bay, but no sign of a rock ledge comes to the surface on this whole space until we come upon the green shales south of Antrim Village.

At Muskegon, several deep borings have been made—one a number of years ago by Mr. Whitney, to the depth of 1230 feet; another, the deepest ever made in Michigan, reaches a depth of 2627 feet. Of the first boring a register was kept to a depth of 657 feet. The boring commenced in drift deposits, which were penetrated 223 feet before the first ledges of solid rock were struck. The following shows the descending order of the beds:

Sand rock	50 ft.
Iron pyrites	3 in.
Sand rock	16 ft.
Shale	3 "
Sand rock	22 "
Shale	17 "
Shales and sand rock alternating	326 "

At a depth of 330 feet below the surface, and also at 643 feet, copious water streams were found, which rise to the surface, making an overflow of mineral water of quite an agreeable, refreshing taste. In the lower part of the boring salt brine was found, which, however, does not rise and mingle with the upper streams.

Of the deep boring, an accurate record of which would have been of great scientific interest, I could only get the general results, given from memory, by one of the superintendents of the work.

Drift deposits	235 ft.
Shales of lighter and darker color, alternating with seams of sand rock	450 "
Strong flow of mineral water.	
Blue shales, with some harder seams	775 "
Hydro-carburetted gas, drops of rock oil, and saline water.	
Soft blue shale	150 "
Red shale	150 "
Lime rock, with seams of shale	300 "
Salt-bearing rock, with seams of sandstone	50 "
Dark-colored lime rock	250 "
Gypsum beds, alternating with limestone	195 "

Dark, loose, porous lime rock, 82 feet thick, forms the bottom part of the bore-hole. It is to be regretted that no special pains were taken to preserve a regular set of specimens from each pumping. Few of them were kept in the office, mostly of shaly or arenaceous character, but of the horizons of the lime rock and gypsum beds, which I was very desirous to see, I could find nothing preserved. It is probable that the lower 800 or 900 feet of the boring penetrates the Hamilton and Helderberg groups, and that the salt brine found in the lower end of the well belongs to the Onondaga series, like the salt wells of Alpena, and of Goderich in Canada.

In previous pages, I have led the reader over the different outcrops of the upper division of the Waverly group, as developed in Michigan, and, occasionally, I gave an account of deep borings made in places vicinal to the outcrops. This upper division, principally composed of sand rock with intermediate subordinate seams of shale, has, as far as known by means of the deep borings in different parts of the State, a thickness of from 250 to 350 feet. The higher portion of the deposits is a porous, middling, coarse-

grained sand rock, with little calcareous cement, and rarely fossiliferous. Prof. Winchell named these strata Napoleon group, to distinguish them from the lower, often very fossiliferous beds, composed of more fine-grained micaceous sand rock, with seams of harder ledges rich in calcareous cement, which lower division he names Marshall group. He asserts the two divisions to be always separated by a seam of shale several feet in thickness, but such a regularity in the disposition of the rock beds of this horizon does not exist; shale beds are found everywhere in alternation with the sand-rock ledges, and in the different exposures of limited vertical extent, it is almost impossible to tell which of the special sand-rock ledges or shale beds we have under observation. Neither is the presence or absence of fossils in the rock beds a feature to be relied upon. A large portion of the lower beds, considered to represent the Marshall group, contains no fossils, yet the absence of fossils at Napoleon is no proof that those particular strata do not contain any. The rock of the quarries at Stony Point is so absolutely similar to the Napoleon sandstone, and is generally so barren of fossils, that nobody would doubt its identity with the other. It is only lately, by the more extensive opening of the quarry, that fossiliferous seams were discovered, which were before not known to exist.

It has been stated that Prof. Winchell considers the sandstones of Marshall as the lower terminus of the carboniferous rock series, typically distinct by its fossils from the next subjacent shaly beds which he connects with the Devonian rocks by the character of their fauna. Such a difference in the fauna is not perceptible; the fossils of the Marshall sandstones and the subjacent shales are not only generically in full harmony, but a great number of species are common to both. This lower shale formation is the surface rock in the south part of Hillsdale County and Branch County; the transition from the upper sandy division to the lower is not defined, as should be expected in rock beds with two distinct faunas; the beds are in fullest conformity of deposition, and the material composing them does not change. In the upper we have a sand rock with subordinate beds of shale; in the lower we have the same sort of shales alternating with subordinate beds of the sand rock. The outcrops of the shale formation in the counties mentioned are never of great vertical extent, and their horizontal extension is much interrupted by incumbent drift deposits. An artificial section through this shale formation is recorded by Dr. Bennett, of Coldwater, and specimens from all the pumpings during the progress of the boring were carefully saved by him and kindly handed over to me. The locality of the boring is a few miles west of Coldwater, near Branch Station. The following details of the boring can be given:

Drift	26 ft.
Soft blue shales	177 "
Hard blue shales, containing Crinoid stems and Chonetes	13 "
Soft blue shale	4 "
Hard blue lime rock, with quartz	1 "
Soft shale	10 in.
Hard calcareous sand rock	10 "
Soft sand rock	4 "
Water rising to the surface.	
Hard calcareo-argillaceous sand rock, with many shell fragments	2 " 6 "
Soft shale	2 "
Pyritous shale	7 "
Soft blue shale, with many shells	4 " 5 "
Hard blue rock (lime rock)	1 " 9 "
Soft blue shales	3 " 3 "
Argillaceous hard lime rock, of blue color, with many shells	1 " 8 "
Blue shale	2 "
Hard sand rock	2 " 8 "
Soft shale with fossils	2 " 10 "
Hard calcareous sand rock, with shells, Crinoid stems, etc	1 "
Shale and sand rock alternating, containing fossils and iron pyrites	33 "
Hard blue limestone, with calcspar and pyrites, shells	1 "
Salt brine.	
Shale and sand rock, with shells	11 " 6 "
Hard blue lime rock, with shells	1 " 6 "
Soft blue shale, with seams of sand rock, pyrites, and dark bituminous particles.	22 "

Similar shales, alternating occasionally with a seam of sandstone or limestone, continue to a total depth of 447 feet below the surface.

Only half a mile east from this drill-hole, on a higher level, in a brick-yard, shale beds of a seemingly higher position than those penetrated in the drill-hole are well denuded. The exposure comprises about 25 feet of strata, principally a soft blue shale with interstratified seams of arenaceous, thin-bedded flagstones, and full of lenticular iron-ore geodes of concentric structure, containing sometimes a loose, shaking nucleus. The superficial crust of the geodes is generally transformed into hydrated sesquioxide of iron; the internal portions are gray, compact, amorphous protocarbonate of iron. The shale beds, otherwise horizontal, are considerably flexured in serpentine lines, which disturbance in all probability was caused during the drift period by pressure of the advancing glacier masses on those beds which they encountered. The base of the hill capped with this shale is all enveloped by a mantle of drift deposits. No fossils were found in this locality.

Similar shales are uncovered in another brick-yard on the north side of the city of Coldwater; they are likewise crowded with iron geodes, some of which are fossiliferous, inclosing Chonetes Illinoisensis, etc. Below the shales, argillaceo-micaceous sandstones come to the surface, which contain iron geodes similar to those of the shales. All the hillsides north of Coldwater River valley, for several miles eastward from Coldwater, are composed of this shale formation covered by a more or less thick coating of drift material, but in other parts of the State, brick-yards generally use the drift clay. In the vicinity of Coldwater, all the clay used for brick-making is derived from the shale beds of the Waverly group, which are ploughed up and left to the influence of the weather for about a year, by which time the shale has decomposed into a soft, plastic clay. In the brick-yard of Mr. Merritt, 2 miles south of Union City, Town. 5, R. 7, west, Sect. 16, the surface beds are sandy shales with seams of calcareo-ferruginous rock, containing many small cylindraceous nodules composed of compact carbonate of iron, besides a number of partially very finely preserved fossils. Below these beds are yellowish gray soft shales, used for brick-making, which also contain numerous kidney-ore concretions of lenticular form.

The ore nodules were formerly collected and melted in a blast furnace at Union City, which is now given up. Half a mile north from the brick-yard on Mr. Randall's farm, the shale beds are seen in outcrops along the banks and in the bed of Coldwater Creek, amounting in the exposures to about 30 or 40 feet. The lowest strata seen in the bed of the river are dark blue hard shales, with gray carbonate of iron geodes and concretions of iron pyrites; above them some arenaceous seams pervade the shale beds, following which are the beds seen in the brick-yard. The fossiliferous, calcareo-ferruginous bed, and to some extent also the kidney-ore geodes, contain the following species of fossils: Chonetes Illinoisensis, Strophomena rhomboidalis, Terebratula eudora(?) several Spirifers not accurately determined, Spirigera lamellosa, Lingula, various species of Nucula, Myalina, Platyceras, Loxonema, Pleurotomaria, Bellerophon cyrtolites, Bellerophon galericulatus, Goniatites Oweni, Nautilus, Prœtus, some Bryozoa, and others, not yet properly determined.

South of Coldwater, in the town of Algansee, on Pencil Creek, in the ravines of drift-covered hills, the shale formation, with its intermediate seams of sandstone and of kidney-ore geodes, can he seen nicely exposed. Some of the iron geodes are fossiliferous. In the town of Reading, the shale formation is everywhere found under a thin coating of drift when digging wells, etc.; natural outcrops in the ravines and beds of creeks are also often encountered. The shale is sometimes considerably arenaceous and pervaded by regular sandstone ledges. These latter often contain fossils, but the best preserved are always found in the calcareous or ferruginous seams or in the geodes. Besides the other forms mentioned previously as found near Union City, I found in an outcrop in Reading a large Nautilus digonus.

The drift deposits of this region contain in places large quantities of fragments of the Marshall sandstone, inclosing an abundance of fine fossils; one of these localities is near Round Lake, in Sect. 32, of Allen township, where, by the excavation of a road bed, masses of this sand rock were thrown out. To the west and southwest of Coldwater, the shale formation is very soon lost under the drift cover spread over the entire southwest part of the State. The drift of all the western counties, as St. Joseph, Kalamazoo, Van Buren, and Allegan counties, is mixed with large

quantities of kidney-ore nodules from the shale formation, which are crowded with finely preserved fossils, identical with those found in the exposures of Branch County. To enable a comparison with the fossils of other strata, I will enumerate the forms collected from these nodules in the drift. The larger portion of them are not specifically determined, because a great many of them are undescribed forms, while in some cases I have used specific names with the intention of indicating a similarity rather than a full identity.

Of corals a species of Zaphrentis and a Pyrgia are noticed. Of Crinoids, heads of Platycrinus and numerous stems of other forms occur. Bryozoa, as Fenestella, Polypora, Stictopora, and Trematopora entirely compose certain ferruginous rock fragments. Brachiopods are represented richly by Lingula, Discina, Productus semireticulatus, Productus punctatus and two other small species of Productus, Streptorhynchus crenistria, Spiriferina spinosa, Spirifer setigerus, Spirifer Carteri, Syringothyris, Spirigera lamellosa, Terebratula Eudora, Meristella, Chonetes Illinoisensis, entirely composing large boulders; Rhynchonella, two species, Strophomena rhomboidalis, and Orthis; of Lamellibranches, five species of Nuculoid shells, Myalina, Modiola, Cyrtodonta, Orthonota, Cypricardinia, Conocardium, Lucina, Allorisma, Schizodus, and several forms of Aviculopecten. Of Gasteropods, I distinguish four species of Platyceras, a Pleurotomaria, Loxonema, Murchisonia, Bellerophon galericulatus, Bellerophon cyrtolites, and a Tentaculites; of Cephalopods, Trematodiscus digonus, various forms of Orthoceras and Nautilus, Goniatites Oweni, Goniatites Allei, fragments of Prœtus or Phillipsia, numerous specimens of Cypridina, and Fish remains.

A large proportion of these species I can recognize among the collections I made from similar iron geodes from localities in Ohio, at Sciotoville, and in the strata of Bagdad, and other exposures of the Cuyahoga shales, which latter, in lithological characters, also bear considerable resemblance to our Michigan shale formation. Prof. Winchell, who made a special study of these Ohio fossils, correctly recognizes the Cuyahoga shales as equivalent or analogous with the Marshall sandstones. I can not conceive, therefore, how he could overlook the similarity of the fauna of the shale beds of Michigan to those, except on the assumption that he never

paid any attention to the collection of fossils from the shales; but if so, he had no grounds upon which to attempt a demonstration of their Devonian age. The surface configuration of Ohio is very favorable for the study of the Waverly group; it forms a chain of hills extending from the north end to the south end of the State, which are deeply intersected by valleys of erosion, presenting on their slopes sections through the whole series in direct, uninterrupted superposition, and laid open sometimes for miles in extent. Such advantages we do not enjoy in Michigan. The Waverly series was evidently at an earlier period likewise intersected by deep erosions, but during the drift period these valleys became completely filled up again with the rubbish of the drift. Subsequent erosions denuded some rock beds superficially, in limited spots, but no deep cuts through them are laid open; our deepest natural sections do not comprise in any one place more than 50 feet of strata, and of a portion of the lower beds of the Waverly series, which is nearly a thousand feet in thickness, we have little more information than what we get from artesian borings by means of the material pumped up in pulverized condition, a very imperfect mode of studying a formation, the value of which is even lessened by the negligence with which the records of such borings are generally kept. The lower division of the Waverly group is not a shale formation throughout; it incloses in several horizons thick masses of porous sandstones, which are of the highest economical value for us, as the repositories of a concentrated salt brine. The brine, however, does not seem to be confined to this lower horizon, but pervades the whole rock series, in which the sand rock acts as a sponge, absorbing into its pores the saline liquid and retaining it, if the conditions for its retention are otherwise favorable.

In search of this brine, boring experiments have been made in all parts of the State, while in other deep borings, made for a different purpose, brine has been found accidentally. It has been ascertained by these borings that salt brine is not confined to certain localities or to a certain limited geological horizon, but can be found in all parts of the peninsula which are underlaid by the Waverly group, and at the same spot in higher and lower horizons.

Incidentally, I have recorded several deep borings, while giving

a description of the general structure of the Waverly group. A number of others, particularly those made in districts where no superficial outcrops of rock ledges are known, are of interest, and may be mentioned here.

A drill-hole to the depth of 770 feet was made in the Court-house square of Ann Arbor, whose progress I carefully watched, so that I can vouch for the correctness of the record:

Drift above coarse boulder drift, below stiff clay beds mixed with pebbles and a few large boulders	155 ft.
Blue arenaceous shales interstratified with seams of fine-grained sandstone	150 "
Black bituminous shales, evolution of hydro-carburetted gas and rock oil in drops	28 "
Gray sandstone, coarse, containing brine of 1142 spec. weight, leaving 19 per cent residue by evaporation, which is almost pure chloride of sodium	92 "
Blue shales, with subordinate sandstone layers and seams of iron pyrites	100 "
Black shales, very bituminous, with iron pyrites,	85 "
Dark blue arenaceous shales, with iron pyrites and traces of fossils	22 "
Black bituminous shales, with iron pyrites	68 "
Limestone, bluish-colored, with flint	70 "
Total	770 ft

Commenting upon this section, a parallel could be drawn between the upper 178 feet of shale and the Cuyahoga shales of Ohio; the lower black portion, 28 feet in thickness, would correspond very well with the black shales on top of the Berca grit. The sand rock with salt brine, 92 feet, I compare to the Berca grit stones.

The next 275 feet of shales and arenaceous layers have to be taken as the equivalents of the Bedford-Cleveland-Erie shales, and black shales of Ohio, and the lowest 70 feet of lime rock as representing the Helderberg series. In the heretofore described boring at Hillsdale, the brine was found at a depth of 1100 feet below the

surface, and no large sand-rock deposit was met with in the whole interval.

In the boring at Coldwater, brine was struck at 282 feet below the surface. At Constantine, in St. Joseph County, a drill-hole was sunk to a depth of 680 feet below the surface, the boring record of which reads:

Drift	93 ft.
Blue calcareous sand rock	30 "
Blue shales, with red seams	160 "
Gray sandstone	100 "
Strong brine.	
Hard silicious rock	5 "
Evolution of inflammable gas.	
Blue shales	85 "
Hard silicious rock	10 "
Softer rock	10 "
Black shales, readily combustible	160 "
Total	680 ft.

From the upper series of the strata a stream of mineral water rises to the surface, which is used for medicinal purposes, a bathing institution having been established at the spot.

At Niles, a boring was made to the depth of 600 feet, but no accurate record was kept. Mr. Finley, a gentleman who was connected with the enterprise, gave me from memory the following data:

Drift	70 ft.
Sandstones thinly laminated and of variable hardness, about	300 "
Issue of strong salt brine.	
Dark shales about	250 "
Evolution of much hydro-carburetted gas.	

Of several other deep borings made in the southwest part of the peninsula, I could not learn the particulars. The boring made in the State Prison at Michigan City has already been mentioned.

Borings in the western central portion of the peninsula, at Grand Rapids and vicinity, described in Prof. Winchell's report of 1861, need no repetition here. In all of them the Waverly group is found to be the repository of the brine. The borings never were

carried deep enough, under the preconceived false impression that the salt brine had its site in the higher gypsiferous rock series, in the Michigan salt group of Winchell.

In the borings at Muskegon, salt brine was found at a depth of 1250 feet from surface, which would appear to come from the Waverly group; the salt brine found at the depth of 2400 feet in all probability is within the rock series of the Onondaga group.

There remain yet to be given some accounts of borings executed in the salt-producing districts of Saginaw valley. The salt wells of Caseville have a very great depth; one of them is 1735 feet below the surface, but, unfortunately, no record of the boring was kept. I am informed, however, by persons who were present when the boring was made, and who gave attention to the matter, that the upper 900 feet went principally through a blue shale, sometimes through red shales, with no important seam o harder rock in the whole interval. At 900 feet, a large body of a whitish sand rock was struck which contained strong brine; another supply of brine was found near the bottom of the well, likewise in a sand rock. No limestone formation, or any other rock series indicating a lower horizon than the Waverly group, was met with in the boring, which commenced in the top part of the above-named series, immediately below the incumbent gypsum formation.

One of the first borings made in Saginaw valley, and at the same time the most accurately recorded, is the well of the East Saginaw Salt Mining Company. Dr. Lathrop, who kept the records, communicates to me the following details of it:

Drift	92 ft.
Sandstone	78½ "
Dark shale	26 "
Light shale	14 "
Sandstone with seams of coal	23 "
Brine, 10 degrees salinometer.	
Shales	12½ "
Sandstone with seams of coal	10 "
Blue shales	36½ "
Brine, 14 degrees salinometer.	
White sandstone	106 "
Limestone, fœtid	4½ "
Sandstone	5½ "

Limestone	4 ft.
Sandstone	6 in.
Limestone	6 ft.
Sandstone	1½ "
Limestone	8 "
Sandstone	6 in.
Limestone	5 ft.
Sandstone	6 in.
Limestone and sandstone, mixed	12 ft.
Sandstone	2 "
Limestone, sandstone, and shale mixed	14 "
Shales	3 "
Sandstone, light color	11 "
Salinometer, 26 degrees.	
Shales	38 "
Sandstone, fine-grained, blue	2 "
Salinometer, 40 degrees.	
Shales	13½ "
Sandstone, hard	2 "
Salinometer, 44 degrees.	
Shale	3 "
Sandstone, hard	6 in.
Shale	4 ft.
Shale, arenaceous, darker and lighter	18 "
Sandstone, hard, blue	8 "
Salinometer, 60 degrees.	
Sandstone, softer, blue	2 "
Salinometer, 64 degrees.	
Shales, dark	15 "
Sandstone	5½ "
Shales, dark	3½ "
Sandstone, hard, blue	1 "
Sandstone, gray, coarse	3 "
Shales, dark	7 "
Sandstone, micaceous, softer and harder	5 "
Sandstone and light-colored shale	5 "
Salinometer, 90 degrees.	
White soft sand rock	5 "
Very hard rock	2 in.
Shales, dark	6½ ft.

Hard, calcareous sand rock	10	in.
Shales, dark	2	ft.
White sand rock mixed with shale	8	"
Sand rock	99	"
Salinometer, 94 degrees.		
Shales generally of bright red color	64	"

These latter extended as far as the drilling was carried, which was to a depth of over 800 feet.

Since the time of this first boring, many more than a hundred other salt wells have been sunk in Saginaw valley, in all of which about the same general order of superposition of rock beds is observed. The coal measures and the subcarboniferous limestone formation are in all of them superimposed on the salt-bearing sandrock beds of the Waverly group. A weak brine is found even within the coal measures, but the valuable brines are always found lower, within the Waverly group, at a distance of from 600 to 1000 feet below the surface. Beneath the sand rock saturated with the strongest brine there are found in nearly all the wells red-colored shales, which are for the practical salt man a sure guide in his boring that he has reached or nearly passed the salt-producing level. North of Saginaw River, the same results are obtained by deep borings. At Kawkalin, two salt wells have been sunk, one to a depth of 810 feet, the other to 1133 feet. The drift is there about 100 feet thick, then follow about 300 feet of shale and sand rock, with seams of coal, then 100 feet of limestones and gypsiferous shales. About 700 feet below the surface, a sand rock from 90 to 100 feet in thickness is found, which is saturated with a strong brine. In the deeper well, below the sand rock, is a series of red shales.

Southeast of Saginaw, 6 miles from Bridgeport, a very deep boring has been made lately by Mr. Blackmar. The boring penetrated

Drift	90	ft.
Shale	270	"
Coarse sand rock	90	"
Brine, 63 degrees.		
Blue shales	45	"
Red shales	200	"
Gray arenaceous shale	850	"

Sandstone	110	ft.
Strong brine.		
Gray shale	20	"
Limestone	2	"
Total	1764	ft.

Further south, at Flint, a boring of 1200 feet was made a number of years ago, concerning which Dr. Clark gives me the following general information:

Drift	68	ft.
Sandstone	67	"
Shales and sandstone, with seams of coal	35	"
Sandstone	108	"

From the depth of 260 feet a strong stream of sweet water rose to the surface. From there to a depth of 1200 feet, alternations of shale and sandstone occurred, and in the lower portion of the drill-hole a strong salt brine was found.

At Flint, several other deep borings were made through the coal measures into the Waverly group, but in none of them could the existence in that locality of the subcarboniferous limestone series be ascertained. A boring made in Section 5 of the town of Owosso, in Shiawassee County, is reported to me by Mr. Courier, of that place, as follows:

Drift	121	ft.
Shale	20	"
Coal	4	"
Shale	54	"
Hard rock	15	"
Shale	33	"
Sand rock	220	"
Limestone	3	"
Shale	64	"
Limestone	3	"
Soft shale	20	"
Sandstone with brine	77	"

after which were blue and red shales to the depth of 1000 feet below the surface.

I have now given a description of the observations which I was enabled to make on the surface distribution and structure of the Waverly group, from an examination of the different natural outcrops, and from the results communicated to me of different deep borings made in all parts of the State, and will proceed to briefly recapitulate the principal facts derived from such investigation.

The Waverly group seems to be spread in a basin-like sheet over all the peninsula, with exception of the country north of the river systems of Au Sable River, on the east side, and of Manistee River, on the west side, besides a triangular area in the southeast corner of the State, which is occupied by the Helderberg group and by the black shales, as may be seen by a glance at the geological map connected with this report. This basin-shaped rock series is, in the centre of the peninsula, overlaid by the coal measures and by the subcarboniferous limestone, but is everywhere there within the reach of deep borings.

The essential constituents of the formation are sand rock and shales, with subordinate admixture of calcareous or ferruginous layers or nodular concretions. It is a shore deposit. All shore deposits are composed of coarse materials, carried there from the neighboring continental surfaces; their nature depends upon the nature of the surface material of those continents, and the deposition of the sediments under the changeable wave action on an ocean shore is necessarily more irregular than that which takes place in the deep water remote from the shore.

The stratification often becomes discordant, and frequent changes in the material are induced by local influences; while in one place a shale bed forms, in another near by a sand-rock ledge may be accumulated. This fact is noticed in every shore deposit, recent or old. A comparison of the strata in different outcrops of the Waverly group will for these reasons rarely allow of an identification of certain beds, and often not even of their exact horizon in the series. Still greater must be the discrepancy in the results of boring experiments, where direct observation of the rock beds is excluded, and we have to depend on the examination of comminuted fragments; and what makes the case worse yet, is that these fragments can rarely be examined by the scientific observer himself—he has to depend on the statements

made to him by well-borers, who have rarely much knowledge of lithology, while each calls the rocks by his own names, which are not always easily understood.

By the fossils contained in the rock beds we can sometimes ascertain their horizon, but the fossils are so unequally distributed that we may, in a seam which in one place contains tens of thousands, fail to find a single one in another not far removed; and where outcrops are generally of so very limited extent, we often have the bad luck to hit upon just such a barren portion, leaving us without a key by which to ascertain the exact position of one bed in relation to others.

The thickness of the Waverly group in Michigan is considerable, probably never less than 1000 feet, and in some places more than that. Its thickness seems to be greater in the northern and central parts of the peninsula than in its southern part. The upper division, prevalently a sand rock, with only subordinate layers of shale, and seams of harder sand rock cemented by much calcareous matter, has an approximate thickness of from 300 to 350 feet. Fossils are more abundant in the lower beds than in the upper, and are locally distributed. The great preponderance of Lamellibranches is remarkable, but I do not take this to be a peculiarity of the fauna during that period, being inclined to consider the nature of the deposits in connection with the animal forms inclosed by them. Lamellibranches are inhabitants of the sands of shore lines, and consequently must preponderate over dwellers in the deep sea, which by chance only are thrown out amongst them, just as is the case on the shell beaches of the ocean of the present day.

The lower division, chiefly a shale formation, is much greater than the upper; it is interstratified with arenaceous beds and with seams of calcareous and ferruginous concretions; frequently, also, several heavy sand-rock masses, sometimes 100 feet in thickness, are found interstratified between the shales, as is proved by deep borings. Whether these heavy sand-rock deposits occupy a certain equivalent position in different localities, or are local deposits, can not be positively asserted. All we know of the matter is derived from the results of a few borings. If we compare the boring records of the salt wells in different parts of the country, we find that, after penetration of the upper sand-rock division, usually not less than 400

feet of a shale formation are found before the deeper massive sand rock beds are struck, which latter, in the technical language of the salt manufacturer, are called the salt rock, because they supply him with strong, valuable brine. The brine is not confined to a certain horizon in the Waverly group; it seems to pervade all of it, but has accumulated only in beds sufficiently porous to absorb it from the surrounding rock mass, and sufficiently protected from the percolation of surface waters to retain the solution of the salt in concentrated form. These conditions are much better fulfilled by the deeper beds than by the more superficial. In the majority of salt wells, high above the productive level, there is found a weak brine which increases in strength the nearer we come to the principal, more deeply situated repository. Experience has taught the salt manufacturer that, after exhaustion of the first salt rock, by boring deeper, sometimes, but not always, another sand rock saturated with strong brine can be found, termed by him the second salt rock; but this designation is not applicable to a rock having a certain geological position, as it relates only to the conditions of a locality, and as the equivalent of the second salt rock in one well may be in another the upper or first salt rock.

In the salt wells of Tawas, Caseville, Port Austin, Port Hope, White Rock, etc., the salt rock is inclosed by the deeper shaly division of the Waverly group. The upper strata of the formation, as the sandstone of Point of Barques, and the grindstones, contain no salt in these localities; they have been leached out owing to their superficial position. The salt wells of Saginaw, on the other hand, seem to furnish their supply of brine from the upper sand rocks corresponding to the Point of Barques sandstone or the grindstones. They are deeply buried under the coal measures and the carboniferous limestone, which prevent the atmospheric waters from percolating through them. The brine contained in these beds even rises into the superincumbent layers of the coal series, with the waters circulating below it, which all are under a certain hydrostatic pressure driving them upward to the surface.

From all the facts known, we must suppose that the salt exists in the strata as a solution, retained in the porous sand rock as in a sponge. Indications of solid rock salt have never been noticed in any of the salt wells of Saginaw district. I have stated that brine is found in almost every part of the State where the Waverly

group can be reached by deep borings; in many localities a brine of equal strength with the best brines of Saginaw district has been found, without an attempt made to utilize it.

The manufacture of an article as cheap as salt depends not only upon the supply of good brine, but upon the expense of converting the brine into the merchantable article. In this respect, only large saw-mill establishments, with their immense mass of waste fuel, can enter into successful competition with the Eastern and Canadian salt works, with a fair chance of profit. In all other cases, its manufacture would hardly more than pay the expense of the fuel used for evaporation of the brine.

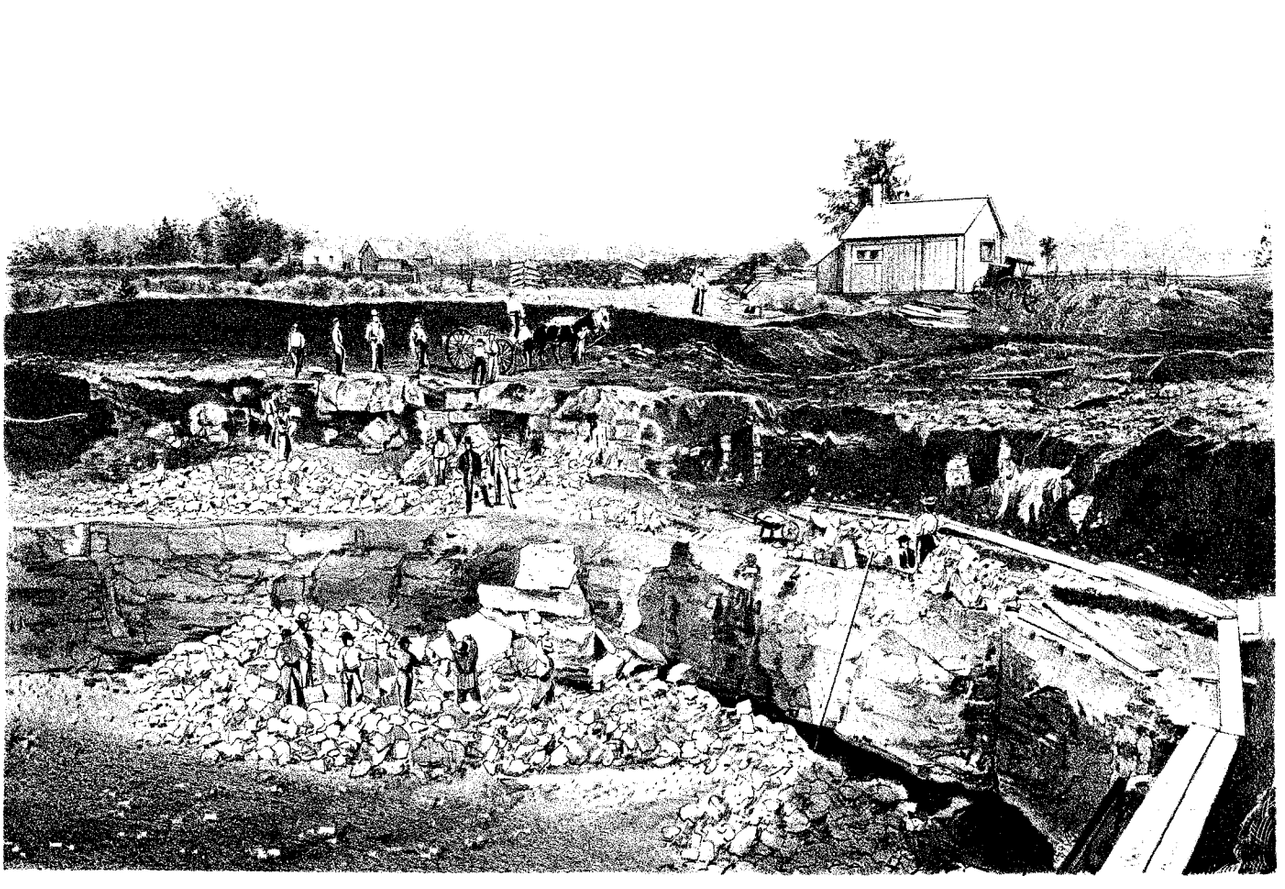
An exposition of the salt-manufacturing process, of chemical analyses of the salt brines of different localities, statistical records of the salt production in Michigan, etc., are given in an appendix elaborated by the State salt inspector, Dr. Garrigues, who kindly offered his help, and, being in the possession of all the facts relating to the matter, was far better qualified to make this part of the report than I could be, however well disposed.

CHAPTER IX.

CARBONIFEROUS LIMESTONE.

THE rock beds succeeding the Waverly group indicate important changes in the condition of things caused by the altered nature of the ocean sediments. The sandy material so much prevailing toward the end of the Waverly period begins to vanish; in place of arenaceous ledges interlaminated with the still continued shaly sediments, we find beds of limestone, and gradually the shales become narrower subordinate seams, until the upper part of the series is exclusively a limestone formation. The upper limestones resemble, in rock character and by their fossils, the upper division of the subcarboniferous limestones of the Mississippi valley; the lower part of the formation, which, locally, incloses heavy gypsum beds and attains a considerable thickness, is indubitably the equivalent of the inferior division of the western subcarboniferous limestones, but can not be exactly parallelized with a certain horizon of that series.

The lower gypsiferous part of the group has been described by Prof. A. Winchell under the name of *Michigan salt group*. I have previously stated that the salt brines of Michigan are derived from the subjacent Waverly group. Gypsum and salt are frequently found associated in other parts of the world, which circumstance probably induced Mr. Winchell to locate the salt in this higher rock series; but the fact of the occurrence of the salt brine in a lower position can not be denied on the ground of mere theoretical speculation. The carboniferous limestone series is very unequally developed on the peninsula; in some parts we find it scarcely represented, while in others the upper calcareous division is well developed, but not the lower gypsiferous beds, which seem to be of restricted local extent. The lowest beds of the group can be ob-



J. Bien. lith.

QUARRY OF THE GRANDVILLE PLASTER CO

served in the vicinity of Caseville, on the farm of Mr. Klump, in Town. 18, Range 11, Sect. 18, where bluish drab-colored limestone beds of dolomitic, or partly of arenaceous character, repose on the upper coarse-grained sand-rock ledges of the Waverly group, similar to those exposed some miles east of the place, at Hat Point.

The limestones contain a species of Productus with very convex ventral valve, shallow, sinuated in the median line, and covered by from 40 to 50 fine sub-equal ribs, a Retzia similar to Retzia vera Hall, Terebratula (similar to Eudora), Spirifer Marionensis, and Spiriferina spinosa. At Oak Point, a short distance north of the locality just mentioned, fragments of similar fossiliferous, arenaceous lime rock are thrown out by the lake, and in its bottom, a short distance off shore, larger angular blocks of the same are found. Some of the slabs thrown ashore are almost totally composed of fragments of Brachiopod shells, besides other bivalves, Crinoid joints, stems of Bryozoa, etc. In dredging out the harbor at Caseville, rounded, strongly drift-worn limestone boulders of the same lithological character, and inclosing similar fossils, are brought up with the mud masses; among them are dark, bluish-colored, fine-grained limestones, crowded with shells of Lamellibranches, Myalina, Modiolopsis, Schizodus, with some Brachiopods, Rhynchonella, Retzia, Terebratula, etc., intermingled. Other calcareous rock boulders are of a slaty, laminated structure, of a dark, nearly black color; and filled with band-like, compressed stems, divided by regular constrictions into suborbicular segments. The bands seem originally to have been hollow utricules, with veinous, longitudinal carinæ; their substance is brownish, horn-like, and semi-translucid; most probably they are vegetable organisms. Other palæontologists to whom I showed the specimens suggest that they are related to Graptolites. A short time after I found these slaty boulders, whose position was not known to me, I discovered in the bed of Rifle River, at Island Rapids, Town. 21, R. 3, Sect. 28, the same rock in place; besides the stems mentioned, it contains a Productus and some shells resembling Modiolopsis. It forms the lowest beds in the rapids, visible to a thickness of 3 or 4 feet; above them are from 6 to 8 feet of limestones, of crystalline structure and dark gray color, full of Crinoid joints and shells or their fragments. Among them I recognized a large Aviculopecten, a Rhynchonella, Spiriferina spinosa, Productus, and quite numerous specimens of an

annulated Orthoceras, resembling Orthoceras annulato-costatum of Meek and Worthen. The specimens are thickly incrusted with laminated strata of an amorphous limestone mass, which resemble the incrustation by a Stromatopora, but have no trace of organic structure. The siphon of the Orthoceras is central. An outcrop of the underlying Waverly sandstone, two miles above Island Rapids, has been previously described. The immediate contact of the superimposed limestones with the sand rock is not seen; the river bed in the interval is formed by drift, and the slopes of the hillsides bordering the river are all drift. Another locality where these lower beds of the carboniferous limestone series can be observed is on Cass River, 30 miles south of Caseville, in Town. 13, R. 11, Sect. 16. At the farm-house of Mr. W. H. Brown, situated close by the river bed, the water flows in rapids over the oblique edges of rock beds dipping at a moderate angle down stream. Here we find a coarse-grained whitish sand rock with small punctiform, ferruginous dots, and sometimes containing stems of Lepidodendron and other vegetable remains. Interstratified with them are greenish, micaceous sand-rock ledges and arenaceous, shaly seams. This sand rock is the equivalent of the Point of Barques sandstone, and forms, with few exceptions, the bed of Cass River for 6 or 8 miles up its course to Indian Rapids, which were mentioned when I gave a description of the outcrops of the Waverly group. Only a few steps below Mr. Brown's house, the sand-rock ledges are overlapped by a bluish argillaceous limestone of a dull, earthy fracture and moderately soft. It was from this rock that the Indians used to carve their smoking-pipes. It contains numerous nodular concretions of Zincblende, or Druse cavities filled with this mineral, or with Brownspar and Dolomitspar. The Zincblende is mistaken by the inhabitants for Galena, and the same mistake occurs on the old maps of surveyors, lead ore being indicated as occurring in the vicinity of Cass River. Stories are afloat according to which Indians used to gather large quantities of lead on Cass River and transform it at once into bullets, but I have little belief in such accounts, especially since I have failed to find any thing to substantiate them; the only mineral observed by me was Zincblende. This lime rock contains a moderate number of fossils, Productus, Spirifer Marionensis, Spiriferina spinosa, Syringopora ramulosa, and Orthoceras (annulato costatum?), the same as those found

in the bed of Rifle River. Some vegetable remains can also be observed. The thickness of this limestone may reach 8 or 10 feet; above it is a seam of coarse-grained, drab-colored, rusty dolomite rock, which is crowded with casts of Spirifer Marionensis and various kinds of Lamellibranches, Terebratula Eudora? Retzia, and others. Purer calcareous beds, nearly all composed of shell fragments like those at Oak Point, are interstratified here, and higher we find blue argillaceo-arenaceous limestones, of an absorbent, porous character, which contain somewhat abundantly the Productus species mentioned several times before, but few of other fossils. A hard, calcareous bed with flint concretions overlies them, and then follow arenaceous shales and harder sand-rock ledges of a bright red, or yellowish green and red variegated color; some of the layers are in brecciated condition. The total thickness of the red layers may be 15 or 20 feet, of the entire section exposed in the river bed, 50 feet. Further down stream, the strata disappear under the drift, and no rock is exposed in the bed of Cass River until Tuscola village is reached, where small outcrops of the coal measures are observed. Up stream, between Brown's farm and Indian Rapids, by undulations of the rock beds the Waverly sandstone becomes sometimes bent downward into a synclinal trough, and the intermediate depression is filled out with the higher fossiliferous limestones, containing Zincblende concretions.

Next above the described rock series the horizon of the gypsum deposits begins, but a direct superposition of the strata is nowhere observed, and the gypsum, as I have intimated before, is only found in local deposits, many places on the same geological level with these bearing no signs of it whatever. The largest exposures of the gypsum formation are found on the shore of Lake Huron, at Alabaster Point, where beds of pure gypsum, covered by only a few feet of drift, lie quite near the surface. The gypsum beds are deeply eroded by the solvent action of atmospheric waters; during the glacier time, also, much of the soft rock became destroyed, or intersected by large, deep grooves which are now filled up with drift material. The practical quarryman in search of gypsum is guided in his explorations by certain surface indications.

The surface in those places where the gypsum is close under it is full of small pot-holes and intermediate hillocks, and he knows

by experience that the depressions indicate places where the superficial gypsum beds have been dissolved, or carried away by some cause, while in the hillocks he is always sure to find a well-preserved mass. In the quarries of Messrs. Smith, Bullard & Co., the superficial gypsum bed is 15 feet thick; large masses of white or rose-colored granular gypsum and smaller fragments of the same pure substance are cemented together by seams and veins of gray argillaceous gypsum into one solid, compact bed, variegated and mottled in some spots like castile soap, or of much coarser brecciated structure where the larger masses of pure gypsum are cemented. Below the gypsum bed follow calcareo-arenaceous, thinly laminated flagstones, and shale beds of dark greenish drab-color, seen uncovered in a thickness of about 6 feet. The flagstones are very fossiliferous; particularly abundant is a Myalina, next so are Allorisma, Aviculopecten, Edmondia, Retzia globosa, and Spiriferina spinosa. The owners of the quarry have bored to the depth of 20 feet below its bottom, and have found only a few feet down another very thick gypsum bed, which for the present is not opened. About 4 miles south of Alabaster Point, the gypsum formations rise in bluffs along the shore to the height of about 25 feet. The strata in question seem to be next above the gypsum of the Alabaster Point quarries. Lowest, at the water level, heavy, somewhat concretionary masses of gypsum project; above them follow about 10 feet of soft green shales full of small nodular concretions of gypsum. The shales are covered by an arenaceo-calcareous rock, in beds of from 4 to 6 inches in thickness, which in one place where gypsum has been quarried is directly covered by drift masses, the surface of the ledges being plainly drift-marked in a direction from northeast to southwest. Only a few steps further south from this locality, these upper drift-marked ledges are overlaid by from 6 to 8 feet of arenaceous shales, or by soft greenish sandstones of discordant stratification, and frequently ripple-marked; and on them a seam of brittle limestone 15 inches or 2 feet thick, with many flint concretions, forms the top of the bluffs. This calcareous rock with flint nodules forms the surface rock under the drift, extending from here down to White Rock Point, where a number of additional light-colored limestone beds are found connected with it, and laid open in a few limited escarpments along the lake shore. Next above these limestones of White Rock Point follow

the limestones of Aux Grees Point; but a direct contact between the beds is not seen, the interval from White Rock Point to Point Aux Grees being filled by a sand beach, and the country back from the shore being all deeply drift-covered.

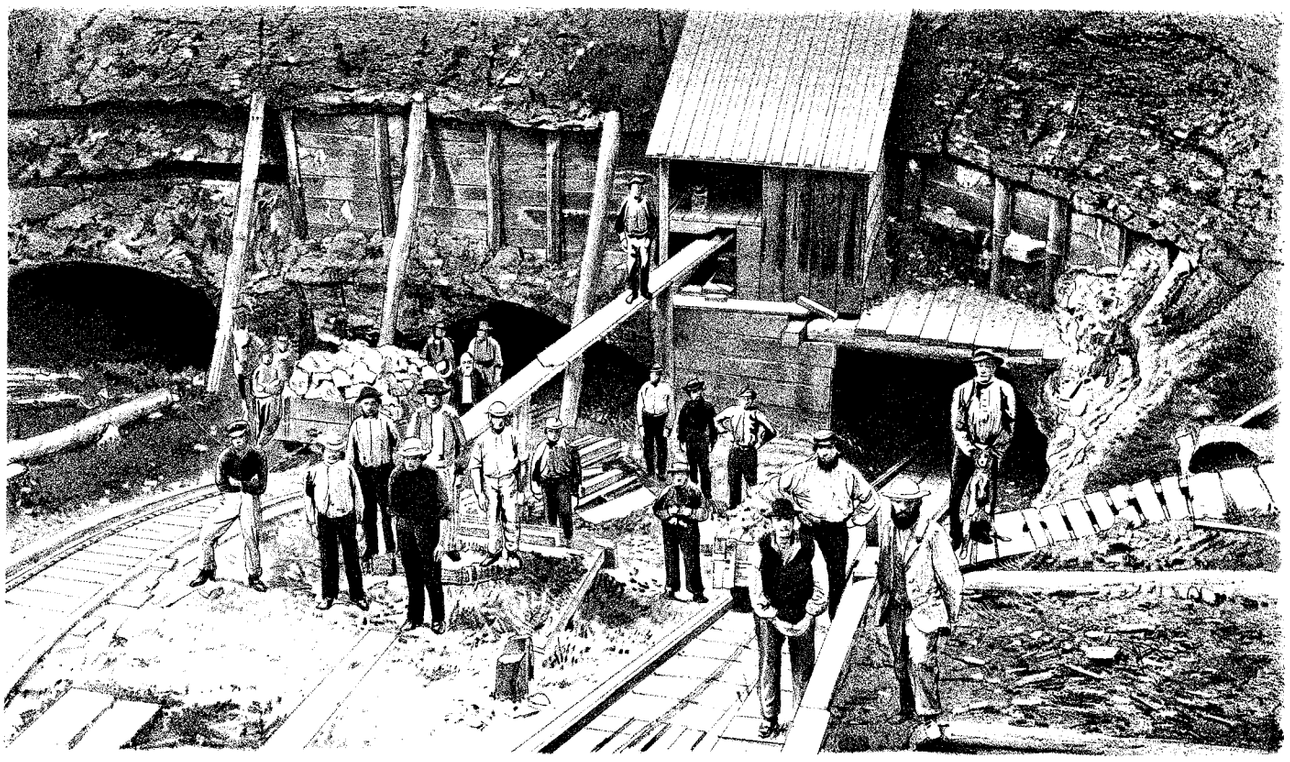
Gypsum beds are frequently penetrated in boring for salt in Saginaw valley, but from these not much is to be learned of the detailed structure of the gypsum formation, and the limits of this horizon, either upward or downward, are not clearly recognizable. In some of the bore-holes of Saginaw valley, no gypsum beds were found at all, but the presence of gypsum within the rock beds is perceived in these wells notwithstanding, by the large quantity of gypsum which the water holds in solution. The manufacturers have to carefully close off from their pipes the water streams coming from the gypsiferous horizon, as it will incrust their cavities in a very short time and cause obstructions. In the salt wells of Kawkalin, the gypsum is struck at a depth of 400 feet from the surface. In some wells of Bay City the gypsum horizon is about 700 feet below the surface. Further south, in Blackmar's salt well, near Bridgeport, and in the borings at Flint, Lansing, etc., no gypsum beds were found.

West of Alabaster Point, for a distance of 30 miles the gypsum formation can be found near the surface on all the head branches of Aux Grees River. In Town. 21, R. 5, Sect. 20, the shales inclosing gypsum beds are seen in the bed of Aux Grees River and on its banks. Shales of blue or greenish color, interstratified with calcareo-arenaceous seams, inclose large concretionary masses of pure white, rose, or salmon-colored granular gypsum, in quantities which would invite to mining enterprises, but for the fact that gypsum has a limited demand, and that the necessary supply can be much more cheaply quarried in the gypsum beds near the shore, which, from present appearances, are not likely to be exhausted for a great many years to come. Some miles northeast from this latter spot, in Town. 21, R. 5, Sect. 12, is another similar exposure of rich gypsum deposits, and numerous smaller exposures are noticed in the beds of creeks between that locality and the lake. In the central part of the peninsula, along the supposed northern division between the coal field and the Waverly group, no rock exposures whatever are known; likewise along the same geological belt arching across the south part of the peninsula, no gypsum deposits have ever been dis-

covered, but on the western edge of the belt we meet again with large gypsum deposits in the vicinity of Grand River. The gypsum formation is found close under the drift extending from the southern limits of the city line of Grand Rapids to within a mile or more south of the village of Grandville, covering in all about 6 or 8 square miles, and found everywhere over that space within a distance of not more than 50 feet from the surface. Some spots there may be found where the gypsum beds have been destroyed during the drift period, but, as a rule, it may be with safety looked for everywhere in the district. Seven gypsum quarries are now in operation in the vicinity of Grand Rapids, situated on both sides of Grand River, and if the demand for gypsum were to increase tenfold, there would still be no lack of material.

In most of the quarries, a bed of pure gypsum much cut up by erosions is found close under the drift; below that bed are dark gray shales with seams of argillaceous limestones and arenaceous beds, amounting to various thicknesses, in different localities; then follows a gypsum bed from 8 to 12 feet in thickness, and under it are again shales and limestone beds with thin seams of gypsum.

In the plaster quarries of the Grand Rapids Plaster Co., on the west side of Grand River, the upper layers in the bluff are soft arenaceous shales, interlaminated with seams of limestone and arenaceous flagstones, having an abundance of globular or lenticular nodules of rose-colored granular gypsum, as well as seams of a brown gypsum, in large, columnar crystals, together with thin seams of a perfectly colorless, translucid selenite. At the base of the bluffs, two thick beds of gypsum project, partly composed of pure white or reddish granular gypsum with gray, veinous, mottled seams; partly of a more impure brecciated mass of gypsum and gray limestone cemented together, which latter, if the limestone is mingled in undue proportion, has to be thrown aside as waste rock. In this locality, the gypsum is mined by driving subterranean galleries into the bluff. A view of the mine is represented in the plate accompanying this report. A large plaster mill is erected close to the mine, where the impurer gypsum is ground for agricultural purposes, the purer rock being selected and ground separately for conversion into plaster-of-paris, while the finer granular masses are occasionally used for ornamental purposes, such as the



J. Bien, lith.

QUARRY OF THE GRAND RAPIDS PLASTER CO.

cutting of it into vases, etc., and polishing it. The rest of the quarries are worked in the ordinary style of stone quarries. In the Grandville quarries, of the Grand Rapids Plaster Co., we find highest a series of argillaceous, drab-colored, easy weathering limestones with seams of shale, which, locally, are found to be quite fossiliferous, containing several forms of Lamellibranch shells, Schizodus, thick-shelled, large Nuculas, and other forms; Brachiopods, such as Chonetes, and an Orthoceratite, Crinoid stems, Bryozoa, etc., are also found; but in particular, Fish remains in somewhat worn condition are abundant. Scales, teeth, dorsal spines, and numerous coprolites, mixed with water-worn pieces of shale, sandstone, and quartz pebbles, and cemented by carbonate of lime, compose the fossiliferous seams. The non-fossiliferous portions of this rock, which, on chemical analysis, gave,

Carbonate of lime	48
" magnesia	27
Hydrate of iron oxide and alumina	4
Argillaceous residue	18
	97

might perhaps be converted into hydraulic cement. Below these upper strata a white gypsum bed, a few feet in thickness, follows, which in some places lies directly under the drift, and is very much eroded and cut up into isolated blocks, quite surrounded by drift material. The next lower strata, amounting to about 4 feet, are argillaceous limestones and soft, dark gray shales, which rest on a heavy bed of gypsum from 8 to 12 feet in thickness. The lowest strata seen in the quarry are again limestones and dark shales with thin seams of white gypsum. In the lately opened Wyoming Plaster quarries, about half a mile northwest of the Grandville Plaster quarry, 25 feet of rock beds are uncovered. First come about 8 feet of drift, then 3 feet of a calcareous laminated sand rock with purer limestone seams of a greenish-gray color; next lower is a 5-foot bed of white gypsum, then calcareous sand rock and dark bluish shales, amounting to 7 or 8 feet; lowest is a plaster bed, already penetrated to a depth of 17 feet without having reached its limit. The lime and sand-rock beds are very plainly ripple-marked, and on some of the slabs are the relief casts of large, irregu-

larly reticulated sun cracks; their surface is covered by thin laminæ of colorless, translucid selenite.

Fossils I could not find in this quarry, except some small fragments of the before-mentioned water-worn fish-bones. The thickness of the gypsiferous rock series can not be estimated from the exposures in the quarries; by borings it has been ascertained to be about 160 feet. In an artesian well sunk at the principal business place of the city, in Mr. Powell's block, a lime rock 36 feet in thickness was first penetrated under the drift; then followed an alternation of shales, gypsum beds, and lime-rock ledges, to a depth of 204 feet from the surface. The bottom of the well is in sand rock, and a fine stream of pleasant potable mineral water discharges from the tubing to refresh the thirsty. A more detailed account of a boring made in Beyrich's brewery to a depth of 236 feet may give an idea of the sequence of rock beds in the vicinity of Grand Rapids:

Drift	35 ft.
Limestone	1 " 6 in.
Blue shales	7 "
Gypsum	1 " 6 "
Blue shales	6 " 6 "
Flinty rock (?)	3 " 6 "
Shale, soft	7 "
Blue shale, harder	1 "
Shale, soft	7 " 6 "
Flint	2 " 6 "
Shale	6 " 6 "
Pyritous rock	1 " 6 "
Shale	7 " 6 "
Pyritous rock	1 " 6 "
Shale	11 "
Pyritous rock	1 "
Shale	2 " 6 "
Pyritous rock	2 "
Shale	8 "
Pyritous rock	2 " 6 "
Sand rock	3 " 4 "
Shale	4 "

Sand rock	5 ft. 2 in.
Gypsum	5 "
Sand rock	6 "
Shale	2 " 6 "
Gypsum	5 "
Blue shale	4 " 6 "
Hard, flinty rock	6 "
Gypsum	6 "
Shale, blue	4 " 6 "
Pyritous rock	8 "
White sand rock	55 "
Blue shale	6 "
Total	236 "

There is an ample flow of mineral water from this spring, quite as pleasant to drink as that from Mr. Powell's well, but it is not a water fit for brewing purposes, to supply which the boring was originally intended.

The upper calcareous division of the carboniferous limestone series is, at Grand Rapids, directly superimposed on the gypsiferous shale formation; the beds of transition from one to the other could formerly be seen in the river at the foot of the rapids, but at present all that part is filled up and covered over with large buildings.

The approximate thickness of the limestones at Grand Rapids is 50 or 60 feet; the lowest beds are in streaks mingled with sand granules or alternating with thin seams of sand rock; the higher are free of arenaceous admixture, and are stratified in moderately thick beds, which contain some fossils and many druse cavities filled with brown-colored spar crystals. Most observable among the fossils are large fish-teeth, various forms of Fenestella, Polypora, Trematopora, Lithostrotion mamillare, and a few Brachiopods. In a few quarries, close to the west side of the river, these strata can be seen. Formerly they were more extensively exposed in the river bed and in the banks on the east side, but by the erection of dams across the river and of buildings along its sides, nearly all are now hidden from observation. Next above these massive beds, which serve a good purpose as a building material for rough walls, follow thinner-bedded limestones interlaminated with calca-

reous shales. These are uncovered in some old quarries not far from the Detroit and Milwaukee Railroad depot, and are used for lime-burning; the fossils inclosed are Allorisma clavata, Productus Flemmingii, Lithostrotion proliferum, Lithostrotion mamillare, numerous Bryozoa, Phillipsia, and a few others. In the river bed west of the Milwaukee depot, other limestone ledges of a reddish color and of silicious character overlie the former, but the river is at present rarely low enough to allow of their being seen. North of Grand Rapids the limestone formation is soon lost under the heavy drift masses; also eastward, through the towns of Ada and Cascade, all is covered by drift, but the numerous limestone fragments intermingled with the drift make it probable that the formation underlies these towns. Westward from Grand Rapids the sandrock ledges of the Waverly group form the surface rock under the drift, and are denuded in a few limited spots. The supposed extension of the carboniferous limestone belt passes northward over Newaygos, curves diagonally through Osceola County, and, taking an eastern direction near the second correction line, strikes with a curve southeastward toward the north shore of Saginaw Bay. The first outcrops of the limestone along this described course are found at the headwaters of Rifle and Aux Grees rivers, whence they continue to the lake shore. The rest of the interval exhibits no rock ledges of any kind, and the drift is so deep that erosions by rivers, or ordinary wells or other artificial excavations never reach the underlying older strata.

Southward from Grand Rapids the opportunities for following the carboniferous limestone belt are not more favorable than to the northward; we find it first denuded at Bellevue, 60 miles southeast of Grand Rapids. Borings at Middleville, Hastings, and other places, lying in the supposed direction of the limestone belt, did not reach to the rock beds at a depth of over 100 feet. At Bellevue, over a space of about 6 square miles, the carboniferous limestone is at the surface, or covered only by drift deposits of moderate thickness. In the bed of Battle Creek, and in a railroad cut south of Bellevue village, we find as the lowest strata of the exposures a greenish-white sand rock of middling fine grain, partly soft and friable by pressure with the fingers, partly hard, and firmly cemented by an abundance of sparry calcareous material. Such calcareous sand rock reflects the light from its fractured surfaces in the same manner as if they were the fissure plains of a crystal or of innumerable parallel crystals; its chemical composition is 69 per cent of quartz with 30 per cent carbonate of lime. Upward in the series the arenaceous beds are gradually replaced by pure limestones, but thin seams of quartz sand are yet occasionally wedged in between the calcareous layers. Not unfrequently the strata of this horizon are in brecciated condition; locally they are found to be very fossiliferous—numerous Fish-teeth (Helodus, Cladodus, etc.), Productus Flemmingii, Bellerophon sublævis, Zaphrentis spinulosa, Fenestella, Polypora, and Trematopora being the forms noticed. The next higher strata are pure, light-colored limestones with smooth, conchoidal fracture, in beds of variable thickness, interlaminated with concretionary seams of Hornstone; fossils are generally not very abundant, but certain seams are crowded with them over widely extended surfaces. The stems of Lithostrotion proliferum, also Syringopora ramulosa, Allorisma clavata, and various Bryozoa, are not uncommon. The numerous quarries of Bellevue are opened in these beds, which reach 8 or 10 feet in thickness. Their chemical composition is:

Carbonate of lime	96
" magnesia	1.0
Hydrate of iron oxide	0.5
Insoluble residue	1.5

In the quarries, we observe above these limestones a stratum of a brown ferruginous dolomite with dull, earthy fracture, and about 2 feet in thickness, and following next to it about 3 or 4 feet of light-colored limestones identical in appearance with the beds below. Higher still is another belt of brown, ferruginous dolomite rock, about one foot in thickness, and either in continuous layers wedging out at both ends, or in seams of irregularly-shaped septaria surrounded by calcareous shale. A few feet of light-colored, thin-bedded lime rock deposited on top of the brown concretionary seam are the highest strata noticed.

The brown dolomite rock is composed of

Carbonate of lime	56
" magnesia	23
Iron oxide hydrate, with some alumina	5.5
Silicious residue	9.0

The total thickness of the strata exposed at Bellevue I estimate to be about 50 or 60 feet. The rock is generally quarried for lime-burning; as a building-stone it is used in the vicinity, and large quantities of it have been used in the construction of the foundation for the State House at Lansing. The rock was broken into fragments, and filled into the bottom of the ditches for the foundation, over which a liquid hydraulic cement was poured. South of Bellevue, along the valley of Battle Creek, the rock soon disappears from sight; at the junction of the creek with Kalamazoo River, the beds of the Waverly group are near the surface, and between Bellevue and Battle Creek outcrops of the gypsum formation should appear in the bed of Battle Creek, but no indications of this mineral have ever been found there.

The trend of the formation is to the southeast; travelling in this direction, the first indications of the carboniferous limestone are found again some miles north of Albion, and from there across the centre of Jackson County many isolated patches of the limestone are met with. It is often impossible to determine the exact stratigraphical relations of these outcrops to the surrounding sand rock and shale strata of the coal measures; the beds have been evidently considerably disturbed during the drift period, segments of hills having been carried away by the advancing stream of drift masses from their original resting-place, and deposited, as they are now found, in more or less uptilted, irregular position inclosed within the drift, but with the relative stratigraphical order of the beds to one another fully preserved. Several such large masses of carboniferous limestone within the drift are intersected by the Michigan Central Railroad in the interval between Albion and Jackson. A short distance northeast of Parma village the carboniferous limestone underlies quite an extensive area, and several quarries were once worked in it. The rock is of dark-bluish color, full of sparry and silicious veins; it contains Allorisma clavata, Crinoid joints, etc. As a building-stone it has little value, nor is it good for lime-burning, having too great an admixture of silicious matter. Above the blue lime rock is a brown, cellulose dolomite rock equivalent with the brown dolomitic seams of the Bellevue quarries; its composition is,

Carbonate of lime	63.7
" magnesia	11.4
Hydrated iron oxide and alumina	18.4
Silicious residue	2.9

South of Parma, in the township of Spring Arbor, the carboniferous limestone has many outcrops; one is on Mr. Roberts's farm, Sect. 17, where a quarry was opened forty years ago by the present owner for the purpose of burning lime, which in those early days of settlement was a great desideratum and found a ready sale. The quarries are on the slope of a hill facing south. Lowest is a sand rock of light greenish color and moderately fine-grained; part of it is soft and porous, while other beds are rendered very compact through an abundance of calcareous cement. In alternation with the sand rock are soft, plastic, light-colored shales or arenaceous shales. Above the sand rock, which in the upper ledges changes into a sandy limestone, beds of a pure lime rock follow with a thickness of from 8 to 10 feet; some of the beds are of crystalline structure; others have a smooth, conchoidal fracture, and are often in brecciated condition, re-cemented by veins of calcspar. On top, the brown dolomite, so often mentioned before, is found again. Fossils are quite rare in this locality. Along the wagon-road from the quarries to Jackson, several other outcrops of the carboniferous limestone are passed by within the limits of Spring Arbor township. On Mr. Shoemaker's land, in Summit township, 3 miles south of Jackson, another exposure of the carboniferous limestone can be observed. At the foot of a hill sloping toward a marshy flat land, there is a rather coarse-grained, whitish-green sand rock containing flint concretions, and cemented hard by calcareous matter. Above it are beds, still arenaceous, which should be classed as limestones; they are partially in brecciated condition, inclosing within an arenaceous, re-cemented lime-rock mass, pure limestone fragments with smooth, conchoidal fracture. Still higher beds are a purer lime rock, not brecciated, with some flint nodules, and crowning the section we find again 4 or 5 feet of the brown, ferruginous dolomite rock, partly of cellulose structure, easily decaying into angular fragments of a rough, earthy surface. The purer beds of the limestone contain,

Carbonate of lime	94 per cent.
" magnesia	1 "
Iron	1 "
Quartz sand	4 "

The entire section comprises about 18 feet of strata. North of Jackson, on Portage River, about a mile east of its entry into Grand River, the carboniferous limestone is found on top of a hill, the southern slope of which is formed by steeply inclined sand rock and shale beds, with seams of coal. Their dip is southward.

The lowest beds of limestone exposed are of a nodular, brecciated character, composed of rounded lumps of a light-colored, smooth fracturing limestone, with seams of green-colored harder and softer shaly substance filling the interstices; the higher beds are a smooth, compact, brittle lime rock of light color, also in shattered condition, and full of stylolithic segregations. Fossils are rare; sometimes a Productus, Allorisma clavata, Bellerophon sublævis, or a species of Rhynchonella, is inclosed. The strata seen in the quarries reach a thickness of 15 feet. Mr. Wright, the owner of one of the quarries, drilled a hole within its limits to a depth of 53 feet. First, 9 feet of the upper lime rock in the quarries were penetrated, then 5 or 6 feet of the greenish, brecciated lime rock, followed by 2 or 3 feet of a reddish-colored limestone. Below came 8 or 10 feet of hard, calcareous sand rock, and, lowest, a coarse, soft sandstone. Only about 30 steps from this bore-hole, across the road, a shaft of 25 feet in depth was dug, which first went through highly inclined black shales, and then through sand rock belonging to the coal measures.

On the opposite, south side of Portage River, the sloping hillside over which the road to Jackson leads is formed by coarse-grained, soft sandstone similar to the sandstone of the Jackson coal mines. Near the top, greenish calcareous sand rock, with seams of greenish shale, is seen in the road ditches, and right above it are 5 feet of well-stratified limestones with delicate laminar striation resembling a Stromatopora, but apparently not of organic origin. The same limestone beds are pervaded by numerous vertical flexuose channels, laterally anastomosing, and much resembling moulds formed around the clustered stems of a Syringopora. Some of the cavities were filled with spar, but I

could not discover organic structure. The limestone of Portage River makes an excellent white lime; its composition is,

Carbonate of lime	96.9
" magnesia	1.0
Alumina and iron	0.7
Insoluble residue	1.4
	99.0

North of Portage River, along the eastern margins of the central coal field, no outcrops of the carboniferous limestone are known. South of Saginaw district, through borings made along this line, or more toward the centre of the peninsula, the carboniferous limestone series is found very poorly represented, and frequently seems to be altogether missing.

At Lansing, many deep borings have been sunk, one to a depth of 1400 feet, and one in the yard of the Lansing Hotel to a depth of 740 feet, of neither of which was I able to get a record. Another well in the State Reform School, having a depth of 506 feet, was carefully recorded; but the identification of rocks by comminuted, sand-like particles, as they are brought up by the sand pumps, is so difficult that one can rarely get from the well-borers, who generally keep such records, names appropriate to the various formations encountered. Contemplating such a record, with the intent to form an idea of the exact nature of the superimposed rock series, one is often disposed to give up in despair, if he is over-scrupulous to give rein to his imagination, or to arrange things to suit his own notions. The register of the boring at the Reform School reads as follows:

Drift (alternations of clay, sand, gravel and boulders)	101 ft.
Soft sand rock	3 "
Hard fire-clay	4 "
Soft, white sand rock	13 "
Soft, sandy fire-clay	15 "
Hard sand rock	119 "
Hard fire-clay, alternating with beds of sand rock variable in color from whitish to blue.	64 "
Cherty lime	1 "

Gray lime	4 ft.
Sandy fire-clay mixed with seams of harder rock	51 "
Soft sand rock	37 "
Hard gray limestone	2 "
Soft white sand rock	15 "
Blue limestone	1 "
White fire-clay	1 "
Sand rock	4 "
Fire-clay with iron pyrites	50 "
Soft sand rock	5 "
Blue limestone	16 " 6 in.

In deep borings made at Flint, no rocks similar to the carboniferous limestones have been found, neither does the record of Blackmar's salt well, south of Bridgeport, say any thing of limestone beds perforated; but in nearly all the boring records of Saginaw and Bay City, the horizon of the carboniferous limestones is plainly discernible. In the Saginaw Bay district, we find fine, natural exposures of the carboniferous limestones, northward on the branches of Rifle and Aux Grees rivers.

If we follow Aux Grees River from the point where I have described the gypsum beds (in Town. 21, R. 5, Sect. 20), upward to Sect. 30 of the same township, we find the creek running over arenaceous limestone ledges, and in its banks about 12 feet of limestone strata are seen above the water-line. The lower arenaceous limestones are interstratified with dark, blackish shales. One of the lower beds is also pervaded by the Syringopora-like ramifications of cherty substance which I have described in the limestones found north of Jackson, on Portage River; here also no organic structure can be discovered. The upper portions of the ledges in the outcrop are light-colored, smooth-fracturing limestones, containing many hornstone concretions, and of fossils, an abundance of Allorisma clavata, with other species, such as Productus Flemmingii, Syringopora ramulosa, Zaphrentis spinulosa, and various forms of Fenestella. A chain of outcrops of these limestones extends between the parallel streams, Rifle and Aux Grees, to Point Aux Grees. This point is a low land-tongue of not over 10 feet elevation above the lake level. On both sides for the distance of a mile it is lined with low cliffs of calcareous sand-rock ledges, with flint

nodules, the upper, more limestone-like arenaceous beds of which contain Zaphrentis spinulosa, Lithostrotion proliferum, Syringopora ramulosa, and Productus Flemmingii. Above the arenaceous beds are 6 or 8 feet of light-colored brittle limestones with an abundance of flint nodules, interlaminated with thin seams of greenish shales. The limestones contain, besides the fossils mentioned, Fenestellas and other Bryozoa. In former years the limestone was quarried there, but at present the place is abandoned. The Charity Islands are composed of the same rock beds as Point Aux Grees. On the largest of them, on which a lighthouse is built, the northeast shore presents the best exposures. The bluffs are nowhere over 8 feet high, being generally lower. One place exhibits a very interesting example of discordant stratification. The lowest beds, a light-colored, ripple-marked, calcareous sand rock, project in a gentle arch about one foot above the water level, and from both sides higher strata dip away from the convexity at a sharp angle, resembling the anticlinal position of an uplift, with about 50 feet of rock beds on each side of the arch, in an imbricated order, and having at their projecting ends about the same level. The higher ledges of this anticlinal series are still arenaceous, but the lime prevails, and for them the name of lime rock is more appropriate than that of sand rock. They contain flint concretions, Zaphrentis spinulosa and Lithostrotion proliferum, and the surface of nearly all of them is ripple-marked. Over the surface of this anticlinal series, horizontal limestone ledges are deposited in obvious discordance with the subjacent ones. These upper ledges are a pure lime rock, free of sand, but inclosing numerous flint nodules, and interlaminated with thin seams of calcareous shale. Lithostrotion proliferum, Syringopora ramulosa, Fenestella, Polypora, Productus Flemmingii, Allorisma clavata, and Fish-teeth are the usual fossils, but are not found in great abundance. The thickness of these upper horizontal beds is about 8 feet. Higher strata are not observed on the island; its west side is low, marshy, and covered with loose rock débris and sand. The subjoined sketch illustrates the irregularity of stratification which I have just descrbed :

The most complete exposure of the carboniferous limestones is seen on Wild Fowl Bay, 6 or 8 miles southwest of Caseville. We find on the shore there, below the water level and emerging above it, a greenish-white calcareous sand rock, visible in a thickness of 4 or 5 feet. Next above is a layer of gray limestone with cherty nodules, about 1 foot in thickness, overlaid by a thin seam of shale; then a 6-inch bed of delicately laminated limestone, and a seam of sand rock of a few inches; on it lie several somewhat differing ledges of an arenaceous limestone of laminated structure, amounting to 2 feet, upon which follow in the order given, an 8-inch layer of dark gray bituminous limestone with smooth fracture, a blackish, thinly laminated calcareous shale, 2 feet thick, full of scales, teeth, and bones of small fishes, besides a species of Cypris, or Cythere, and a dark gray limestone of smooth, conchoidal fracture, in three 1-foot beds, of which the upper one is pervaded by Syringopora-like, flexuose, anastomosing channels, similar to those already described as existing in several outcrops in other localities. The section is terminated by about 10 feet of light-colored arenaceous limestones, with an alternation of purer calcareous and prevalently sandy seams. These upper beds contain many fossils, Zaphrentis spinulosa, Lithostrotion proliferum, Syringopora ramulosa, various forms of Fenestella, Polypora, etc., Productus, Allorisma clavata, and Fish-teeth (Cladodus, Helodus). The higher levels of the slope are covered by drift. A mile east from the shore, on the farm of Mr. Crawford, and on the adjoining lands forming the plateau of a lake terrace, a series of lime-rock ledges is uncovered, which appear to be the next higher strata to the section just described. The beds are light-colored, pure limestones, occasionally interstratified with a thin seam of sand rock; certain seams are full of hornstone concretions, while others are quite free of them. Fossils are also very unequally distributed, being rare in some of the layers, while others are crowded with silicified corals, Lithostrotion proliferum, and Lithostrotion mamillare, which are also found loose, strewn about the fields in immense numbers and beautifully preserved.

The highest layers found on this plateau are brown, ferruginous, cellulose dolomites of a rough, earthy fracture, irregularly traversed by veins of quartz or calcspar. Further east, the rock ledges disappear under heavy drift masses. The purer ledges of the lime-

stone on Crawford's farm have been used for lime-burning, but at present the kilns lie idle. The islands of Saginaw Bay, lying in front of Wild Fowl Bay, are all underlaid by this limestone formation. On several of them, particularly on Mr. Heinzelman's Island, quarries are opened which provide the cities along Saginaw River with the necessary stone for foundation walls and like purposes. To supply a local demand, a portion is converted into lime.

CHAPTER X.

COAL MEASURES.

In regular order of succession, the carboniferous limestone formation is followed by a complex of sandstone and shale deposits with intermediate seams of coal, termed *coal measures*.

This series occupies the central portion of the Lower Peninsula, and is supposed to cover about one fifth part of its entire surface; but over its greater extent the formation is hidden by drift deposits, and its limits on the north and west sides of the basin are rather taken for granted than known. The thickness of the formation could be ascertained in a few localities only; it seems in Michigan not to exceed 300 feet, and is often less—a thickness which, compared with the development of the coal measures in our neighboring States, Ohio and Illinois, is very insignificant. In proportion to the thickness of the formation is also that of the inclosed seams of coal, of which we generally find only one of sufficient thickness for mining enterprises, while our neighbors can boast of six or seven productive beds, besides a number of smaller intermediate seams not taken into account.

The approximate limits of the coal measures on the peninsula are within a line drawn from Sebawing, on Saginaw Bay, toward Holly, in the south part of Genesee County, and from there prolongated in a southwesterly curve to Jackson. From Jackson the line goes west, passing a few miles north of Albion; it then strikes northwest, passing some distance east of Bellevue, to Hastings, whence, northward, the extent of the formation is only guessed at. The western edge of the coal measures is supposed to intersect the Detroit and Milwaukee Railroad line near Lowell, thence to go north, touching Big Rapids, and from there to run in a northeastern curve, diagonally through Osceola County and the northwest corner of St. Clair County. The line does not seem to transgress the second correction line; it goes parallel with it along

the northern end of Gladwin County, from which point the formation is again known through actual outcrops; it enters the northwest corner of Bay County, and extends in a southeast direction toward the mouth of Rifle River, striking the shore of Saginaw Bay. The rim of the formation is a few miles north of the Rifle River valley.

The first discovery of coal in Michigan was made in the vicinity of Jackson, situated near the southern rim of the coal field. The formation is there, in various places, naturally exposed, and is found, in digging cellars or wells within the city limits, under the cover of only a few feet of drift.

A coarse-grained, whitish sandstone is the highest of the rock series. The east side of Grand River presents various bluffs of this sand rock, in the northern part of the city. Walker's coal mine is located in one of these, and its lately erected buildings are closely attached to the vertical rock walls from which the material for their erection was quarried. A short distance south of the coal mines is the Michigan State Prison, which stands on the sand-rock ledges of the coal measures. Its walls are built of the same material, dug out from the spot, or from others in close proximity to it.

This upper sand rock has an approximate thickness of 30 feet. By an undulation of the strata, some shale beds below the sandstone come to the surface in the interval between the State Prison and Walker's coal mine, but this is the greatest depth to which natural sections go; the deeper beds are only known by artificial borings, of which I will enumerate some, communicated to me by Mr. Walker, and by other parties. The shaft of Walker's coal mine is 54 feet deep, commencing in sand rock 26 feet, followed by shale beds with kidney-ore nodules, 17 feet; bituminous coal, 4 feet; fire-clay, 7 feet. Below the shaft an excavation to a further depth of 30 feet went through nothing but shales and arenaceous rock seams. Total depth of excavation, 84 feet.

Half a mile east of Walker's mine is Porter and Hubert's mine, the shaft of which, 64 feet deep, commences in drift 11 feet in thickness, followed by,

Sandstone, coarse, whitish	30 ft.
Shale, dark	17 "
Coal	4 "

Fire-clay opened for several feet.

Mr. Walker records of a boring made a short distance north of his coal mine, near the pottery works, the following series of rock beds in descending order:

Sandstone	20 ft.
Sandy fire-clay	2 "
Hard shale	2 "
Hard sandstone	2 "
Soft greenish shale	2 "
Sand rock, hard	6 in.
Green shale	2 "
Sandstone, hard	8 "
Sandstone and shale	2 "
Black shale	3 "
Gray fire-clay	5 "
Bluish fire-clay	7 "
Cherty sandstone	3 "
Black shale	7 "
Coal, hard	8 in.
Coal, soft	3 " 6 "
Fire-clay, black and white	8 " 6 "
Gray chert rock	2 " 6 "
Fire-clay	9 " 1 "
Black shale and chert	10 " 6 "
Brown shales with kidney ore	11 " 6 "
Hard white sandstone	41 "

Other test-borings made on the land of the Coal Mining Company of Jackson, as recorded by Mr. Walker, are:

No. 1 begins below the sand rock:

Black shale with kidney ore	12 ft.
Fire-clay	6 "
Black shale	13 "
Coal, bituminous	4 "

No. 2:

Black shale	8 ft.
Fire-clay	5 "
Black shale	9 "
Coal	4 " 6 in.

Carbonaceous shales, sand rock, and iron pyrites below.

No. 3:

Sandstone	2 ft. 6 in.
Fire-clay	5 " 6 "
Black shale	16 "
Coal	4 " 6 "

Carbonaceous shales and sandstone as in No. 2.

No. 4, situated close to the State Prison ground:

Sand rock	27 ft.
Dark shale	2 " 10 in.
Coal	2 " 6 "
Slaty coal	8 "

Sand rock below.

No. 5, behind the chemical works:

Drift	11 ft.
Sandstone	30 "
Black shale	13 "
Coal	4 " 6 in.
Coal, poor	9 "

Hard sand rock at bottom of boring.

No. 6:

Drift	2 ft.
Sandstone	16 "
Coal	2 "

No. 7:

Drift	4 ft.
Sandstone	27 "
Black arenaceous shale	16 "
Black shale	2 " 10 in.
Coal	4 "

No. 8:

Sandstone	23 ft.
Black shale	8 "
Hard rock with pyrites	6 "
Black shale	10 "
Coal	4 "

No. 9 is a boring made on the west side of Grand River, in the hill-side opposite the coal-mine locality.

Drift	6 ft.
Sandstone	27 "
Conglomeratic sandstone	2 "
Bituminous shale	8 in.
Small coal seam.	
Soft black shale	2 "
Black shale with kidney ore	19 "
Bituminous coal	1 "
Fire-clay	8 "
Fine-grained sandstone	3 "
Black shale	1 " 6 "
Fire-clay	7 "
Sandstone and shale alternating	40 "

The shaft of the Woodville mine, 3 miles west of Jackson, intersects,

Drift	12 ft.
Sandstone	30 "
Dark shale	43 "
Coal	4 "
Shales	3 "

This mine is now abandoned.

We see, by a comparison of these sections, many minor differences in the sequence and thicknesses of the strata, but a general conformity conspicuous throughout. The highest position is always taken by a light-colored, coarse-grained sand rock of from 25 to 30 feet in thickness; below it, invariably, shales or alternations of sandy fire-clays with shales are found, in a maximum thickness of 40 feet, but usually in much thinner beds. Next a bed of coal between 3 and 4 feet in thickness follows in almost every one of the localities, and under it are arenaceous shales or sand rock. In the exposures at Jackson, the upper sandstone is frequently found in thick, tolerably compact beds, which are useful in supplying building-stones; other beds are thinly laminated, of irregular, discordant stratification, often soft and friable between the fingers. Between the harder solid ledges conglomeratic seams are frequently wedged in, or kidney ore and pyritous masses are disseminated; locally the ledges are colored a dark chocolate brown by a ferruginous cement uniting the quartz granules. Occasionally, also, a narrow coal seam can be observed, and vegetable remains, such as Calamites, are not uncommon. In an outcrop east of the Jackson Pottery the sand rock is locally bent into serpentine curves, as if the ledges had been corrugated by some force pushing sideways on them before they were fully indurated. The outcrop is capped by heavy masses of boulder drift and clay, and at the foot of the sand rock the clay pits of the pottery are opened.

The shale beds below the sand rock are usually of a dark, blackish, silky, shining color, partly hard and slate-like, partly soft and very fissile. They contain a species of Lingula, and often also compressed shells of Lamellibranches, besides trunks of Stigmaria, Sigillaria, and Lepidodendron transformed into iron pyrites. Nodules of kidney ore are abundantly intermingled with the shales. Interstratified with the latter there is frequently found a fine-grained, argillaceous sand rock, called fire-clay by the miners, in which trunks and leaves of Stigmaria are almost always plentifully inclosed. Some of the stems are found covered with leaves radiating in all directions, as if the apex of a branch had been immersed in the liquid clay paste without any disturbance or compression of the expanded leaves. The leaves are long and band-like, flat at the outer part, subcylindrical, clavate, and connected at the basal ends with the stems.

The coal of the Jackson mines is bituminous, of a strong, resinous lustre, with delicate laminar striation parallel with the bedding. Split open in this direction, it presents a mottled structure; a part of the mass is a shining, amorphous bitumen; another part is porous, with the vegetable structure of charcoal. It breaks vertically with a smooth, shining cleavage, with nearly square angles. Compressed stems of Lepidodendron and Sigillaria can often be recognized in the mass, either transformed into bitumen or preserved by a mould of iron pyrites. A seam of iron pyrites is found almost invariably interstratified with the coal, but can be readily separated; the remainder of the coal is not contaminated with an unusual proportion of the pyrites, still the quantity is large enough to render it unfit for blacksmith's purposes. The iron pyrites of the mines can be sold to advantage for a price equal to that of the coal, to the sulphuric-acid manufactory at Jackson. The heat-producing qualities of the coal, for boiler use, etc., are excellent; it burns with a bright flame, leaving a small residuum of ashes. Its tendency

to bake in the furnace, renders a breaking up of the half-melted mass necessary to the securing of a sufficient draught. This is remedied by setting the bars of the grates wider apart than in those intended for the use of hard coal. By distillation at red heat, the coal gives off 44 per cent of volatile matter.

The strata beneath the coal in some of the borings just recorded are found to be arenaceous shales and fire-clay, while in others the coal was directly underlaid by a sand rock. Prof. Winchell terms this sand rock, Parma sandstone, asserting that, in this position, a large body of sand rock is invariably deposited throughout the coal area of Michigan. Such regularity in the sequence of strata does not exist in the coal formation. The beds in it are usually of local extent, so that a position which in one place is occupied by a shale bed may in a neighboring locality be filled by a ledge of sand rock. The whole series is a constant alternation of shale and sandstone beds, and every natural or artificial section teaches us that an immense variety exists in this alternation. The deeper part of the formation incloses several heavy sand-rock beds, which in lithological characters are almost alike, so that in the limited exposures presented to our view, the determination of the exact relative positions of such beds becomes practically impossible. In case we adopt this Parma sandstone, we will rarely have an opportunity to identify it with any degree of certainty.

Two miles west of the Woodville coal mine, we find on Sandstone Creek, close to the Michigan Central Railroad, another abandoned mine. The surface rock is a soft dark shale with concretions of kidney ore and iron pyrites, which latter often represent trunks of Stigmaria. The coal seam, a little over 3 feet in thickness, had only this soft shale for a roof. The mining therefore required too costly timbering, and was consequently abandoned. On the sloping hillside, north of the mine, at the foot of which the shales are well exposed in the creek bed, and at a higher level, a patch of subcarboniferous limestone is found, apparently in undisturbed position; the top of the hill is formed by drift. This position of the strata is decidedly abnormal, and one or the other of the rocks must be dislocated; but every thing is so covered up by drift and sod, that it can not be told, from the visible surface exposures, which of the two is in its place and which dislocated. Numerous similar abnormal positions of the strata can be noticed

along the southern margin of the coal field. One of the localities has already been mentioned incidentally while describing the carboniferous limestone of Portage River. At that place the coal measures lean in steeply inclined position against the slope of a hill, capped with the carboniferous limestone. East from the limestone quarries the shales of the coal measures inclose thick beds of plastic fire-clay, full of the stems of Stigmaria, and abounding in kidney-ore concretions. The Jackson Pottery draws large quantities of its clay from these diggings. The owner of the clay pits informs me that he bored with an auger through 50 or 60 feet of soft shale and clay, and found no hard rock bed to resist its progress.

In Spring Arbor township is another coal mine on Sandstone Creek, which, like the before-mentioned one, two miles further north, in the bed of the same creek, has only shales for a roof; it was worked, however, at the time of my visit. Its coal seam is 3 feet thick, and resembles the coal of the Jackson mines. The shales incumbent on the coal are about 30 feet thick. They contain numerous geodes of kidney ore and stems of Stigmaria transformed into iron pyrites. Below the coal, for a number of feet, shales continue, and then a heavy sand rock follows. Not many steps from the mine a well was drilled to the depth of 65 feet; its lower part went through sand rock altogether, and at the depth mentioned a copious stream of good, drinkable water was struck, which rose to the surface, and has since continued to flow freely.

North of Albion, the quarry of Mr. Fisk is indicated in Winchell's geological report for 1861 as a typical exposure of his Parma sandstone. The sandstone is a whitish, coarse-grained, partly conglomeratic, soft rock, similar to some layers of the sandstones of Jackson. Mr. Geiger, a well-borer, living in the immediate vicinity of the place, informs me that he bored through 19 feet of the sand rock, and struck a bed of good coal, 3 feet in thickness, underlying which were other sandstones. This coal seam would be unusual if the incumbent rock has really the position Mr. Winchell gives it; but from my own observations in the surrounding country, I am inclined to take the sand rock as the equivalent of Mr. Winchell's Woodville sandstone.

North of Jackson County, in Eaton and Ingham counties, the presence of seams of coal has been ascertained through artesian

borings; but none appeared to be valuable enough to induce mining enterprises. At Mason, a mile south of the village, the upper coal sandstone is naturally exposed in the bed of the creek, and a thin coal seam has been lately discovered beneath it. In a drill hole sunk in the court-house yard of the village, thin seams of coal were likewise penetrated.

Four miles north of Mason, a large mass of coal connected with shale and sandstone beds in stratified order, was found standing in almost vertical position in the surrounding drift; the discoverers entertained great hopes of making their fortunes, and, indeed, succeeded in selling the place at a high price to a speculative genius, who, after I told him what he had bought, vanished from the place, leaving behind a good deal of money and some unpaid debts. In the mineral well of Mr. Frost, at Eaton Rapids, a seam of coal was struck at a depth of 120 feet from the surface; the incumbent rock beds were alternating strata of shale and sand rock, amounting to 100 feet; the upper 20 feet were drift.

In the banks of Grand River, two miles above Eaton Rapids, the upper sand rock of the coal measures projects in bluffs about 12 or 15 feet in height; the rock is of a darker bluish or ferruginous color than usual, and is interstratified with blue shales. It contains Calamites and other vegetable remains, and pyritous concretions.

In the artesian borings at Lansing, no coal of appreciable thickness was found. At the rapids of Grand River, one mile and a half above Lansing, the upper coal sandstone makes an outcrop, and has been quarried on a small scale. Six miles south of Lansing, near the railroad from Eaton Rapids to Lansing, a bed of coal 8 feet in thickness was said, some years ago, to have been discovered on the farm of Mr. Minie, but the report did not turn out to be correct.

At Charlotte, in Eaton County, a boring was made to a depth of 730 feet. In this the sand rock of the coal measures was struck below a drift cover of 50 feet; some small seams of coal were found beneath the sandstone, but I was not able to find out the details of the boring record. The facts which I mention were communicated from memory by accidental observers of the boring.

In the vicinity of Chester, Eaton County, the coal comes close to the surface and often crops out in the ravines of little Thornapple Creek. In one of these outcrops, a coal seam of 3 feet comes out

under black shale beds, and is underlaid by light-colored shales, and fire-clay containing Stigmaria. Lately a number of experimental borings have been made in the vicinity of Chester. The coal formation is found considerably eroded and partially swept off during the drift period. The shales and inclosed coal seams are generally deprived of the protecting roof of sand rock and lie close under the drift, which is a very unfavorable condition for mining. The coal seams appear also to be often replaced by hard black bituminous shales. Of one of the borings at Chester, I received the following record: Drift, 8 feet; hard black shales, slate-like, and inclosing thin seams of coal, from 6 to 8 feet; whitish, fine-grained sand rock, containing Stigmaria, Lepidodendron and Calamites, 7 feet; whitish plastic fire-clay, 30 feet; black shales with pyrites, 30 feet; white fire-clay with hard, ferruginous bands, found at the bottom of the bore-hole.

The most instructive natural section through the coal formations which we have in the State, is seen at Grand Ledge, in the valley of Grand River, 10 miles below Lansing. The river has carved its bed there to a depth of about 60 feet below the general surface level of the country. The upper part of the hills bordering the valley is formed of drift; the lower presents a section through the rock beds of the coal measures. The village of Grand Ledge is located nearly in the centre of the outcrops, which continue up and down the river for about a mile. The strata rise and sink in undulations, which bring the higher and lower beds to repeated outcrops on the same level. The order of stratification, often visible in sections of large horizontal extent, gives a fair opportunity for observing the changes to which a stratum in its horizontal extension is often subject with regard to thickness and quality of material. The observed variability explains why, in the numerous sections seen within the limited space of a few miles, no one exactly corresponds with the other, although many of them represent about the same horizon.

The upper part of the formation is a coarse-grained sand rock from 25 to 30 feet in thickness. In the locality where I saw it best exposed, the rock occupies one of the depressed curves of an undulation such as has been alluded to, and at both ends of the exposure lower rock strata come up alongside the upper beds on the same level. The sand-rock ledges form a compact body, with only insig-

nificant intermediate seams of shale, or with an occasional coal seam of a few inches thickness wedged in. Calamites and other vegetable imprints, besides concretions of kidney ore and of iron pyrites and conglomerate seams, are usually found inclosed within the rock mass. In grain and hardness, it fully resembles the upper sandstones of Jackson; its color, however, is a somewhat darker yellowish shade. Locally the rock becomes very hard and has a dark, chocolate-brown color from containing an abundance of ferruginous cement; a part of this brown rock is coarsely conglomeratic. Next below this sand rock, which borders the river in vertical cliffs for nearly the length of a mile, we find blue shales of arenaceous character, interlaminated with thin layers of sand rock, all amounting to a thickness of about 15 or 20 feet. Under these is a coal seam 2½ feet in thickness, and of very good bituminous quality. It wedges out in places or changes into a black, carbonaceous shale. This seam is worked at times by single workmen, as a temporary occupation when they have little else to do. The coal seam rests on a gray, argillaceous, laminated sand rock with softer shaly seams, which both inclose a large quantity of coaly vegetable remains, Lepidodendron, similar to Lepid. Wortheni, Stigmaria ficoides, trunks and leaves. The thickness of the beds is about 5 feet. Lower comes a fine-grained, whitish sand rock in even, compact beds, 8 feet in thickness. Directly under this sand rock is a 15-inch bed of good bituminous coal. Lowest in the outcrop are about 25 feet of additional strata, principally sand-rock ledges, with some intermediate shale seams. In the bed of the river at this spot, large, hard sand-rock slabs, of very even bedding, and from 2 to 3 inches in thickness, are laid open, which would make excellent flagstones for paving sidewalks. The aggregate thickness of the given section is about 90 feet; it begins with the centre of the synclinal depression and is followed downward with the stream. Up stream a rise of the strata is seen, but the next lower strata to the upper sand-rock deposit are not uncovered as plainly as at the lower end of the depression. After passing a covered interval of about 60 steps, in going up stream, the following descending section is observed:

Drift, up to the plateau of the hillsides	30 ft.
Blue soft shales with kidney ore	15 "
Sand rock with Stigmaria	2 "
Thinly laminated shaly sand rock	4 "
Black carbonaceous shale, or coal in its stead	1 "
Sand rock with Stigmaria, from	1 to 2 "
Blue shales, partly arenaceous, containing kidney ore	7 "
Black shale or coal	several inches.
Sand rock with Stigmaria	2 ft.
Blue shale	2 "
White ripple-marked sand rock thinly laminated	4 "
Nodular white sand rock, with ferruginous dots and interlaminated with seams of shale, visible	3 "

The lower beds are submerged.

This section is directly continued by an artesian boring, made at the Mineral Spring Hotel, to a depth of 105 feet. The boring begins in the last-mentioned sand rock, which is found to be 20 feet thick; beneath follow 5 feet of fire-clay, then 40 feet of white sand rock, a seam of coal 16 inches thick, carbonaceous shales from 3 to 4 feet, and lighter-colored shales 12 feet. At 80 feet below the surface a conglomeratic sand rock is struck, from which a copious stream of water rises to the surface. The sand rock continues to the depth of 105 feet, where another water-stream is struck. The water has an agreeable mineral taste. On the opposite side of the river, subsequent to this boring, another well was opened, which seems to be in subterranean connection with the well of the Mineral Spring Hotel, whose tube had to be shortened 2 feet in order to secure an overflow after the other well began to discharge its stream.

A good section through the formation can be observed in the ravines of a creek entering Grand River from the south, a short distance west of the village, and another, in the bluffs just below it, and opposite the section last described. Highest in this latter, under a few feet of drift, are 15 feet of arenaceous shales with nodular seams of sand rock and kidney-ore concretions, and a band of carbonaceous shale with seams of coal; beneath follow 8 feet of a fine-

grained, greenish-white sandstone in thick, even beds, identical with the sand rock found in the first section intermediate between the two coal seams. This rock is quarried and worked into cut-stone, window and door sills; it is of fine quality, better than any of the coal-measure sand rocks I had seen before. The beds at one end of the quarry are much thicker than at the other, and seem to wedge out. Under the quarry-stone a foot or two of arenaceous shales, laminated by black, coaly seams, follow, and then a coal bed 15 inches thick. The coal is of very good quality, even for blacksmiths' use, and is occasionally obtained by working the quarry for its sand rock. The coal seam rests on bluish arenaceous shales, and, lower, beds of sand rock form the base of the bluff and the bed of the river. The banks of the river, at intervals for the distance of 8 miles, present more limited outcrops than those near Grand Ledge, but after that no more rock is denuded in the river-bed until Ionia township is reached, where, in Section 23, the upper sand rock of the coal measures comes to the surface, or is only covered by a thin coating of drift. The quality of this sand rock is superior to the equivalent beds at Grand Ledge or at Jackson; it can be quarried in blocks of large dimension, and is of proper durability for building purposes. It has a reddish tint or is a variegated red and white. In the quarries I observed an interesting example of discordant stratification. The surface of a sand-rock ledge is seen deeply eroded by furrows and excavations as if it had been a long time exposed to the action of the atmosphere, and this eroded surface is coated with a smooth, argillaceo-ferruginous cuticle. On this ledge another deposit of sand rock follows, which fills out all the inequalities of the lower bed. We must, therefore, suggest a temporary emergence of the lower stratum before the next ledge could be deposited over it. From Mr. Blanchard, of Ionia, I received the record of a boring in the vicinity of the quarries, made to a depth of 450 feet. It penetrated in

Sand rock	80 to 110 ft. in thickness.
Shales and fire-clay	4 ft.
Coal from	20 in. to 4 "
Fire-clay	2 "
Sand rock, fine-grained	40 "

Coal seam, thickness unknown.

The deeper strata were alternations of sand rock and shales. At 300 feet below the surface, a copious stream of sweet water was struck, which rises in constant flow to the surface, proving very refreshing to the laborers of the quarry.

West and north of Ionia, the coal formation disappears under the drift, and no other borings have been made in these directions by which we could ascertain the extent of its distribution as the surface rock. To encounter the coal formation again, we have to return eastward. In Ingham County, shale beds inclosing a coal seam come to the surface on Cedar River, near Williamston; not far off from this exposure, a shaft has been sunk, and for several years past a mine has been in operation which produces a good quality of bituminous coal. The shaft commences in a drift-mass 15 feet thick; right under the drift a coal seam of 20 inches is found; next to this is fire-clay with seams of sand rock, 12 feet; black shale, 3 feet; white, soft fire-clay, 3 feet; kidney ore, 6 inches; black, slate-like shales containing Lingula, Discina, Productus, and compressed Lamellibranches, 2 feet; coal from 3 to 3½ feet; fire-clay, 4 feet; the shaft extends about 12 feet below the coal seam, through gray shales. A seam of pyrites is generally connected with the coal, but can be easily separated; otherwise the coal is tolerably clear of pyrites. Specimens of Sigillaria and Lepidodedron are common in the pyritous seam. Besides the vertical shaft, a sloping gallery is driven to the bottom of the mine, in which the sequence of the rock strata can be studied most commodiously. Mr. Rush, the agent of the coal mine, has explored the vicinity of Williamston for coal, and kindly gave me the results of his experiments, which I set down here. In a boring 4 miles west of Williamston, close to the river, were found,

Drift	18 ft.
Black slate	4 "
Coal	2½ "
Fire-clay	6 "
Black shale	12 "
Shaly sandstone	10 "

Half a mile south from the latter place a boring went 60 feet through drift, without reaching the older rock beds.

A boring at the railroad depot of Williamston gave

Drift	16 ft.
Sandstone, soft, white	12 "
Coal	6 in.
Light shale	6 "
Dark shale	8 "
Coal	3 "
Fire-clay	3 "
Black shale	2 "
Fire-clay	4 "
Black shale	4 "
Fire-clay	4 "
Black shale	13 "
Light shale	7 "
Black shale	5 "
Fire-clay	3 "
Shale	14 "

Half a mile southwest of the depot another boring went through

Drift	28 ft.
Sandstone	6 "
Light gray shale	10 "
Dark shale	6 "
Black shale	7 "
Coal	1 "
Fire-clay	4 "
Shale	3 "
White sand rock to end of the boring	20 "

In a boring 200 yards north of the coal shaft, across the river, there were encountered,

Drift	4 ft.
Sandstone	13 "
Dark gray shale	1 "
Coal	3 "

Below, fire-clay and shales.

North of the locality just mentioned were found:

Drift	18 ft.
Coal	7 "
Fire-clay	6 "

and black slate and lighter shales to the depth of 60 feet in all below the surface.

The above experiments show a uniform distribution of a coal seam about 3 feet in thickness over this whole district. Its position is often too superficial, without a proper roof, for advantageous mining. In nearly all the borings two seams of coal are found, of which the upper one is generally too narrow to be of practical value. The two seams are separated by from 15 to 20 feet of intermediate beds.

The next disclosures of the coal measures we find on Shiawassee River, near Owosso, and Corunna, in both of which places coal mines are opened. The shaft of the Owosso mine is close to the river, within the village limits. It begins in a blue shale with coaly, vegetable remains, under which a coal bed of 15 inches is found resting on fire-clay 6 feet in thickness; then another coal seam, likewise of 15 inches, succeeds. The bottom part of the shaft, which is 40 feet deep, is formed by shales and fire-clay; the fire-clay is partly of a hard, sandy nature, and contains numerous stems and leaves of Stigmaria ficoides. The coal is of a rich bituminous quality and tolerably free of sulphur, but the seams are too thin to be profitably mined. Several companies tried to work it, but gave it up after a short time, as not returning enough to cover the expense.

At the Detroit and Milwaukee Railroad depot, a boring to the depth of 307 feet has been executed. Its record runs:

Drift	40 ft.
Fire-clay	5 "
Blue shale	20 "
White arenaceous shale	8 "
Blue shales, partly arenaceous	107 "
Coal	6 in.
White sandstone	16 ft.
Shales	22 "
Blue sand rock, alternating with shale	46 "
White sand rock	11 "
Dark shale	5 "
Sand rock	27 "

Shales to the bottom of the boring.

The bottom of the Shiawassee valley, near Corunna, is all formed

of rock beds of the coal measures, where the erosions of the drift period have not destroyed them and filled their place with débris.

The upper sand rock of the formation is in many places entirely swept away, and the shale beds below lie denuded at the surface. The two mines opened at Corunna, a mile or two east of the village, have begun their shafts in the shale beds; one of them, the more northerly situated, was abandoned at the time of my visit; the other, located within a short semicircular bend of the river, was worked. In the oblique drift leading to the bottom of the mine, the following section is offered:

Drift	9 ft.
Shale, dark, partly black	30 "
Sandstone	4 "
Black slaty shales, containing Lingula and Discina, besides compressed Lamellibranches	6 "
Coal	1 "
Fire-clay	4 "
Black slaty shales, as above	8 "
Coal from	3 to 4 "
Fire-clay	4 "
Black shales	4 "

Arenaceous shales continue to the bottom, which is 80 feet below surface. The beds are found in the mine rising and sinking in undulations. The fire-clay seams are usually arenaceous and contain stems of Stigmaria. The shale beds contain lenticular concretions of kidney ore, in the non-decomposed condition of gray, amorphous carbonate of protoxide of iron; seams and nodules of iron pyrites are also found dispersed throughout the whole formation. In the coal seam the pyrites are concentrated into a band of a few inches in thickness. The coal is of bituminous quality, of the same character as the Jackson coal. Not far off, west from the mine, the shale formation is found covered by the upper coarse-grained sand rock inclosing stems of Calamites. The visible thickness of the rock is about 15 feet, but it is probably thicker if it could be seen better exposed. Other outcrops of the sandstone are to be found in the river bed 4 miles above Corunna. The coal measures are frequently noticed in the bed of the Shiawassee below Owosso, as far down as St. Charles. A locality of particular interest is near the

mouth of Six-Mile Creek, 6 miles north of Owosso. In the bluffs of the Shiawassee River we observe the lower part formed of blue shales, with seams of sand rock and abundant concretions of kidney ore; the top is drift with a considerable intermixture of angular débris from the underlying strata. Under the shale, emerging a few feet above the water and partly submerged, are layers of a black, shaly lime rock, visible in a thickness of 4 or 5 feet, containing numerous fossils, partly in calcified, partly in pyritous condition; particularly observable is a large nodose Nautilus, described by Meek and Worthen under two different names, N. latus and N. Winslowi. A large Orthoceras is quite common, and other forms are Spirifer cumeratus, Productus nanus, a Spirigera, Chonetes, Myalina, Platyceras, Bellerophon, Crinoid stems, and compressed specimens of a Zaphrentis.

The same limestone is seen a quarter of a mile off in the bed of Six-Mile Creek; its ledges are there more even-bedded flagstones, less shaly than those seen in the Shiawassee River. Close under the lime rock is a 15-inch bed of coal, quantities of which have been taken from the river bed when the water is very low. The coal reposes on a soft, plastic clay of greenish-white color, which incloses stems of Stigmaria and large, calcareous, nodular masses of cone-in-cone structure. Stems of Stigmaria are also found in the upper shales of the bluffs and in the geodes, when split open fronds of ferns are sometimes found, but their occurrence is rare. A few steps from the mouth of Six-Mile Creek, some parties made an experimental shaft about 30 feet deep, and from that point drilled to 100 feet below the surface. From the material thrown out of the shaft, I see that shales of various color, with seams of sand rock and conglomerate, besides an abundance of kidney ore, compose the surface layers as far as the shaft went. Mr. Ott, the owner of the land, informed me that four beds of coal, amounting in all to 11 feet, were found in the boring. He gave the same account to Prof. Winchell, who has described in his report for 1861 the details communicated to him, to which record I refer the reader. The record in itself is somewhat doubtful, and the hesitation to take it as a true representation of facts is increased by the subsequent acts of the discoverers of so rich coal deposits (11 feet within a vertical thickness of 20 feet of strata). Mr. Ott ends his

story by saying that the men, after they had reached the depth of 100 feet, left the place at once, not to return again.

The valley of Flint River cuts through the carboniferous series near Flushing, northwest of Flint. Two miles above Flushing the bed of the river is formed by a hard, fine-grained sand rock full of Stigmaria, stems, and leaves; several feet of it emerge above the water-line. Above follow about 4 feet of blue arenaceous shales, likewise with Stigmaria stems; next higher are 5 feet of dark shales containing kidney-ore concretions; above them is black shale with thin seams of coal, amounting to about 3 feet in all. Greenish, micaceous sandstones 25 feet in thickness follow, above which 15 feet of dark gray shales constitute the highest ledges of the section. The sand rock is in part thinly laminated with discordant stratification. Another part is in regular beds, varying from 18 inches to 2 feet in thickness. The rock incloses fine specimens of Calamites and thin, coaly veins, besides numerous concretions of iron pyrites. It can be quarried in tolerably large blocks, and is used for cut-stone of a fair appearance. At the time the building contracts for the State House at Lansing were let out, this sand rock was offered to the building committee as a first-class material, by parties from Flushing. In consequence of this offer I was ordered by Governor Baldwin to examine the quarries and the rock, which I did, reporting conscientiously, to the best of my knowledge, that I considered the rock of the Flushing quarries as of middling good quality, suitable for buildings of less weight than the State House was likely to have, but that, for an edifice of such dimensions, I did not think the rock had sufficient firmness. I expressed also my doubts in regard to its durability when exposed to the severe winter frosts. These views were not mere surmises, but were based upon the appearance of several buildings in Flint, in the construction of which the Flushing stone had been used. These buildings had then been standing about ten years, and I found their sills and water tablings so much damaged by exfoliation within that short time that I could not think of recommending the stone. I make this statement in justification of my report to the committee, which roused against me the indignation of the Flushing quarrymen. I have no doubt their anger has passed off ere this, as, upon reflection, they must see that I could not honestly have acted otherwise than I did in the matter.

In Saginaw Bay district, thin coal seams were frequently found in boring for salt, and several experimental borings in search of coal were made in the district a good many years ago, but no sufficient inducements for coal-mining could be discovered. During the last few years the report of the discovery of rich beds of cannel coal in the valley of Rifle River has caused great excitement, not only in Saginaw district, which is specially interested in such a discovery, but throughout the whole State. In order to ascertain the actual state of the case, I examined the Rifle River district with particular care, and give here a brief statement of the observations made.

The first explorations for coal on Rifle River were induced by some pieces of cannel coal found in the bed of the river by a settler living close by it. Some gentlemen of Bay City, hearing of the fact, began to examine the surroundings of the locality indicated to them, and after experimenting awhile, succeeded in finding, at a depth of only 18 feet below the surface, a deposit of black shales and cannel coal, the latter, according to their reports, having a thickness of 7 feet. They sunk a shaft to the depth of 27 feet; the upper 14 feet of the excavation were loose drift masses; under them, seemingly, a three-foot ledge of a hard, calcareous sand rock was found; then came a hard black slate a few feet in thickness, the lower 7 feet in the shaft being thought to be all cannel coal. When I visited the spot, the shaft was full of water, and I could not ascertain the facts as accurately as would have been desirable; but from the examination of the material taken out of the shaft, which was all there yet with the exception of a few barrels of coal taken away, I came to the following conclusions: That the sand rock next under the drift and above the black slate was not a ledge in its natural position, but a large boulder of the arenaceous beds of the lower horizon of the subcarboniferous limestones, the same rock which forms the cliffs on Point aux Grees; that the remainder of the excavation went through a deposit of a black, highly bituminous slate, 10 feet in thickness. Three feet of these slates were considered as such, and the rest were taken for cannel coal; but I rather think the proportion is inverted. The true cannel coal in the promiscuous mass thrown out from the shaft was the smaller part of the whole, and even admitting

that the best pieces of the coal had been picked out from the heap before I saw it, the quantity taken away could be but very small in comparison with the slate masses left there. The transitions of the slate rock into cannel coal of good quality are represented in all gradations; much of the slate is so rich in carbon, that it burns freely, but leaves so large a proportion of ashes as to make it unfit for fuel.

The seams of true cannel coal interstratified with the slates burn with a residue of a small quantity of pulverulent ashes. The slates contain numerous specimens of a small Lingula, and on several slabs I found clusters of fish-scales scattered over a space having the outlines of a small fish in decomposed, compressed condition. After my first visit to the coal shaft, it was pumped out, was somewhat deepened, and a gallery was driven from its bottom 30 feet sideways. Some weeks later, when I visited the shaft again, I found it abandoned and filled with water, but from the additional rubbish thrown out, it can be seen that the black slate is underlaid by an arenaceous fire-clay inclosing stems and leaves of Stigmaria.

The position of the shaft is in Town. 19, R. 4, Sect. 3. In the same section two other experimental borings were made on the opposite side of the river. In one, sand rock was struck under a cover of 25 feet of drift; the boring went 20 feet into the sand rock, and was then interrupted, no signs of coal being found. The other boring, executed by Mr. Ortmann, of East Saginaw, was continued to a depth of 190 feet. First came drift 21 feet, and then alternations of blue shales and sand rock; near the bottom a seam of iron pyrites was found, and under it black shales, but no coal.

Another drill-hole, three quarters of a mile southeast of the above borings, sunk to a depth of 100 feet, struck sand rock and shale beds under a drift cover 60 feet in thickness, but found no signs of coal. Another boring to the depth of 100 feet, in Sect. 17 of the same town, went altogether through drift, without reaching the rock. Further east, on the lower part of Rifle River, Mr. Ramsdall made some experiments, in Town. 19, R. 5 east. He found drift, 36 feet; sandstone, 35 feet; blue shale, 34 feet; pyritous rock, 2 feet; blue shales, 14 feet, until, at 120 feet below the surface, the boring was given up. South from there, in Town. 19, R. 4, Sect. 10, he found,

Drift sand	75 ft.
Clay	25 "
Sand rock	7 "

Shales of various color, partly black, and a 4-foot bed of fire-clay were the rock beds next penetrated to the depth of 200 feet; at the bottom a dark gray hard rock was found—no coal.

Another boring in the same town had, at the time the record was given to me, reached a depth of 122 feet, and was still within the drift. Several other borings were made in the vicinity of Rifle River with no better success.

A natural outcrop of the coal-bearing rock series is seen in the river bed, Town. 19, R. 4, east, Sect. 4, below a dam built across it. Highest is a yellowish, rather soft sand rock, from 10 to 12 feet in thickness, interstratified with some seams of dark bluish shale, and containing ferruginous concretions and vegetable remains (Calamites). Lower are from 2 to 3 feet of a shaly, micaceous sand rock, of irregular, discordant stratification, thinly laminated by intervening linear coaly seams, and with the strata frequently distorted into serpentine flexions. Next below are 15 inches of a dark blue arenaceous shale with kidney ore, its strata also flexured, or broken into a brecciated mass. The lowest visible beds are a white sand rock inclosing numerous water-worn, ferruginous pebbles and pieces of shale, besides thin, linear seams of coal. About 5 feet of it emerge from the water. Other outcrops are found further down the river. On Mr. Kinney's farm, Town. 19, R. 5, east, Sect. 10, blue arenaceous shales, with some thick ledges of sand rock forming the top part, are all that can be seen. Still further down the river, within the village of Omer, the bed and its banks are formed of a white, soft sand rock of discordant stratification, interstratified with some thin shale beds, and containing narrow veins of coal not over an inch in thickness. Toward the mouth of the river the formation disappears under drift deposits. While the explorations on Rifle River were going on, some boring experiments had also been made along the line of the Lansing and Saginaw Railroad, near Deep River, and near Standish, which were attended by a somewhat better success than most of the experiments on Rifle River. At Deep River station, Mr. Stephens sunk a drill-hole to a depth of 120 feet, and found,

Drift	28 ft.
Light-colored sand rock	57 "
Blue shale	7 "
Coal (cannel)	5½ "
Black shale	5 "
Coal	2½ "
Soft shales, with seams of sand rock and iron pyrites	12 "
Solid limestone, entered	2 "

Below the drift deposits a stream of sweet water was struck, which rises in a constant flow to the surface. From the material brought up by the sand pump, it is impossible to determine with accuracy the thickness and quality of a coal seam, which is found in connection with a coal-like slate rock, as in this boring. Mr. Stephens, the owner of the place, after obtaining so favorable indications, determined to investigate the matter thoroughly by sinking a shaft down to the coal beds, and I am informed that the work is already in fair progress, which, if accomplished, will finally solve the question as to whether valuable coal beds can be expected within this district or not. It is to be hoped that of the 13 feet of black deposits found in the boring, 7 feet may turn out to be good cannel coal, as the supposition is; but even a somewhat thinner seam would be a discovery of great importance for Saginaw district.

At Standish, another boring for coal was in progress. When I was there, it had reached the depth of 129 feet; it went through

Drift	52 ft.
Sand rock	27 "
Blue arenaceous shales with seams of iron pyrites and narrow bands of coal	27 "
Coal	13 in.
Blue shales and fire-clay	14 ft.
Sand rock	2 "
Shale	6 "

Subsequently, as I am informed, a thicker coal seam was met with by a continuance of the boring. On Tittibawassee River, at Mr. Shattuck's farm, 6 miles west of Saginaw City, explorations have been in progress for several years back, by which the presence of a coal seam has been ascertained. Last fall they commenced to sink a shaft to the coal bed, but since then I have not heard how far the work has advanced.

The coal fields of Michigan, supposed to cover a space of 8000 square miles, are up to the present day of very inferior importance in the economy of the State. Only four mines are in actual operation, and these are worked with but a small force of men.

Searching for the causes of this neglect of apparently so great stores of wealth buried beneath our feet, we find one of them in the imperfect exposure of the rock beds, which, with the exception of those in a few limited districts, are all deeply covered by drift deposits. This would be no serious impediment, if the coal seams were spread in a continuous sheet over the surface of a certain horizon; we could then without much risk go down and uncover them; but all coal deposits are confined originally to certain limited basins, and if we consider that the coal series, as the youngest of the stratified rock beds found on the peninsula, has been without protection by later deposits, exposed to the vicissitudes of untold ages, we must expect to find a large proportion of the deposits destroyed and swept off; in particular, during the drift epoch, the coal formation must have suffered immense destruction from the moving glacier masses. The direct proof of this is furnished by the large quantity of débris of the coal measures mixed with the drift material; but the drift action has not only destroyed a large proportion of the coal formation, but has at the same time filled up the eroded gaps with loose drift material, hiding the extent of destruction from observation, and thus rendering our mining operations always hazardous in a deeply drift-covered region, because we have no means whereby to know how much of the supposed underlying rock strata has escaped destruction.

The same erosive forces have acted on the coal formation of Ohio, but there the valleys of erosion intersecting it have not been filled again with drift masses. The erosion has rather facilitated access to the coal beds, and laid the strata open for observation in natural sections miles in length. There success to miners' enterprises is assured by the same revolutionary forces which have proved so detrimental in the case of ours. Another reason for the small development of the coal-mining industry in Michigan is undeniably