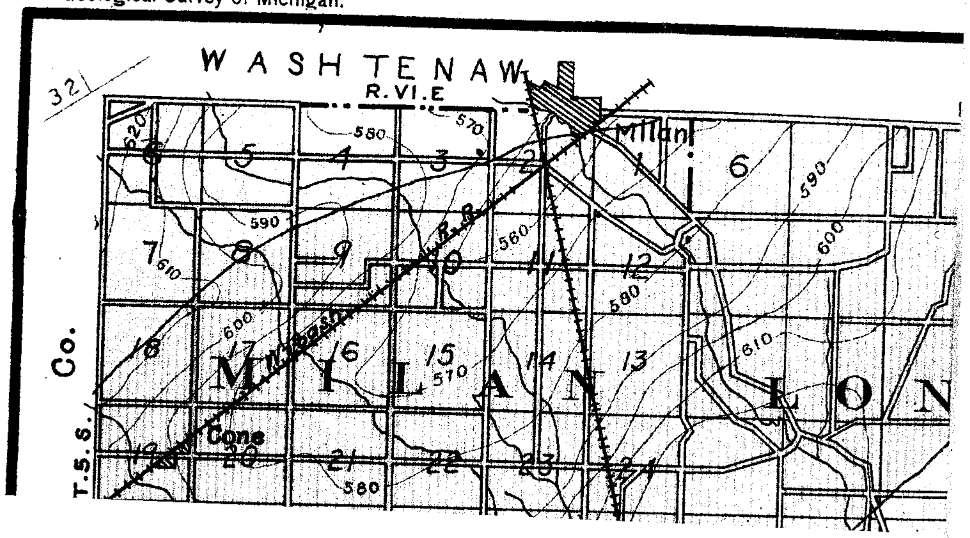
Geological Survey of Michigan.




GEOLOGICAL SURVEY OF MICHIGAN

# LOWER PENINSULA

1896-1900

## VOL. VII

PART I. MONROE COUNTY, W. H. SHERZER
PART II. HURON COUNTY, A. C. LANE
PART III. SANILAC COUNTY, C. H. GORDON

GEOLOGICAL SURVEY OF MICHIGAN
ALFRED C. LANE, STATE GEOLOGIST

VOL. VII
PART I

# GEOLOGICAL REPORT

ON

# MONROE COUNTY
## MICHIGAN

BY

W. H. SHERZER

ACCOMPANIED BY SEVENTEEN PLATES AND EIGHT FIGURES INCLUDING
THREE COLORED MAPS

PUBLISHED BY AUTHORITY OF THE LAWS OF
MICHIGAN
UNDER THE DIRECTION OF
THE BOARD OF GEOLOGICAL SURVEY

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OFFICE OF THE STATE GEOLOGICAL SURVEY,
LANSING, MICH., June 21, 1900.

*To the Honorable, the Board of Geological Survey of Michigan:*

HON. HAZEN S. PINGREE, *President.*
HON. PERRY F. POWERS.
HON. JASON E. HAMMOND, *Secretary.*

GENTLEMEN—Herewith I transmit the Report, maps and illustrations of the report on Monroe county prepared by Prof. W. H. Sherzer, the issue of which, as Part I of Vol. VII, you have authorized. Five hundred copies as you have voted are issued separately, while the remainder of the edition is reserved to be bound up with the remaining parts, upon which the printer is now at work. This and the following report upon Huron county are of rather exceptional size, because the two counties themselves are of exceptional geological interest. They have more than usually numerous rock exposures, and taken together, they cover pretty fairly the whole variety of rocks and surface conditions in the Lower Peninsula. Thus dwellers in the other counties thereof will find much information which they can apply to their own homes.

Some of the valuable results of Prof. Sherzer's work are: the description of the considerable thickness and extent of the Sylvania glass-sand, a work of great value to a State so exceptionally well situated for glass manufacture as Michigan; the description of the deposits of high grade limestone and strontianite, both of which may be important factors in beet-sugar manufacture, while the former is also in great demand for the manufacture of soda ash; and the determination of the limited extent and economic value of the oil and gas. The professional geologist will appreciate the light thrown on the Helderberg question, and on the detailed history of the Great Lakes.

With great respect, I am your obedient servant,

ALFRED C. LANE,
*State Geologist.*

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ERRATA.

Page 129, line 9 from bottom, for Chamberlain read Chamberlin.
Page 181, Table XII should be Table XIII.
Page 199, line 4, for Cushino read Cousino.
Page 219, Table XIV should be Table XV.

# CHAPTER I.

## INTRODUCTION.

### *A. Geographical.*

§ 1. Location.

The county which constitutes the subject of this report occupies the extreme southeastern corner of the lower peninsula of Michigan. To the north are Wayne and Washtenaw counties, to the west Lenawee county; Lucas county of the state of Ohio, forms the southern boundary while the eastern is formed almost entirely by Lake Erie. The county covers about 560 square miles, distributed over fifteen townships between 41° 44′ and 42° 6′, north latitude; and between 83° 11′ and 83° 46′, west longitude.*

§ 2. Railroads.

Eight lines of railroads intersect the county in all directions and no portion of it is beyond the sound of their heavily loaded trains. Parallel with the lake shore and back from it from one to five miles, the Michigan Central and Lake Shore traverse the county in a northeast and southwest direction. To the west the Pere Marquette enters from the north, swings to the southwest near Monroe and passes into Ohio about a mile west of the two preceding roads. The Detroit and Lima Northern enters the county from the west, from Dundee turns northeastward, crossing the Pere Marquette at Carleton and enters Wayne county at the northeastern corner of Ash township. Having the same general direction as all of the preceding and the common purpose of centering in Detroit, a branch of the Wabash grazes the northwestern corner of the county.

*The exact location of points somewhat near the four boundaries of the county, as determined by the government engineers, is as follows:

| | Latitude N. | Longitude W. |
|---|---|---|
| Gibraltar lighthouse | 42° 05′ 25.90″ | 83° 11′ 14.80″ |
| Turtle Island lighthouse | 41° 45′ 08.80″ | 83° 23′ 28.80″ |
| Monroe lighthouse | 41° 53′ 27.70″ | 83° 19′ 53.20″ |
| Triangulation Station near Dundee | 41° 55′ 28.08″ | 83° 40′ 13.93″ |

Heading for Toledo, the Ann Arbor gives a nearly complete northwest and southeast section of the county through Milan and Dundee to Alexis junction with the Pere Marquette. Nearly parallel with it the Toledo-Adrian branch of the Lake Shore cuts the extreme southwestern corner of the county. The only east and west road within the limits of Monroe county is the Monroe-Adrian branch of the Lake Shore, passing through Petersburg. These last two branches of the Lake Shore system are of historic interest since they were the first railroads in the northwest. The Toledo-Adrian road was originally built by private enterprise in 1836 and was known as the Erie and Kalamazoo railroad. For about a year the cars were drawn by horses over wooden rails, when the "strap rail" was laid and the first locomotive introduced. The road from Monroe to Adrian was constructed in 1839 by the then infant State of Michigan for the purpose of opening up the interior and was operated by it until 1846, when it was sold to the Michigan Southern Railroad Company.

§ 3. Proposed lines.

During the summer of 1899 the bed for a new road from Toledo to Detroit was in process of construction, lying between the Michigan Central and Lake Erie, to be known as the Detroit and Toledo Shore Line. The grading from Toledo to Monroe is well advanced and will probably be completed within the limits of the county during the coming summer. By closely hugging the shore of the lake and of Detroit River it is claimed that the distance between Detroit and Toledo will be materially lessened. An electric road intended to connect these two cities awaits completion. The grading from Erie to Monroe is practically done, following throughout the greater part of the distance the main highway, and a power house has been constructed in Monroe. The franchises have been secured for an electric road from Ypsilanti to Milan which it is expected will be continued to Adrian, thus crossing Milan township. It is reported to be the intention of the promoters of this road to construct a line from Milan, through Dundee, to Toledo. Still another road, with branches from Ann Arbor and Detroit, is expected to enter the county north of Carleton and to follow the approximate line of the Pere Marquette to Monroe. With such development of steam and electric lines, connected with every farm by means of substantial stone roads; with the private telephone, free rural delivery of mail, and the attendant improvement in educational



facilities, the life of the farmer is one to be envied, and the question of keeping the son and daughter upon the farm will be largely settled.

§ 4. Miscellaneous data.

Table I gives an alphabetical list of the townships of the county, their postoffices and some miscellaneous information relating to them, gathered from latest available sources. It shows the population in 1894 to have been 33,181. The city of Monroe is the county seat, having in 1894, a population of 5,613. There are three incorporated villages, namely: Dundee, 1,115; Petersburg, 446; and Milan, 964.

## *B. Historical.*

§ 5. Early boundaries.

Early in the century just closing, "Wayne County" comprised the entire lower peninsula of Michigan, a part of the upper peninsula as well and adjoining portions of Ohio, Indiana and Wisconsin. From this vast tract Monroe county was set off in 1817, by proclamation of Gen. Lewis Cass, then governor of Michigan Territory; the present Wayne county having been established two years earlier. The original proclamation by which the boundaries of the county were first established is here given.

"WHEREAS, It is considered that the public good will be promoted by the erection of a new county in the said Territory;

*Therefore*, I do, by virtue of tne power and authority in me vested, constitute the whole of that portion of said territory of Michigan which is included within the lines and limits following, that is to say: Beginning at the mouth of the river Huron of Lake Erie, within said territory; thence up the said river in the middle thereof until its intersection with the line between the third and fourth tier of townships south of the "base line," so called; thence due west with the said line until it shall intersect the present Indian boundary line, namely, to the western line of the first range; thence with said line due south to the southern boundary of said territory; thence along the southern boundary thereof, easterly to the southeast corner thereof; thence northerly along the eastern boundary of said territory to a point due east from the place of beginning; thence to the place of beginning; to be and remain henceforward a separate county, to be called the county of Monroe.

* * * * * * * * * *

Given under my hand and the great seal of said Territory, at Detroit, this fourteenth day of July, A. D. one thousand eight hundred and seventeen, and in the fortieth year of the Independence of the United States of America.

LEWIS CASS."

An inspection of the present map will show that as thus outlined the county was much larger, upon the north and west particularly. A second proclamation, issued five years later, reduced it to its present limits, but attached to it the county of Lenawee, from which it was separated in 1826.

"The county of Monroe, established by an executive act of July 14, 1817, shall be bounded as follows:

Beginning at the boundary line between the United States and the province of

TABLE I.—*Statistical data of Monroe County, Michigan.*

| No. | Township. | Tier south. | Range east. | Population, 1894. | Area in acres Supervisors' assessment, 1896. | Acres in farms. 1898. Improved. | Acres in farms. 1898. Unimproved. | Number farms. 1898. | Average size of farms in acres. | Postoffices. |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Ash | 5 | ix | 2,039 | 22,485.99 | 13.818 | 3,877 | 251 | 70 | Carleton. Grafton. |
| 2 | Bedford | 8 and 9 | vii | 2,075 | 25,100.35 | 15,455 | 4,153 | 291 | 67 | Samaria. Temperance, Lambertville. |
| 3 | Berlin | 5 and 6 | ix and x | 1.850 | 22,334.17 | 7,326 | 2,387 | 58 | 167 | South Rockwood. Newport. |
| 4 | Dundee | 6 | vi and vii | 3,303 | 29,828.48 | 20,000 | 9,000 | 665 | 44 | Dundee, Rea. |
| 5 | Erie | 8 and 9 | viii | 1,476 | 18,356.15 | 11,960 | 505 | 153 | 81 | Erie. |
| 6 | Exeter | 5 | viii | 1.912 | 22,811.79 | 14,975 | 4,166 | 266 | 72 | Exeter, Scofield, Maybee. |
| 7 | Frenchtown | 6 and 7 | viii, ix, x | 1,958 | 29,425.23 | 18,629 | 3,115 | 261 | 83 | Brest, Steiner. |
| 8 | Ida | 7 | vii | 1,594 | 23,409.75 | 14,768 | 4,122 | 261 | 72 | Ida. Lulu. Morocco. |
| 9 | LaSalle | 7 | viii and ix | 1,333 | 16,109.55 | 12,638 | 2,307 | 183 | 82 | LaSalle, Yargerville. |
| 10 | London | 5 | vii | 1,373 | 22,596.91 | 10,777 | 4,480 | 201 | 76 | London, Oakville. |
| 11 | Milan | 5 | vi | 2,105 | 22,506.63 | 12,239 | 1.510 | 161 | 85 | Milan, Azalia, Cone. |
| 12 | Monroe | 6 and 7 | viii and ix | 6,490 | 13,271.07 | 7,328 | 1,980 | 116 | 80 | Monroe. |
| 13 | Raisinville | 6 and 7 | vii and viii | 1,775 | 29,757.34 | 19,908 | 3,587 | 245 | 96 | Strasburg, Raisinville, Grape. |
| 14 | Summerfield | 6 and 7 | vi | 2,038 | 26,193.68 | 13,669 | 5,367 | 223 | 85 | Petersburg. |
| 15 | Whiteford | 8 and 9 | vi | 1,860 | 25,984.80 | 16,455 | 4,503 | 291 | 72 | Whiteford Center, Gert, Ottawa Lake. |
| | Totals | 5 9 | vi-x | 33,181 | 350,171.89 | 209,945 | 55,059 | 3,626 | 73 | 33 offices. |



Upper Canada, where the southern boundary of the county of Wayne intersects the same, thence with the said southern boundary, west to the mouth of the river Huron of Lake Erie; thence with the said boundary, keeping the middle of said river, to the line between the townships numbered four and five south of the base line; thence west to the line between the fifth and sixth ranges east of the principal meridian; thence south to the line between the Territory of Michigan and the State of Ohio, thence with the said line to the boundary between the United States and the province of Upper Canada; thence with the said boundary line to the place of beginning. * * *

In testimony whereof I have caused these letters to be made patent, and the great seal of the said Territory to be affixed. Given under my hand at Detroit, this tenth day of September, in the year of our Lord one thousand eight hundred and twenty-two, and of the Independence of the United States the forty-seventh.

LEW. CASS.

§ 6. Indian occupation.

The earliest inhabitant, of whom we have any definite traces in southeastern Michigan, was the so called "Mound Builder." If the Palæolithic man of Europe had any representatives in this region his remains and crude implements are yet to be discovered and identified. The tendency of recent investigations of the Ohio and Mississippi valleys is to destroy more and more, the gap between our historic, eastern Indian and the mound building type of savage who depended more upon the soil for his subsistence and defense. It must be admitted, however, that he was intellectually the superior of the Indians who dispossessed him of his fertile fields and drove him, probably southwestward. He cultivated the soil extensively, wove cloth, burned pottery, manufactured a superior stone implement and worked our copper mines for the red metal. For purposes of burial and sacrifice, and apparently for use as signal stations from which messages could be flashed across the country after approved modern methods, he constructed hemispherical and conical mounds of loose earth. Some very interesting mounds of this character along the St. Clair and Detroit rivers were explored thirty years ago by Henry Gillman, of Detroit, and described in publications of the Smithsonian Institution, the American Association for the Advancement of Science, and those of the Michigan Pioneer Society. At favorably located points fortifications were constructed, sometimes of great magnitude, displaying a surprising degree of military skill and testifying to the patience and industry of these people. Two semi-circular structures, now covered by the city of Toledo, were described by G. K. Gilbert, Vol. I, Geological Survey of Ohio, 1873. Although no mounds or fortifications are known within the limits of our county, the characteristic implements are here found, and we are certain that this interesting type of savage man roamed its forests, drank from its clear springs and navigated its waterways. History opens with tribes of the great

Algonkian nation in possession of this region; the Ottawas, Chippewas and Pottawattomies. The Wyandottes, or Hurons of the French, originally dwelt upon the St. Lawrence and are believed to have their descent from the powerful Iroquois of New York. They were, however, attacked by the latter, driven to Michigan and continually persecuted by them, being at one time almost annihilated.

§ 7. Early settlements.

Col. Francis Navarre is credited with being the first white settler within the present limits of Monroe county. He settled in 1780 near the mouth of the River Raisin, known by the Indians as "Namet Cybi," and in 1785 secured from his "Pouteouatamie" friends a deed to a considerable tract of land, lying south of the river, which land is still largely held by his descendants. In 1784 over one hundred families of Canadian French arrived and founded Frenchtown, upon the north bank of the Raisin, opposite Monroe. The same year other French families settled along the creeks to the north and south.

§ 8. War of 1812.

This part of Michigan was a portion of New France up to the year 1763, when it came into possession of the British and was actually held by them until 1796, although nominally transferred to the United States in 1783, at the clase of the Revolution. By Hull's Treaty of Detroit, in 1807, the Indian titles to lands in the county were extinguished, except nine sections of land upon the Macon reserved for the above four tribes. Encouraged by the British these Indians became unfriendly and during the War of 1812, the eastern part of the county became the scene of bloody hostilities. Marching to the relief of Detroit Gen. Winchester, with 1,000 Kentucky troops, was surprised January 22, 1813, by British and Indian allies and suffered a most crushing defeat; nearly all being killed or captured. The scene of the battle and the terrible massacre, was on the banks of the Raisin, about a mile east of the site of Frenchtown, but as the river was frozen it extended southward as far as the poor soldiers succeeded in eluding their savage pursuers. Gen. Winchester, who was spending the night at the cabin of Col. Francis Navarre, was himself captured and taken to Fort Malden, Canada. "Remember the Maine" is but a paraphrase of the Kentuckians' "Remember the Raisin," used later as a battle cry. In 1818 the bones of the unfortunate troops were collected and buried with



honors at Detroit in the Protestant burying ground. In 1849 they were transferred, along with others from the battlefield, to Frankfort, Kentucky. The disgraceful surrender of Detroit in August, 1813, was followed within less than a month by the glorious naval victory of Commodore Perry and the stars and stripes again soon floated over the city. Five times had the flag changed within the half century.

§ 9. Growth of population.

These frontier troubles and the malicious report of the government agents in regard to the soil and climate of this portion of the State had much to do in retarding its development. The entire white population of the territory in 1800 was 551, in 1810 but 4,762, of whom nearly one-third were in Monroe county. During the next ten years it increased to 8,896 only, but jumped to 31,639 from 1820 to 1830. In the decade during which the territory acquired statehood, the growth in population was most surprising, reaching 212,267 in 1840. Owing to its fertility, location and natural resources Monroe county had more than its share in this increase. The following table tells the story of its gradual development:

| | |
|---|---|
| 1810— 1,340 | 1860—21,593 |
| 1820— 1,831 | 1864—22,221 |
| 1830— 3,187 | 1870—27,475 |
| 1837—10,611 | 1874—30,111 |
| 1840— 9,922 | 1880—33,624 |
| 1845—13,861 | 1884—33,353 |
| 1850—14,698 | 1890—32,337 |
| 1854—18,030 | 1894—33,181 |

§ 10. Southern boundary.

Before the present boundaries of the county were finally established the question of the line between the State of Ohio and Michigan Territory had first to be settled and this brought on the temporary turmoil, known as the "Toledo War." The celebrated "Ordinance of 1787," by which the Northwest Territory was organized, provided that the boundaries should be altered "so as to form one or two states in that of the said territory which lies north of an east and west line drawn through the southerly bend, or extreme of Lake Michigan." The map which was then regarded as official was the "Mitchell map," published in 1755 before any accurate survey of the lake had been made, and this map represented Lake Michigan as terminating at latitude 42° 20′ N. This line passes through the city of Detroit and if the apparent intention of the framers of the ordinance had been carried out the writing of the geological history of Monroe county would have been done by the Ohio Survey. It was ascertained later that Lake Michigan extended much further south and that this east and west line would somewhere strike the western or southern shore of Lake Erie. The act of the Senate and House of Representatives of 1802, authorizing the State of Ohio to form a constitution and state government, placed the boundary "on the north by an east and west line drawn through the southerly extreme of Lake Michigan, running east, after intersecting the due north line aforesaid, from the mouth of the Great Miami, until it shall intersect Lake Erie, or the territorial line, and thence, with the same, through Lake Erie, to the Pennsylvania line aforesaid." The constitution of Ohio provided, however, that if this line should intersect Lake Erie east of the mouth of the Miami of the Lake (Maumee), then the northern boundary should be a line run direct from the southern extreme of Lake Michigan to the most northerly cape of the Miami (Maumee) Bay. The acceptance of the Ohio constitution, containing this clause, was regarded by the State as authorizing this boundary line, although not so regarded by Congress itself. This line was run in 1817 by surveyor Harris and was known as the "Harris Line." The line claimed by Michigan, namely, that drawn due east from the southerly extreme of Lake Michigan, was known as the "Fulton Line" and between them there was included the strip of land in dispute five miles broad at the west, eight miles broad at Lake Erie and about seventy miles long. Perhaps no serious differences would have occurred between the territory and state if the Erie canal from Cincinnati had not been headed for Toledo, which it would make its northern terminus with all the supposed advantages only on condition that it was a part of Ohio. The attempt to re-mark the Harris Line in 1835 precipitated trouble, the militia from each section being called out and brought almost face to face with one another. Michigan was, however, applying for admission to the union of states and was compelled by Congress to accept as its southern boundary the line claimed by Ohio. This it did most reluctantly and was given as a reward to soothe ruffled feelings, the entire upper peninsula.



### *C. Geological Work within the County.*

§ 11. Previous work.

Nothing in the way of systematic geological exploration was attempted in the region covered by this report so long as Michigan remained a territory. Something was known, however, of its natural resources and the pioneers and traders had begun to utilize its economic products. The principal limestone outcrops had been located and rock removed for lime and building purposes. Quarries had been opened in the Raisin bed at Monroe and Dundee, also in the beds of Swan, Stony, Plum and Bay creeks, upon the Macon and at the head of Ottawa lake. In the region of the natural outcrops, particularly upon the "ridge," stone had been superficially quarried. Lime had been burned upon Plum Creek, at Ottawa Lake and at the Macon quarries. The bed of glass sand seven miles northwest of Monroe had been opened and found to produce a good quality of glass. Brick had been burned at Newport, Brest, Dundee and in London township, upon the Saline. The salt springs along the latter stream were known and utilized in an early day by both Indians and settlers.

§ 12. Houghton survey.

Upon the acquisition of statehood Michigan immediately established a "Geological Survey," the act of the Legislature being approved by Gov. Mason, February 23, 1837. Dr. Douglass Houghton was appointed State Geologist, with Bela Hubbard and C. C. Douglass, Assistant Geologists, and S. W. Higgins, topographer and draughtsman. During the summer following a hasty examination was made of the county by Dr. Houghton, having chiefly for its object "the determination of the rock formations, their extent and order of superposition." Under the head of the "Grey Limestone" he speaks of its outcropping edge as extending from the rapids of the Maumee to those of the Raisin, "which may without doubt, be considered identical with the mountain limestone of European geologists."*

The silicious nature of the limestone encountered in ascending the Raisin was noted and from such beds the glass sand layer was stated to have been derived by disintegration. Calcite, as "hog tooth spar" was observed at Monroe; celestite and tremolite (strontianite?) at

*1838. Report of the S. G. (first annual.) H. D. No. 24, pp. 276-317; separately, No. 14, pp. 1-39; p. 7.

Brest. The deposits of marl and the mineral springs to the south of Monroe were briefly described. Brine was stated as occurring north of a line drawn from Monroe to Granville, Kent county, which line strikes across the county just south of its northwest corner. As an appendix to his first report, Dr. Houghton published a series of suggestions to those residents disposed to assist in the work (In Senate, February 1, 1838), and 115 questions pertaining to the bed rock, soils, water supply, subterranean forests, peat, marl, iron ore, streams, lakes and surface boulders.

The detailed study of Monroe county was assigned to the assistant Bela Hubbard and was reported upon in the Second Annual Report, February 4, 1839.*

The general topography of the surface, its springs and streams, the soils, subsoils, and timber were studied and described. The natural and artificial rock exposures were visited and the strata determined to be dipping northwest, or northwest by north, at an angle of about 5°. This dip was afterwards† lessened to 15 feet to the mile, but found to vary from 10 to 20 feet.

No attempt was first made at the correlation of these strata with one another, or with those of other regions. Beds of peat and marl were located and their use in the amelioration of the natural soils repeatedly emphasized in the reports. The "Lake ridge," which cuts across the northwestern corner of the county, extending for many miles in either direction, was correctly interpreted as marking the former extension of the lakes. The abrupt change which here occurs in the topography, as well as in the character of the soil and the timber was noted and clearly understood. The surface boulders were termed "erratics" and were recognized as having been transported by some imperfectly understood agency from the north. The surface scratches upon the limerock at Brest and Point aux Peaux were measured and found to be N. 50° E., N. 60° E., N. 65° W. They were ascribed to the "attrition of hard bodies moving in a strong current," (p. 113). In the same report (Second, p. 65), Higgins announces the completion of his topographic map of the county, but if it was ever published all trace of it seems to have been lost. It was very probably similar to his map of Wayne county which appeared the next year in the Third Annual Report.‡

*Second annual report of the State Geologist. H. D. No. 23, pp. 380-507; S. D. No. 12, pp. 264-391.

†Fourth Annual Report, p. 135; H. S. and J. D. No. 11, pp. 472-607, separately H. D. No. 27, pp. 1-184; p. 135.

‡Annual report of the State Geologist (third, map of Wayne county); H. D. No. 27, Vol. II, pp. 206-293; S. D. No. 7, Vol. II, pp. 66-153, separately No. 8, pp. 1-120.



A still more detailed study of the geological features of the county was made by Hubbard and further reported upon in the Third Report, above referred to. The limestone was stated to occupy a horizon higher geologically than the blue limestones and shales of Cincinnati (Hudson River Group), but to be below the "black strata" (St. Clair shale), and without doubt is equivalent in position to the "Cliff limestone," of Indiana (p. 83). Three belts of rock, with quarries and outcrops, were recognized as crossing the county in a northeast and southwest direction. The most easterly, and consequently the oldest, is described as a compact limerock, light gray to blue in color, sometimes veined, sometimes oölitic, and carrying distinctive fossils. The most westerly range, highest both topographically and geologically, is somewhat sparry, geodiferous and bituminous, carrying some fossils of a different species from the former. The middle range consists of highly silicious rock, passing into pure sandstone. The individual grains of the glass sand he recognized as consisting largely of perfect quartz crystals. The term "diluvium," or "diluvion" was applied to what is now known as the "drift," made up of "detritus of the upper portion of our coal series, which has been broken up and washed away, and in part of sands and fragments of the primary rocks, transported from a more northerly region." (p. 83). The following, quoted from page 89 of this report, is of interest since it furnishes a clear, concise statement of the views held sixty years ago, and not yet entirely discarded, concerning the origin of this "diluvium."

> "It has been already remarked that in general all the rocks are covered with a mantle of clays, fine detritus of the lime and sand rocks, or loose water-worn fragments of still older rocks, swept from the north by the currents of a universal ocean and deposited during the general subsidence. Some evidences of the direction of these currents were noticed in my report of last year. Among these are the diluvial furrows and scratches on the surface of the limerock, the appearance and direction of which correspond with observations made in some of the more eastern states."

Allusion is made in the next report (Fourth p. 116), to Lyell's iceberg theory, as though the above explanation was not entirely satisfactory. In discussing the origin of the erratics he remarks that they came from the north "Whatever may have been the causes which swept these materials over the face of the rocks, whether oceanic currents or bodies of *floating ice.*"

Owing to the inaccessibility of the reports of this first geological survey Hubbard is not generally credited with the work which he did in the way of deciphering, at this early day, the history of our great lakes. Mention will be made of this again in connection with the glacial history of the county. The deposits from the ancient bodies of water he termed "alluvions" to distinguish them from the "diluvion" described above, and "ancient alluvions" to distinguish them from the "recent alluvions," now forming, or having been very recently formed, as marl, peat and bog ore. The "Tertiary clays" (till) were regarded as present in Monroe and Wayne counties, as well as over two-thirds of the lower peninsula. In the Fourth Report (p. 109) Douglass identifies certain limestones in the northern part of the peninsula as Corniferous, and correlates them provisionally with those of Monguagon (Trenton) and hence also with those on the Macon. The geological formations identified and differentiated by this survey, so far as Monroe county is concerned, are shown below.

6. Recent Alluvions.
5. Ancient Alluvions.
4. Diluviums, or Erratic block group.
3. Tertiary clays.
2. Black aluminous slate.
1. Limerocks of Lake Erie.
    c. Corniferous.
    b. Silicious limestones, passing into sand.
    a. Compact gray or blue limestone.

§ 13. Winchell Survey.

With the accidental drowning of Dr. Houghton in Lake Superior, October 13, 1845, further geological work ceased in this region and was not resumed again until the Second Geological Survey was organized by Dr. Alexander Winchell in 1859. In the meantime new outcrops had been discovered, new quarries had been opened and old ones deepened. Many wells had penetrated to the rocks, giving information in regard to the surface deposits and in regard to the rocks themselves. Much geological and palæontological work had been done in New York, and Canada, calculated to throw light upon Michigan geology. Dr. Winchell began his field work in May, 1859, with a re-examination of Monroe county, assisted by two of his students, Messrs. A. D. White and Lewis Spalding. Owing to the large amount of territory to be covered, only a short time could be devoted to this region. The First Bien-



nial Report, published in 1861, contained the results of this field work* (pp. 58-68). The light colored, argillaceous limestones of the Davis quarry, west of Ida, were identified as those of the Onondaga Salt Group, on account of the gypsum present. The same beds were believed to appear at Ottawa Lake and to be struck in the deeper portions of the Plum Creek quarries, and the suggestion is made that gypsum be sought for at these localities, as well as in the gorges of Otter Creek. The thickness of the Onondaga in Monroe county is given as 24 feet; the first 10 feet of which is a chocolate colored limestone, the remainder fine ash colored, argillaceous limestones, with acicular crystals (p. 140). The Upper Helderberg is given a thickness of 60 feet in the county, and was made to include the brecciated dolomites of Stony Point and Point aux Peaux, the two beds of oölite, the Sylvania sandstone and the purer limestones on the Macon.

The work of the survey was interrupted by the War of the Rebellion and not resumed again until 1869, with Dr. Winchell again State Geologist for two years. Materials for a valuable volume were prepared but were never published in the manner intended. Some of it, however, appeared in Walling's Atlas of Michigan and was subsequently put out (1873), as a small volume bearing the title "Michigan." The occurrence of the Lower Helderberg (Waterlime) had been announced in 1870. This formation was recognized in the quarries in the eastern part of the county and considered to attain a thickness of 60 feet. The geological map which accompanies the volume gives a narrow strip of Lower Helderberg, three to four miles wide, following the shore of Lake Erie, with a broad belt of Corniferous to the west and embracing nearly the entire county. Small islands of Salina, with marginal strips of Lower Helderberg, are represented at Ida and Ottawa Lake, and apparently also at Monroe and Brest. The Little Traverse appears as a narrow belt, with the general strike and position which the Corniferous ("Dundee") is now known to possess, while the Huron shale covers the remaining northwest corner of the county. This corner is just grazed by the Marshall sandstone. The formations which overlie the Lower Helderberg are thus seen to be displaced to the east. The following "generalized section" was intended to include all the Monroe county beds, except-

*1861. First biennial report of the progress of the G. S. of M. Embracing observations on the Geology, Zoology and Botany of the Lower Peninsula. Made to the Governor Dec. 31, 1860.

ing the Little Traverse and Huron, which are not here known in outcrop.

IV. Brown bituminous limestones, seen in most of the quarries of Monroe county; also in Presque Isle and Emmet counties, 75 feet.

III. Arenaceous limestone, sometimes resolving itself into beds of friable sandstone and incoherent sand. Monroe county; also Crawford's quarry, 4 feet.

II. Oölitic limestone, as in Bedford and Raisinville, Monroe county, 25 feet.

I. Brecciated limestone, sometimes concretionary, 50 feet.

§ 14. Rominger survey.

Dr. Carl Rominger began his examination of the rocks of our southern peninsula in 1873, making a detailed, careful study of all the beds and their fossil contents. The results of his three years' personal work are recorded in Vol. III, Geological Survey of Michigan, 1876. That portion of the report which deals with the rocks of Monroe, and the adjacent portions of Wayne county is recorded on pages 25 to 37. The limestones of this region he described under the single heading "Helderberg group," but recognizes an upper and lower division, equivalent to the Upper and Lower Helderberg respectively. The lithological characters of the beds are accurately noted and simple analyses given of the more important, some of which will be incorporated into this report. The Sylvania sandstone he gives a thickness of but 8 to 10 feet and, following the earlier reports of the Ohio Survey, regards it as probably the equivalent of the Oriskany sandstone, of New York (p. 29). The oölite of Plum Creek and Little Lake he regards as the geological equivalent of the sandstone (p. 28), being misled by the beds of mottled dolomite which underlie each, but which are actually many feet apart. A still more serious error was made in bringing the base of the Upper Helderberg down to the top of the Sylvania sandstone, based upon the lower percentage of magnesia in these beds. The quarries of Ottawa Lake, Little Sink, Lulu, Ida, Raisinville, Woolmith and Flat Rock are all in beds above the Sylvania and still contain practically enough magnesia for normal dolomite. Both lithologically and palæontologically these beds immediately above the Sylvania must be connected with those beneath.*

Dr. Rominger does not admit the occurrence of the Hamilton

*See Geological Survey Ohio, Vol. VII, p. 47.



(Traverse) in this portion of the State (p. 38), believing that from the thickness of 500 feet near Alpena, it thins out completely before reaching the southern boundary. Reasons will be given later for thinking that the Traverse is well represented beneath its heavy mantle of drift in the northwest corner of the county. Upon the geological map that accompanies Vol. III the structure of Monroe county is much simplified by uniting the Upper and Lower Helderberg into one division, not representing the Sylvania and imposing the St. Clair shale directly upon the Upper Helderberg.

§ 15. Work of present survey.

While searching for natural gas in the early fall of 1887 at the plant of the Eureka Iron and Steel Works, in Wyandotte, the drill from 730 to 1,235 feet passed through a series of layers of pure rock salt. The newspaper announcements of this incidental discovery caught the eye of interested parties in the East and experts were soon upon the ground. The remarkably pure beds of limestone, two miles distant, combined with unusual shipping facilities, made the region almost an ideal one for the manufacture of soda ash and caustic soda. Establishment after establishment has sprung up along the Detroit River, representing millions of outside capital and employing an army of workmen. Other extensive plants are seeking locations and are inquiring for high grade limestone. The rapid development of the Portland cement and beet sugar industries in our State has greatly increased the demand for natural products.

The records of the Wyandotte well above mentioned and of a well at Monroe down into the Trenton which were collected during the administrations of State Geologists C. E. Wright and M. E. Wadsworth were printed in Part II. of Vol. V of the State Reports. There is also a geological map of the lower peninsula in this volume, which shows the course of the Sylvania sandstone, and the terms applied to the various members of the rock series which we use. During this time the records of the Dundee and other wells were acquired by the State Survey, and by the spring of 1896 it was decided to arrange for a thorough survey of this most promising corner of the State and to render available at once, by means of a bulletin, what could be learned of its resources. The work was begun under Dr. Lucius L. Hubbard and after his resignation, continued and completed under the present organization. July and August, 1896, and August, 1897, were devoted to the field work by the writer, assisted the first season by Mr. W. D. Cramer and later by Messrs. R. R. Putnam and De Forest Ross. For purposes of comparison, a careful study was first made of the extensive Sibley quarry, north of Trenton, and of the smaller quarries and outcrops about the Detroit River. Within the county every known natural and artificial exposure of the rocks was visited, the strata studied, samples and fossils collected and each quarry platted. From convenient centers, a study was made of the soils and their distribution and much detailed information gathered in regard to the depth and character of the rocks, the nature of the drift deposits, water supply, timber and crops, indications of oil, gas, etc. From Ottawa Lake a side excursion was made into Ohio to examine the exposures of the Sylvania sandstone and adjacent strata. The delay in the publication of the bulletin necessitated a final general survey of the county, in order to bring the information to date and nearly two weeks in September, 1899, were devoted to this purpose. The Raisin was found to be exceptionally low and a favorable opportunity was afforded for studying the strata over which it flows. As to the results secured and conclusions reached the body of the report must be allowed to speak.

§ 16. Acknowledgments.

It is a pleasure to acknowledge here the uniformly courteous treatment received from the farming population of the county. Much of this report has been rendered possible only through information received from them. Only in a few cases, where they feared that they were being victimized by some new scheme, was information withheld or grudgingly given. It is hoped by getting the benefit of generalizations, based on their combined knowledge, that they may be, in part, at least, repaid. The numerous well drillers, with but a single exception, have given their valuable information, the result of years of labor and the expenditure of much money, freely and gladly. Especial acknowledgment is due Mr. John Strong, of South Rockwood, and his driller Mr. H. S. Dalton, for information and series of samples of the Newport well. To Church & Co., through their courteous manager Mr. K. J. Sundstrom, the survey is very especially indebted for maps, charts, negatives, analyses, and valuable information pertaining to the region, with every facility for the study of their extensive Sibley quarry. The same generous treatment was accorded by Mr. G. F. Smith, at the time president of the Michigan Stone & Supply Co., and by the offi-



cers of the Monroe Stone Co. We are indebted for our topographic base very largely to the county atlas published by Geo. A. Ogle and Co., of Chicago in 1896. Finally, to Mr. Ezra Lockwood and family, of Summerfield township, grateful acknowledgment is made for generous hospitality, conveyances and valuable information, the result of many years' intelligent observation and experimentation in the prairie region.

# CHAPTER II.

## DEVONIAN AND QUATERNARY FORMATIONS.

### *A. Quaternary Deposits.*

§ 1. Thickness.

Except over areas covering but a few square yards, the rock beds of the county are concealed by a mantle of more or less unconsolidated material, varying in thickness from a few inches to about 150 feet. The average depth would probably be from 40 to 50 feet, although there are many square miles within which the depth to the rock is less than 25 feet. The deepest beds of this covering are found in the northwestern corner of the county, where just southwest of Milan, they reach a thickness of 150 feet. In the southeastern part of Erie township a thickness of 80 to 90 feet is attained. Extending in a northeast and southwest direction there are three belts along which this superficial covering is very much less, in some instances being practically absent and thus exposing the bed-rock. The most easterly belt of the three begins in the southern part of Whiteford township, extends northeastward across Bedford, northwestern Erie, the western part of La Salle, through the city of Monroe to Brest and into the eastern part of Berlin township. Throughout this entire extent the deposit rarely exceeds ten feet in thickness and is on an average much less, hence it is accompanied by numerous quarries and natural rock exposures. The middle belt is approximately parallel to the eastern just located and extends from Ottawa Lake sink, through the northeastern corner of Whiteford, across Ida, western Raisinville into the southern part of Exeter township, beyond which the deposit increases to 30 to 40 feet. Upon the map (Plate XV), there is shown by means of the contour lines, the depth of the rock from the general surface of the land. These contours thus show, also, the thickness of these deposits referred to. Just where the sand accumulations of the Forest Beach are added to



those of the clay, an apparent deepening of the rock occurs as shown by the contours on either side of Lambertville and in Sections 19, 20 and 21, of Ida township. The third belt is less well defined, shorter and more interrupted, the thinner portions of the drift being located at Petersburg, Dundee and on the Macon, where it is but two feet thick.

§ 2. General nature.

The great bulk of the deposit above referred to constitutes the so called "drift," an accumulation for which the great continental ice sheet, to be later described, was responsible. This consists, in the main, of a great mass of stiff, blue clay, entirely without stratification and carrying varying proportions of sand, pebbles and boulders. This is technically known as "till." When thoroughly compacted and filled with stones it is popularly called "hard-pan," in which form it greatly retards the operations of ditching and well digging. Upon exposure to the atmosphere, as at the surface or by means of a natural or artificial excavation, the color changes from blue to yellow or a rusty brown, owing to the oxidation of the iron. The alteration in color may extend but a few inches, or it may reach to a depth of fourteen feet or more, as about Dundee. The change in color marks the lower limit of percolating surface water, which depends upon the structure of the bed itself. Embedded in the clay there are frequently encountered lenticular masses of "quick sand," more or less stratified and of varying thickness and extent. Less frequently beds of gravel, from fine to coarse, are encountered, but are probably not continuous under any considerable area. Some of the deposits reported as "gravel" by farmers and drillers are beds of sand simply, or till rather more heavily charged with pebbles than is usual. This is probably true of the beds of "cobble stones" reported as occurring at a depth of 25 feet in Sec. 20 (S. W. ¼, S. W. ¼) of Ash. At the bottom of wells in Sections 4 and 6, and in Sec. 20, at a depth of 30 feet, Milan township, a bed of gravel is reported. In Section 9, still nearer the surface, a three foot bed is said to occur, overlain by 13 feet of clay and underlain by hardpan. Southward in Dundee township, Section 8 (T. 6 S., R. 6 E.), gravel was encountered at 28 feet, and in Section 26 was found overlying the rock. Eastward in London township, Sec. 20, a fifty foot well stopped in gravel. In Summerfield township similar reports of gravel strata were obtained from both farmers and drillers. It overlies the rock in Sec. 4, with a heavy bed of blue clay above, but is struck in Sec. 7 at a depth of 14 to 16 feet and furnishes water at the place of T. M. Taft. In the same section (N. W. ¼, S. W. ¼), at John Long's place, coarse gravel was reached at a depth of 53 feet, overlain by a three foot bed of "putty clay." The gravel was penetrated three feet and the well abandoned because the hole could not be kept clean. In Sec. 27 there is on an average 1½ feet of a sandy loam, one to six inches of blue clay and beneath a stratum of rounded pebbles varying from the size of a pea to that of the fist. The layer is four to six inches in thickness, but may be represented by a few stones simply. Beneath this is a heavy deposit of yellow, followed by blue, clay and hard pan. In Bedford township, Sec. 4 (N. E. ¼, N. W. ¼), a 3 to 4 foot bed of gravel is stated to overlie the rock, which is struck at 26 feet. With the exception of the last record all the reputed layers of gravel occur within the limits of Summerfield, Dundee, Milan and London townships. Some of them may be merely inclined gravel filled fissures or cracks.

§ 3. Boulders.

Scattered rather sparingly over the clay areas of the county are rounded masses of crystalline rocks, such as are known in place—nearest in Canadian regions to the northeast. In the western and northwestern portions of the county they repose directly upon the surface, but eastward are more and more embedded in the soil and frequently struck only with the plow. They consist in the main of gneisses, schists, diorite and diabase, and, occasionally, limestone, sandstone, and conglomerate. A well known type of the latter is represented by a boulder 6x3x2½ feet lying along the roadside at the S. W. ¼, N. W. ¼, Sec. 3 Milan. It contains rounded pebbles of brown and bright red jasper, very characteristic and readily recognized. The parent bed is in western Ontario, north of Lake Huron, and its fragments are found in Ohio, Indiana, Illinois, Wisconsin and even so far south as Kentucky and west as Iowa. In size these boulders vary from cobble stones, and less, up to masses weighing many tons. One of the largest in the county, and probably the largest in this section of the state, lies about one and one-half miles east of the village of Ida, upon the farm of Christopher Knapp, claim 521. It is an enormous mass of hornblendic gneiss, contorted, of a light gray color, having a length of 20 feet, maximum breadth of 15 to 16 feet and standing four feet above ground (See Fig. 1). Presumably there



Fig. 1. Mammoth boulder transported by the great ice sheet and dropped east of the site of Ida. Four feet above ground: twenty feet long.

is as much or more below the surface as there is above, and it can scarcely weigh less than two hundred tons. A large fragment of what appears to be identically the same rock lies upon the S. E. ¼ of Sec. 27, Whiteford township, farm of F. B. Doty. The boulder is 6x10x3½ feet and there is said to be as much rock beneath the surface as in sight. Smaller fragments of the same rock are seen farther south.

A mass of limestone, large enough to be mistaken for an outcrop, lies in the western part of Frenchtown township, upon the property of Alexander Stewart (claim 21, N. River Raisin). It formerly projected above ground but building stone has been removed from it and there is now an opening into it 10 by 18 feet, containing three to four feet of water. It is of a light gray color, has a strong bituminous odor, is rich in corals and brachiopods and effervesces vigorously in dilute acid. It lies directly over a bed of sandy dolomite, very different in its nature from this material. Mr. Frank G. Strong, of Monroe, at one time did some boring about the mass and informs me that upon one side only was rock struck with the auger. It seems very probable that we have here an unusually large mass of Corniferous limestone, which was pushed, or carried, beneath the ice sheet from a point a few miles to the northeast and finally left embedded in the clay. In 1865 Winchell described numerous masses of exactly this nature, occurring in the northern part of Lenawee and Hillsdale counties, the southern and eastern portions of Jackson and southern and western Washtenaw.* These masses were occasionally so large that they were mistaken for outcrops, lime-kilns were erected and lime burned until the supply of stone was exhausted. From an examination of their fossil contents Winchell identified them as Corniferous and concluded that their state of preservation was such that they could not have been transported from the outcrops of this formation known to occur about Mackinac. All the masses of this nature then known lay to the north of the Corniferous outcrop in southern Michigan and northern Ohio and Indiana. The conclusion was reached that they had been frozen into the shore ice of a lake or sea, detached and floated northward, where they were gently dropped upon the melting of the ice floe. The evidence of a northward transportation of drift was further strengthened by the finding of delicate Hamilton and Marshall fossils as much as thirty miles north of the

*Some Indications of a Northward Transportation of Drift Materials in the Lower Peninsula of Michigan. Am. Jour. of Sci., Second Series, Vol. XL, pp. 331 to 338.



southern outcrops of these beds. In the case of the Stewart boulder described, we have an apparently identical mass of limestone lying to the south of the outcrop supposed to have furnished the others. The position of the Corniferous, Hamilton and Marshall beds in eastern Michigan and western Ontario is such that a movement of the ice sheet S. 60° W. would account for the location of the most northern masses described as occurring in this portion of the state, with a maximum journey less than one-half that required to bring them from the northern outcrops. At Stony Point Winchell found glacial striations bearing S. 60° W. This same set occurs at Point aux Peaux, and strikes S. 65° W. at Brest, according to the earlier observations of Hubbard. The glacial striæ, however, found at Trenton and several localities in Monroe county show conclusively that the ice sheet itself actually moved northwestward upon the northern side of the Erie lobe (Chapter VI, § 7), so that the journey made by the rock masses may have been a still shorter one. Much more extensive masses of the same character occur in northern Illinois near Freeport and were described in 1897 by Hershey in a paper upon "The Eskers of the Kansan Epoch."* These are referred to later by Leverett in his recent monograph on the Illinois Glacial Lobe under the heading "Transported rock ledges."† Some of these masses have not been so gently handled and consist in part of angular fragments of the limestone. Two of the largest taken together are stated to cover 100 acres and to attain a maximum thickness of 40 feet. According to Hershey they were pushed along in front of the ice and were never overridden by it.

Only in Berlin and eastern Frenchtown is there any bunching of this surface material sufficient to suggest a morainic deposit. From Stony Point northward the boulders are more abundant, especially upon the "ridge," where the covering of clay is light. In several places the ground is greatly encumbered with cobble-stones, especially upon claims 528, 529, 530 and 531 (N. Stony Creek). In Berlin township, S. W. ¼, Sec. 33, the same cobbles occur in great abundance. It will be shown in another connection that these deposits mark the southern prolongation of a well defined, water-laid moraine, extending from the Huron River northward past Trenton, towards Detroit. (Chapter VI, § 8.)

*American Geologist, Vol. XIX, pp. 197-209, 237-253.
†The Illinois Glacial Lobe. Monograph XXXVIII, U. S. Geol. Surv., 1899, pp. 82-84.

§ 4. Post-glacial deposits.

Under the head of Quaternary belong not only the drift deposits described but others of an entirely different nature and history, which will be only briefly referred to here. Spread over nearly the entire till area of the county, is a layer of dark clay loam; very thin or absent in the western part, but increasing in thickness toward the east and southeast. Its absence over certain areas may be due to erosive agencies. It is quite free from pebbles, shows no distinct stratification, owes its dark color to organic matter and is, agriculturally, of very great importance to the county. No sharp line of demarcation exists between this superficial deposit and the underlying till, one seeming to grade into the other.

Passing northward from Sylvania, Ohio, to Oakville is a broad, irregular belt of surface sand, varying in breadth from two to eight miles. In many places the sand has been heaped up by wind action into mounds and ridges, the latter of which sometimes squirm across several adjoining sections. Near Temperance there branches off from this main belt a secondary one, extending northeastward to Carleton and beyond (See map, Plate VII). This is narrower and much more irregular, but otherwise similar. Transverse belts of similar sand almost completely connect these two belts in Raisinville and Exeter townships. From Milan village there extends southwestward across the township, through Dundee to the northwestern corner of Summerfield, a fairly continuous, but narrow strip of yellow sand, with occasional pebbly patches upon either side.

In addition to the clay and sand deposits of such wide extent, there are others, of a more local nature, to which attention may here be called. Along the rivers and smaller streams terraces of silt have been formed, of considerable breadth and thickness and consisting of clay, sand and organic matter. The surfaces of these terraces constitute the flood plains, in general, and receive slight additions with each inundation. Locally, where there have been lakes and marshes, or where these still exist, beds of marl, peat and bog-ore are found, or are now in process of formation. About some of the extensive springs, the waters of which are highly charged with lime carbonate, deposits of calcareous matter over leaves, twigs and moss, result in the formation of a "tufa."



*B. Devonian Formations.—St. Clair (Genesee) Shales.*

§ 5. General arrangement of Devonian formations.

If all the deposits which have just been described were removed and a general view could be had of the so called "bed rock," it would appear, approximately, as is shown upon the map (Plate I). This constitutes what is called a geological map, in which the belts of color represent certain groups of strata, which have a common structure, composition and history. Being formed within the limits of the same geological period certain distinctive names are assigned to these groups, or to their subdivisions. In Monroe County these strata all have a general northwesterly "dip," with their outcropping edges extending ("striking"), in a northeast and southwest direction. Obviously the strata which were latest formed are in the northwestern corner of the county and the next oldest, in succession, would be encountered as one passed southeastward, across the line of strike. This order of position will determine the order of description of the rock formations.

§ 6. Name.

The youngest member of this Monroe County series is the group of "St. Clair shales,"* so named from their occurrence along St. Clair River. They constitute the lower portion of Winchell's "Huron Group," described in his report of 1861 (pp. 71-80). In the early Ohio reports the beds are referred to as the "Huron shale," "Black shale," "Black slate," and "Shale stratum." Newberry in his report of 1873† describes two beds of shale, the Erie and Cleveland, which immediately overlie the Huron. These three were united by Orton into a single stratum which he termed the "Ohio Shale."‡ An upper and a lower division were recognized, for the latter of which he retained the name Huron shale, and it is this which forms the northwestern corner of Monroe County (See Map I). It is probably nearly equivalent to the Genesee shale of the New York series.

§ 7. General data.

Only about seven sections of the northwestern corner of Milan township are underlain by these shales, the main portion of the stratum lying in Lenawee and Washtenaw counties, and dipping at a low angle to the northwest. They are covered by 100 to 150 feet

*Geol. Sur. of Mich., Vol. V, 1895, pt. II, p. 21.
†Geol. Sur. of Ohio, Vol. I, pp. 152-167, 189-191.
‡Geol. Sur. of Ohio, Vol. VII, 1893, pp. 21-26.

of drift and so are struck only in the relatively deep wells of this region. The actual elevation of the base of the stratum is about 560 feet above tide at Milan (18 feet below the level of Lake Erie), while the elevation rises to 610 feet where it leaves the county. The highest elevation noted is in the extreme northwestern corner of Section 6, where it is about 625 feet above tide. Winchell gives an outcrop of shale of his Huron group as occurring near Adrian, Lenawee County.* If such an outcrop occurs the shales cannot be the St. Clair since these were struck in the well of the Adrian Gas Company at a depth of 524 feet from the surface. Good exposures, however, are found northward about the shores of Lake Huron and along some of the small ravines leading back from the lake.

§ 8. Thickness.

In the Adrian well above referred to, the shales regarded by Lane as the St. Clair show a thickness of 221 feet.† At Ann Arbor in the court-yard well, they appear to have a thickness of 275 feet, according to the same authority.‡ In Ohio these shales show a development of about 300 feet and in western Ontario at Corunna, Lambton county, 213 feet. At Sarnia, according to Brumell, they are reduced to 80 feet. The base of the bed at Ann Arbor has an elevation of 134 feet above tide; at Milan 560 feet, giving a drop in the fourteen miles, in this direction, of 426 feet, or about 30.5 feet to the mile.

§ 9. Lithological character.

Where well exposed, as upon Sulphur Island, Thunder Bay, these shales are seen to be black, very fissile, hard, crisp and sharp; approaching slate, when unweathered. They possess a certain amount of elasticity, and snap and crackle under the feet, as one walks along the beach. They are finely laminated and very evenly bedded. When exposed to the weather they assume a gray, or rusty brown color, from the oxidation of the contained iron. Efflorescences of sulphates of iron, or alumina, form over the surface where it is somewhat protected from the rain. The color becomes darker towards the bottom of the series, due to the greater amount of carbonaceous matter derived from vegetation. Such shales have an oily appearance and a strong bituminous odor. Beach fires on Sulphur Island are said to have burned as long as 16 months, although, ordinarily, the shales are incapable of sustaining combustion. The spontaneous distilla-

*First Biennial Report, 1861, p. 76.
†Geol. Sur. of Mich. Vol. V, Part II, Plate I.
‡Page 47.



tion of this organic matter has yielded large quantities of petroleum and natural gas, products almost always associated with the stratum, in New York, Ohio, Ontario and Michigan. Crystals of pyrite and nodules of marcasite are of common occurrence in the shales. The latter is especially subject to chemical decomposition, forming compounds of iron and sulphur, which stain the shale and impregnate the percolating water. Spherical to ellipsoidal concretions, varying in size from an inch to six feet in diameter, are found embedded in the mass of shale. These consist according to Rominger, of lime carbonate 89%, magnesium carbonate 2%, with 7.5% of insoluble, bituminous and silicious residue. Crystals of calcite and siderite, sometimes with fragments of organic remains, are found toward the center of each concretion. The shales themselves have yielded but few fossils, either in Michigan or Ohio, and those found are mostly of plants. Rominger reports subordinate seams of lime rock showing "cone-in-cone" structure.

A recent number of the Journal of Geology* contains figures and descriptions of the concretions by Reginald A. Daly. The composition is shown to be approximately the same as that given by Rominger. This author calls attention to the deformation of the shale on all sides of the concretion and concludes that they were formed in place within the shale, that they antedate the period of joint development and final consolidation of the shale, and that the deformation resulted from the energy of the process of crystallization, due to a change in volume when the original bicarbonate of calcium was converted into the monocarbonate.

§ 10. Geological position.

Reposing as these lower beds do upon layers of undoubted Hamilton, and with the characteristics above presented, it is exceedingly probable that they are to be correlated with the Genesee shale of central New York. The description of lithological characters would apply as well to the shales about Canandaigua Lake as to those of Thunder Bay. That they cannot be regarded as Marcellus, as has been maintained by some, is proven by their position above the Hamilton beds. As yet, however, the lower portion of the St. Clair has furnished no fossils with which to strengthen this lithological evidence of equivalency with the Genesee. For the last forty years the views of those who have worked in this lake region are not in

*February—March, Vol. VIII, No. 2, pp. 135-150. "The Calcareous Concretions of Kettle Point, Lambton County, Ontario."

reality widely divergent. In his report of 1861 (p. 79) Winchell, relying upon the evidence of Billings and Hall says: "In this state of the case we shall be constrained for the present to regard the Huron Group of Michigan, extending from the conglomerate above the gritstones of Huron county, to the top of the argillaceous limestones of Partridge Point, as probably representing the rocks of the Portage Group of New York." In a paper read before the Geological Society of America, in December, 1893, Brumell, of the Canadian Geological Survey, still refers this shale series to the Portage, but in his table includes the Chemung.* According to the later publications of the Ohio Geological Survey, Newberry did not sharply separate his Huron shale, from his Erie and Cleveland above it and in 1873† he reports the occurrence of diagnostic Portage fossils in the Huron, or lowest member of our St. Clair shale. In his chart of geological time, however, he drops the Huron shale to the level of the Genesee. In the Erie he found positive palæontological proof of its equivalency with the Chemung (p. 164). Three years later Rominger referred the entire series to the Genesee.‡ In a little table of the divisions of the Devonian system published in 1886 (Geological Studies, p. 389), Winchell makes the Erie shale of Ohio the equivalent of the Portage and Chemung. The Huron shale he correlates with the Genesee and all together comprise his Huron group. This view harmonizes the apparently discordant views of the various workers and was accepted by Orton. In his report of 1893, he says.§

"The Ohio shale, as Newberry first proved, is certainly the equivalent in the general scale of the Genesee slate, the Portage group, and the Chemung group, the last named being itself a formation of great thickness and extent in New York and Pennsylvania. In other words, the shales of our column fill the entire interval between the Hamilton proper and the Catskill group, and in the judgment of some geologists a wider interval than that named above."

In a paper upon the Devonian system in Canada, published in October, 1899, Whiteaves accepts the Genesee equivalency of the black shale found at Kettle Point, Lake Huron.¶ In the light of our present knowledge then, the 70-80 feet of the shale, found in the northwestern corner of Monroe County, belongs largely, if not entirely, with the Genesee shale of New York.

*Bull. Geol. Soc. Vol. IV, 1893, p. 227.
†Geol. Sur. of Ohio, Vol. I, p. 154.
‡Geol, Sur. Mich., Vol II, 1876, p. 74.
§Geol. Sur. Ohio, Vol. VII, pp. 23-24.
¶Amer. Geologist, Vol. XXIV, p. 231.



§ 11. Lithological history.

The materials of which these shales are composed were accumulated in the off-shore region of the ocean, or some great inland sea. The fineness of the particles indicates that this region was somewhat remote from the land, yet near enough to receive from it, through the agency of waves and currents, the materials resulting from the erosive agencies continually at work. Deposits of such thickness could probably only have been formed over a slowly subsiding sea bottom. Conditions were not favorable for the ordinary forms of marine animals, such as the corals, mollusca, echinoderms and crustacea, and hence the beds are relatively free from the lime carbonate which these forms secrete from the water. The presence of so much bituminous matter indicates that marine vegetation, of a certain type, was very abundant. This bituminous constitutent of the shale is due very largely to the presence of enormous numbers of minute disc-like bodies, with thick carbonaceous walls. These were discovered by Dawson in the shales of Kettle Point, Lake Huron and described by him in 1871, under the name *Sporangites Huronensis.** According to Orton, however, they had been seen previously by B. W. Thomas in the water and clays of Lake Michigan. They are about .01 of an inch in diameter and under the microscope show a papillose exterior, with an attachment scar on one side and a more or less elongated gaping slit upon the other. Remains of *Calamites* and *Lepidodendron* were found in association and Dawson regarded them as spore-cases of the latter tree. Without having seen this article by Dawson, in 1882, Orton described these bodies in the above mentioned journal,† as spore-cases, containing both macrospores and miscrospores. In August, 1883, Dawson read a paper before the American Association for the Advancement of Science, entitled "On Rhizocarps in the Palæozoic Period."‡ From material furnished by Derby from Brazil two new species were described, *S. Braziliensis* and *S. bilobatus.* The spore-cases showed the macrospores in position, so much resembling those of the floating fern of the European rivers, *Salvinia natans*, that the generic name *Protosalvinia* was suggested. His former *Sporangites Huronensis* he considered as the macrospores of related plants, but with their envelopes lost. A similar interpretation is put upon the forms by Clarke who found

*American Journal of Science, 3d Series, Vol. I, pp. 256-263.
†A Source of the bituminous matter in the Devonian and Sub-Carboniferous Black Shales of Ohio, Am. J. S., 3d Series, Vol. XXIV, pp. 171-174.
‡ Proceedings, 1883, pp. 260-264.

them abundant in the Marcellus shale of Ontario county, New York. They are associated with immense numbers of minute sub-spherical bodies, regarded as the microspores.* These later discoveries are in entire harmony with the view early advanced by Newberry in his Ohio report for 1873, page 156. He there calls attention to the difficulty in conceiving of such widespread shallow water conditions, capable of furnishing the necessary shore vegetation, with the evidence of the proximity of the shore so completely wanting. He referred the bituminous matter to former floating plants and imagined the entire area of the black shales to have been one great "Sargasso sea." Fragments of rushes and trees were occasionally drifted seaward by the same current which distributed the sediments themselves. About such fragments, or the bones and teeth of the terrible fish which inhabited these waters, concretions formed, while the mud was still soft. Later great beds of sediment were superposed, the weight of which compressed the soft material to probably but one-half its original volume, forced out the excess of water and produced the crisp, fissile shale.† The pyrite and marcasite were formed wherever soluble sulphates came in contact with putrefying organic matter and oxide of iron, as shown by Bischof many years ago and later by Forchhammer. The sulphates may be derived from the organic matter itself or be in solution in the sea-water in which it is immersed. When sea weeds and iron oxide are in contact double decomposition ensues and the above sulphides of iron result. Forchhammer mentions a beautiful illustration of this action on the western shore of the island of Bornholm where *Fucus vesiculosus* is very abundant, and all the pebbles on the bottom are coated with a yellow coating of pyrite. Upon exposure, however, it is converted into a sulphate of iron. The author concludes with the following clear statement, "Thus it follows, that wherever putrifying sea-weeds come in contact with ferruginous clay, iron pyrites must be formed, which penetrates the clay, and on weathering first forms sulphate of iron, and if no lime be present, will ultimately, by a new decomposition, change into sulphate of alumina."‡

*On Devonian Spores. American Journal of Science, 3d Series, Vol. XXIX, 1885, pp. 284-289.
†It should be said, however, that the presence of rock salt in the St. Clair formation, beneath Bay City, indicates other conditions than those of an open sea.
‡British Association for the Advancement of Science, 1844, pp. 155-169.



### C. *Traverse (Hamilton) Group.*

§ 12. Name and geological position.

To the beds of soft shale and limestone, which lie conformably beneath the St. Clair, the term Hamilton was applied by Winchell in his First Biennial Report. Later, to the same series, the name Little Traverse was applied by the same author. In 1895, Lane suggested the name Traverse alone, since the beds occur in the Grand Traverse as well as the Little Traverse region of Lake Michigan. Rominger used the name Hamilton in describing these Michigan beds and for their equivalents in Ohio the same was used by Newberry. For one member of the group, apparently the only representative in Ohio, Orton retains the name Olentangy shale, a name first suggested by N. H. Winchell for a bed of shale exposed in Delaware County. Hamilton has been very generally, if not uniformly, employed for this series by the Canadian geologists who have worked in the adjoining territory of Ontario. Whatever the name, all workers are agreed from the geological position of the beds, their lithological characters, and their numerous and beautifully preserved fossils, that they are the western representatives of the Hamilton of New York, lying between the Marcellus and Genesee shales.*

§ 13. General data.

An inspection of Plate I, shows that this group covers the northwestern corner of Dundee, nearly the whole of Milan and the northwest half of London townships. It enters from Lenawee County, extends northeastward as a belt from five to six miles wide and continues into Washtenaw and Wayne counties. Its apparent breadth is increased by the topography of its upper surface, for it and the St. Clair shales have been considerably eroded, as shown upon Plate VI. In the lower section, taken along the line of the Toledo and Ann Arbor railroad, at the left hand the Hamilton beds are designated as limestone and shale. They are seen to have been cut to a level below that of Lake Erie, which results in considerably increasing the breadth of the outcrop beneath the drift. The thickness of this overlying drift increases quite regularly, in consequence, from about 45 feet at the southeastern corner of Milan township, to about 150 feet, just southwest of the village. The actual elevation, above

*I used the name Traverse to include Hamilton *and* Marcellus, and so did Winchell, in which usage it would be practically equivalent to Erian in the sense suggested by Clarke and Schuchert, L.

tide, of the surface varies from 636 feet in the northwestern part of Dundee township to 549 feet, where the drift is heaviest southwest of Milan. The dip of the beds is the same in direction and amount as that given for the St. Clair. There are no known exposures of these beds in this section of Michigan, or in any adjoining locality in either Ohio, or Ontario.

§ 14. Thickness.

From well records in northwestern Ohio and southeastern Michigan the Traverse group is known to be rather weakly developed, but to thicken to the north and east. The greatest development known in Ohio is but 20-30 feet according to Orton and in many regions it is not developed at all, the St. Clair then resting upon the underlying Dundee (Corniferous). In his map of the geology of the southern peninsula, published in 1876, Rominger does not represent the Hamilton at all in the southern portion of the state. In the deep well at Adrian there are 95 feet of limestone and shale which may properly be referred to the Traverse. At Ann Arbor, in the court-yard well, 70 feet of bluish limestone with some clay, were penetrated by the drill, probably without reaching the bottom of the series. This is regarded by Lane as Traverse, by Rominger as Upper Helderberg (Corniferous) and by Winchell as both, in part. At Royal Oak 215 feet of limestone and shale are referred to the Traverse. On the St. Clair river the total thickness is 300 feet. Eastward in Ontario, at Oil Springs, the group is 240 feet, at Petrolea 296 feet and at Kingstone's mills 396 feet in thickness. About Alpena it has increased to 600 feet, according to estimates of Rominger. Within the limits of Monroe County the bed has not been completely penetrated and we have no reliable data from which to determine its thickness. It is probably, however, not far from 100 feet, judging from the dip of the rocks and the apparent outcrop and surface topography of the beds. This estimate agrees also with the thickness found at Adrian.

§ 15. Lithological characters.

In the typical regions of west central New York the Hamilton beds consist of soft, bluish calcareous shales, with a few thin layers of bluish to gray limestones; the principal one of which is the so called "Encrinal limestone," scarcely more than a foot in thickness, but remarkably persistent. The shales break into coarse, lumpy fragments, not particularly fissile, never crisp and elastic as are the Genesee just above. When struck they seem dull and dead and when



wet give a strong earthy odor and soapy feel. They readily soften into a blue clay when sufficiently exposed to the weather. These characters are always sufficient to readily distinguish the Hamilton shales from those of the Marcellus, Genesee and Portage. The Michigan representatives of these Hamilton beds seem to retain enough of these characters so that they may be separated from the St. Clair above and the Dundee beneath, even when their fossil contents cannot be procured. In southeastern Michigan and western Ontario there is a far greater development of limestone, at the expense of the shale, than in New York. Of the 95 feet in the Adrian well, according to the driller's log, 80 feet consisted of limestone, beneath which was 15 feet of black shale. In the Ann Arbor well referred to above, the 70 feet seems to have been largely limestone with the lower portions of the magnesian variety. Upon the St. Clair River the following section of the group occurs, as published by Lane in Vol. V, Michigan Geological Survey, Part II, (pp. 24-25).

| | |
|---|---|
| Hard pyritiferous argillaceous limestone..... | 2 feet. |
| Shale, "soapstone" ........................ | 12 feet. |
| "Top limestone," often gaseous.............. | 80 feet. |
| Shale, "top soapstone"..................... | 150 feet. |
| "Middle limestone" ........................ | 4 feet. |
| Shale, "lower soapstone" ................... | 65 feet. |
| "Bottom Limestone." (Corniferous.) | |

A somewhat similar series of beds occurs about Petrolea, Ontario, of which the following represents the average section in thousands of wells:

| | |
|---|---|
| Stiff blue boulder clay, drift................ | 100 feet. |
| "Upper limestone," with little black shale at top .................................... | 50 feet. |
| Bluish gray and drab shale, "soapstone" with few hard layers......................... | 120 feet. |
| "Middle limestone" ........................ | 15 feet. |
| "Soapstone," with two or three hard beds.... | 40 feet. |
| "Lower limestone" (Corniferous), giving oil at .... .................................. | 45 and 135 feet. |

The Traverse shales in Michigan are of the character ascribed to the typical Hamilton beds of New York, soft and bluish with a rather high percentage of lime carbonate. Certain layers may become much darkened, however, by bituminous matter. The limestones are typically bluish and argillaceous, but they may become darkened also. Fossils are exceedingly abundant in certain beds and beautifully preserved. The most common are various groups of the mollusca, corals, bryozoa and crinoids.

In the comparatively few wells sunk through the drift over the Traverse belt in Monroe County the description of the rock is very unsatisfactory. It is generally spoken of as hard or soft, as we might expect from the sections above given. From Milan to the southwestern corner of Sec. 18, Milan township, several records of a very hard rock having been first encountered were obtained. In the village of Milan, according to one driller, the rock is an "exceedingly hard quartz rock," according to a second it is a "hard sandstone." Records of sandstone (probably dolomite) were obtained at the southwestern corner of Sec. 18 at Stephen Olds and J. C. Miller's. Two other records of a similar rock were obtained in the northwest and southwest quarters of Sec. 7, London township. At Charles Sanford's N. W. ¼, S. W. ¼, Sec. 9, Milan a very hard rock was struck at a depth of 112 feet. This was so hard that only a few inches could be drilled each day and it was entered but eleven feet. Another hard rock was reported at the N. E. ¼, N. W ¼ of this same section. At the place of Samuel McMullen, N. E. ¼, N. E. ¼, Sec. 17, a well was put down to a depth of 309 feet, rock being struck at 95 to 100 feet. The rock was said to be "shell limerock, more or less honey-combed," and yielded no water. Limestone was also struck at the S. W. ¼, N. E. ¼ Sec. 22, at Patrick Nolan's, in his well 171 feet deep. Rock was struck at a depth of 112 feet, and at 150 feet what seemed to be sandstone. A strong flow of gas was obtained at a depth of 145 feet, was lighted and burned all one night. Mr. B. R. Ford reports limestone at the S. W. ¼, S. E. ¼, Sec. 14, in his 110 foot well. "Soft white rock," which might refer to a much softened limestone, or to a highly calcareous marly shale, was struck at a depth of 96 feet at the place of E. E. Spink, Sec. 26, N. W. ¼, N. W. ¼. Two records were obtained in this region which are much more suggestive of the typical Traverse shale. At a depth of 100 feet a "soapstone" was reached in the southeast quarter of Sec. 3, upon the place of Samuel Campbell. Thirty-five feet of this "blue soapy stuff" were entered. At Charles Campbell's N. W. ¼, S. W. ¼, Sec. 5, rock was reached at a depth of 142 to 143 feet. It is reported as a "soft mud rock, or soapstone." This was entered twenty feet when a "granite rock" was encountered. In the light of these facts it is difficult to predict the char-



acter of the bed which will be found beneath the drift at any given point within this Traverse area. The problem is complicated not only by the number of beds, of such varying character, but also by the topography of the rock surface.

§ 16. Lithological history.

During the time required for the accumulation and deposition of the marine sediments which form the Traverse beds, broad open sea conditions were changing to those which characterize the off shore. These changes took place in consequence of oscillations in the sea-bottom, causing the shore line to recede or advance; or in the amount and distribution of the fine detritus from the land, carried by waves and currents. When the mud deposition prevailed beds of clay were formed, which required only great pressure to become a shale. The presence of bituminous matter in sufficient quantity to color the deposit black or brown, indicates that the conditions had thus early been established which gave to the St. Clair shale its bituminous character. Conditions were favorable also for numerous forms of life which secrete lime carbonate from the sea-water and as their remains were covered by the deposits they were preserved entire, or after disintegration were mingled with the mud. During long periods the amount of mud was greatly diminished and in this clear open sea bryozoa, corals and crinoids flourished in abundance. Their remains accumulated, were cemented together with a calcareous slime and after being subjected to great pressure and some heat, were partially crystallized, forming the beds of limestone. If sandstone actually exists as is stated by the records given above, shore conditions must have prevailed temporarily and beds of sand accumulated, which were later cemented into compact rock, but probably there is no real sandstone.

### *D. Dundee Limestone.*

§ 17. Name and geological position.

By this local name the present State Geological Survey designates the great limestone belt, which in Michigan, Ohio, and Ontario underlies the Traverse just described. It extends in all directions from southeastern Michigan and covers hundreds of thousands of square miles in the lake region, the Ohio and Mississippi valleys. It represents the upper member of a group of four, which are found well exposed in the Helderberg Mountains of eastern New York and to which group the name Upper Helderberg was given by the geologists of that state. Of this group the Caudagalli grit, Schoharie grit, and Onondaga limestone give out before reaching Michigan, while the Corniferous is the sole representative here. This was so named from the beds and nodules of hornstone which seem quite characteristic of it (*cornu*, a horn; *fero*, I bear), both in New York and Michigan. Newberry and the Canadian geologists generally have used the term Corniferous in referring to the limestone. A. Winchell and Orton have preferred Upper Helderberg, although the former in 1886,* includes the four New York members under the general term Corniferous Group, following Dana.†

Rominger in his report of 1876 uses Helderberg alone to include this Dundee and the underlying so called Monroe beds, but recognizes an upper and a lower division. By early geologists the Hamilton, Corniferous and Niagara limestone in the states to the south and west, were known collectively as the "Cliff limestone." In his state report for 1893,‡ Hall proposes "Onondaga" for the two beds originally designated Onondaga and Corniferous, the hornstone being found distributed throughout the series. In view of this use of terms to

*Geological Studies, p. 390.

†Two papers by N. H. Winchell before the American Association for the advancement of Science refer to the correlation of these limestones and may be summarized here. In 1873 (p. 100) a paper on the Devonian limestone in Ohio gives a section of five members, the bottom one, the Sylvania sandstone (?) being considered equivalent to the Oriskany. The two upper members are bluish and the author contrary to Newberry, would place them with the Hamilton, although they are colored Corniferous on the Ohio County maps. The third member is a light saccharoidal crinoidal limestone (our Dundee limestone?), and the fourth a vesicular or compact magnesian limestone (Monroe beds above the Sylvania?) often popularly mistaken for sandstone. In 1875 (part II p. 57) "On the Parallelism of Devonian Outcrops in Michigan and Ohio," he returns to the discussion of the border line between Hamilton and Corniferous, and shows how A. Winchell on paleontological grounds referred most of these Devonian limestones to the Hamilton, reducing the Corniferous to insignificant dimensions, while Newberry called them all Corniferous, and Worthen called the blue argillaceous limestones Hamilton (our Traverse), and the lower light colored assigned to the Corniferous. According to the author we have the following section from above:

1. Blue limestone.
2. Crystalline crinoidal limestone.
3. Arenaceous limestone.

The Water-lime of Ohio, beneath, has three different lithological aspects, to wit: thin bedded, fine grained drab, with distorted wavy bedding; harsh heavy bedded magnesian with wavy bituminous or carbonaceous films; in patches brecciated, this structure obliterating the true bedding and hardening the whole mass.

‡Thirteenth annual report of the State Geologist, Vol. I, 1894, 207.



designate the same bed of limestone, it seems wise to retain, in a report of this character, the local name given by the present survey.*

§ 18. General data.

An inspection of the geological map of the county (Plate I), shows the Dundee beds striking northeast and southwest, forming a belt, varying in breadth from four to five miles? This enters, from Lenawee County, the northwestern part of Summerfield and the southwestern corner of Dundee townships, grazes Raisinville and forms the southeastern half of London and the northwestern half of Exeter townships, passing into Wayne County. Although conformable with the lower Traverse beds the general dip to the northwest is believed to be less than that given for the upper Traverse and lower St. Clair beds. It is probably from 20 to 25 feet to the mile upon an average, although locally it may be much more or much less. Mr. T. J. Brandt, foreman of the Christiancy quarry, on the Macon, for a number of years, estimates the dip in the 40 rods across as three feet, or twenty-four feet to the mile, and to be in the direction of W. N. W. In the Pulver quarry at Dundee it is much greater, being four and one-half feet in 200, or about 119 feet to the mile, and evidently local. The line of junction of the Dundee with the Monroe is believed to cut through Petersburg and very near Raisinville postoffice. At the latter place, however, the rock lies too deep to be reached by the river and there are no exposures in the bed for some distance upon either side, the river being through this region deep and sluggish. The highest surface elevation of the rock is at the county line, west of Petersburg, where it is 650 feet above tide level.

* A rearrangement of the New York series has been recently proposed by Clarke and Schuchert in *Science*, December 15, 1899. (See also Amer. Geol. February, 1900.) The following portion includes the rocks described in this report:

| System. | | Group. | Stage. | Michigan equivalent. |
|---|---|---|---|---|
| Devonic .. | Neodevonic. | Chautauquan. | Chemung beds. | |
| | | Senecan. | Portage beds.<br>Genesee shale.<br>Tully limestone. | St. Clair shale. |
| | Mesodevonic. | Erian. | Hamilton beds.<br>Marcellus shale. | Traverse group. |
| | | Ulsterian. | Onondaga limestone.<br>Schoharie grit.<br>Esopus grit. | Dundee limestone. |
| | Paleodevonic. | Oriskanian. | Oriskany beds. | (hiatus?) |
| | | Helderbergian. | Kingston beds.<br>Becraft limestone.<br>New Scotland beds.<br>Coeymans limestone. | |
| Ontaric or Siluric | Neontaric or Cayugan ...... | | Manlius limestone.<br>Rondout waterlime.<br>Salina beds. | Monroe beds (?) |

A more or less gradual fall occurs northeastward to the Wayne county line where it is not far from 580 feet, or 70 feet lower. From the river at Raisinville the contours (Plate I) indicate that there is a broad shallow trough in the bed, sloping northeastward, to be more fully described in another connection. (Chapter VI, § 2.)

§ 19. Drift covering.

The superficial covering of drift and soil does not exceed 70 feet and would average perhaps 35-40 feet, so that the bed lies much nearer the surface than the other two described. There are no natural outcrops although the beds are exposed in the bed of the Macon, northeast of Dundee and in the Raisin also. At Dundee the solid layers are exposed in the river just below the dam, but above it are covered by 2½ to 3 feet of sediment. In the western and southwestern portions of Dundee township the maximum covering occurs. At Petersburg slabs of Dundee limestone have been removed from the bank and assumed to have been *in place*, although the limestone in the bed of the river belongs to the Monroe. The junction of the Traverse and the Dundee in the southeastern part of Milan township is covered by about 45 feet of drift. Northeastward the bed has about the same amount of covering, which in the northwestern part of Exeter is increased to from 50 to 60 feet. It is very unfortunate that such valuable layers are so deeply buried and exposed only in the beds of streams where the problem of getting rid of the water is a very serious one.

§ 20. Thickness.

No complete section of the beds has ever been obtained within the limits of the county and its thickness can only be approximated. Judging from the dip and breadth of its supposed outcrop, beneath the drift, it cannot be far from 100 feet. In Ohio the maximum thickness is given as 75 to 100 feet. In the Adrian well the Dundee could not be differentiated from the Monroe. At Wyandotte and Trenton only a portion of the bed was penetrated, while at Detroit it was not entered at all. At Petrolea, Ontario, it is about 200 feet thick and at Alpena 120 feet. Winchell gives the formation at Mackinac a thickness of 275 feet but he included beds that are now known to belong to the next lower division.

§ 21. Lithological characters.

The Dundee is essentially a pure limestone formation with minor streaks and beds of an impure form of quartz, known as chert,



the *hornstone* above referred to. The limestone varies in color from a light gray to brown, in some cases running into blue. The purer varieties show numerous cleavage faces of calcite and are heavily charged with fossils and their fragments. The argillaceous ingredient, so abundant in most of the Traverse limestones, is present in but small quantity, usually a small fraction of one per cent, but may run up to six to seven per cent in certain beds. A very small amount of iron is present (see analyses in Chapter IV, § 2), and the silica in the limestone varies from only a trace up to 9 or 10 per cent. Carbonate of magnesia is present in variable quantities in the various beds, some being remarkably free from it, while in others it may run up to 25 per cent. Analyses of the drill cores at the Sibley quarry show that the amount gradually increases toward the base of the series. The limestones always give a vigorous bubbling, (effervescence), with cold dilute hydrochloric acid when it is applied to the solid rock. Most of the beds have a strong oily odor and semi-fluid bituminous matter frequently collects in the cavities of fossils. At Petrolea this limestone series yields oil at 45 and at 135 feet.

In the Monroe County and Trenton quarries the upper beds are thin-bedded and shattered, probably due to the action of the great icesheet and later atmospheric agencies. Deeper layers may become heavily bedded, reaching a thickness of several feet. The same layer may be heavily bedded in the deeper portions of the quarry, but at its outcrop beneath the drift appears thin-bedded and much disrupted. Seams of clay very frequently separate the layers, washed in from the surface very probably by percolating water. Orton recognized in Ohio an upper and a lower division of the series. The upper division is more often blue, contains less chert and the beds seldom reach one foot in thickness. The lower is lighter colored, gray, drab and brown, contains more chert and the individual beds may reach a thickness of five feet. The Dundee is not sufficiently exposed in southeastern Michigan to say whether, or not, these divisions can also be recognized here. However, the characteristics of the lower division are all seen in the Dundee, Macon and Sibley quarries, while the upper half of the series is nowhere exposed.

In Michigan the Dundee forms the base of the great Devonian system, sharply separated by its fossil contents from the uppermost

Silurian beds, to be described in the next chapter, but with no evidence of any great structural break. The crustal movements which disturbed the Silurian beds in other sections of the world did not extend to Michigan, although the higher forms of life evolved as the result of such wide spread changes, promptly moved in. The spines and teeth of fishes are not infrequently found at the Sibley quarry, but the underlying Monroe beds have nowhere furnished any trace of a vertebrate. Lithologically the rocks are easily separated when specimens can be obtained, the Monroe limestones being of the dolomitic (magnesian) type and responding very slightly to cold dilute acid on the solid rock. In the drillers' log, however, it is impossible to separate them, and hence the desirability of saving samples of the beds penetrated.

[It is quite possible that there is more of a break between Dundee and Monroe, than appears stratigraphically in this county. In the table of formation equivalents, several appear to be omitted between them. Moreover beside the sudden paleontological difference there are conglomerates near the dividing line at St. Ignace. L.]

§ 22. Lithological history.

The relatively small amount of argillaceous and silicious matter in the limestones would indicate that their materials were accumulated far enough from the shore to escape the ordinary sediments which so largely made up the Traverse and St. Clair beds. Open but shallow sea conditions prevailed throughout the entire period and in the warm pure waters bryozoa, corals, crinoids and mollusks flourished in most wonderful profusion. Veritable coral reefs were formed over wide areas, many of the great colonies still standing where they grew, but imbedded in a matrix of fragments and calcareous slime, the result of wave action. Sharks of a strange type were numerous and contributed their spines and teeth after death. The floating vegetation had not yet, to any extent, invaded the sea, and this form of bituminous matter is absent. The oil which impregnates the rock was derived from the animal remains and was probably formed while the rock itself was in process of formation. Later the great pressure of superincumbent beds, with some heat, and the action of the carbon dioxide of the water compacted and partially crystallized the mass.

According to an estimate made by Dana, limestones due to coral accumulation alone, may gain one-sixteenth of an inch yearly, or five



feet in 1,000 years. This growth he thinks is more rapid than when the limestone results from accumulation of shell remains. To have formed the 100 feet of Dundee limestone would then have required 20,000 years, upon the supposition that it took place at the maximum rate and that there were no periods of halt. While the organisms above referred to were secreting from the water the lime carbonate which it held in solution, other groups, such as diatoms, polycystines and sponges, were appropriating its silica and working it over into their hard supporting and protective structures. Their remains were finally added to the calcareous deposit and contributed to its supply of silica. The two foot bed of chert at the Sibley quarry shows equal quantities of lime carbonate and silica, from 43 to 44 per cent each, with nearly two per cent of magnesium carbonate and two per cent of alumina. The few fossils which it contains are all in silicified condition. It is not easy to satisfactorily account for the existence of such a bed, since it must have been formed before the limestone, just above it and subsequently to that of the bed just beneath. We cannot assume that the silica of the limestone beds was taken into solution and afterwards deposited, as in the case of nodules and veins of flint in the chalk beds. According to Maschke 100 parts of water, by weight, containing carbon dioxide, are capable of dissolving .078 parts of this amorphous silica. Or, stated differently, one cubic foot of such water is capable of dissolving .78 ounces of amorphous silica. According to Hunter sea water contains for each 100 vols. from .63 to 1.69 vols. of carbon dioxide gas. According to the researches of Buchanan sea water upon boiling will give off 2.3 vols. per 100 vols. and upon evaporation to dryness Jacobson found that twice this amount would be liberated. This gas is believed to be in some loose chemical combination since it is greatly in excess of what would be held by the water in response to the ordinary law for gas absorption by a liquid. Dittmar believed that there is practically no free carbon dioxide in the ocean water. The alkaline condition of sea water would enable it to dissolve somewhat more amorphous silica than would be due to the carbon dioxide alone. However, Dittmar, found in his analyses of samples of sea water gathered during the year 1873-6, by H. M. S. Challenger that there was a trace only of silica. If we assume the waters of this ancient sea to not differ essentially from those of today, except to have been saturated with silica, it would require a depth of about 3,000 feet of water to hold in solution the silica in the two foot bed of the Sibley quarry. If we assume that the chert bed was deposited as the result of the evaporation and concentration of the waters of an inland sea, it would require that the level be lowered about 3,000 feet. There is reason to think that this sea was comparatively shallow and becoming more so as time advanced.

Dittmar found that sea water is capable of becoming intensely alkaline, locally, through the agency of a limited amount of free carbon dioxide. In his experiments sea-water with an alkalinity expressed as 50.2 milligrams per liter, when saturated with carbon dioxide gas and digested for some time with calcium carbonate, shows an alkalinity of 314.2 milligrams. When magnesium carbonate is used, instead of the calcium, the alkalinity is increased to 1234 milligrams per liter. After being dissolved the magnesium carbonate and the sodium chloride suffer double decomposition with the formation of a carbonate of soda and a double chloride of sodium and magnesium. It is to the carbonate of soda that the greatly increased alkalinity is due and only a limited amount of the carbon dioxide gas is required since it is again returned in the reaction.

This increased alkalinity would enable the water to hold larger quantities of amorphous silica and if such silica were at hand it would be dissolved. This water upon being diluted, or having its alkalinity neutralized in part, would be compelled to deposit its silica and owing to the attraction which exists between molecules of the same substance, would tend to mass itself about the fragments of silicious organisms. In this way there would be produced an amorphous matrix with embedded fragments of organisms originally silicious. The few calcareous remains present would readily become silicified in such saturated water and we may readily imagine that while these conditions prevailed the bryozoa, corals and crinoids would be killed in the region affected, only a few hardy brachipods remaining, and the formation of limestone be temporarily suspended. The large amount of lime carbonate present in such finely divided state could have been precipitated directly or washed in by waves and currents from adjoining areas over which normal conditions prevailed. This explanation seems to fit best all the phenomena met with in the Dundee chert beds.

# CHAPTER III.

## SILURIAN FORMATIONS.

### *A. Monroe Beds.*

§ 1. Name and geological position.

For this extensive series of beds, to which so many different names have been applied, it is convenient to have a definite local name. In his report published in 1861, A. Winchell describes the greater part of the series as the "Onondaga Salt Group" (pp. 57-60), but some of the lower beds exposed in the county, those at Stony Point and Point aux Peaux, he includes in the Devonian. In 1870 he recognized the latter beds as equivalent to the Waterlime division of the Lower Helderberg, of New York, *Leperditia alta* and *Spirifera modesta,* were found in the county, and on Put-in-Bay island *Eurypterus remipes.* Three years later a map was published showing the geology of the lower peninsula* upon which there is shown a narrow strip of Lower Helderberg, from three to four miles wide following the shore of Lake Erie. Narrow belts of the same are represented as surrounding the small patches of Onondaga, or Salina, at Ida and Ottawa Lake quarries. Newberry in 1873 describes these same beds as the Waterlime Group of the Helderberg formation of New York. He had accepted for the Upper Helderberg the name "Corniferous Group" and restricted Helderberg to what had been known eastward as the Lower Helderberg, made up typically of five divisions; the Waterlime, Lower Pentamerus limestone, Delthyris shaly limestone, Encrinal limestone and the Upper Pentamerus limestone, named in ascending order. The characteristic fossils of the Waterlime were collected and figured, *Eurypterus remipes* and *Leperditia alta.* Rominger, as previously stated, combined these with the Dundee, and applied to both the name Helderberg, but recognized an upper and a lower division, thus bringing this word back

*Michigan, 1873, extracted from Walling's Atlas.

to something like its original meaning. The Sylvania sandstone he accepted, however, as the probable equivalent of the Oriskany, and hence places the break between his upper division, the Devonian, and the Upper Silurian at the top of this sandstone. It will be shown in this chapter that this break is really higher up and, consequently it lies considerably to the west in our geological map. In the later publications of the Ohio survey, Orton uses the term "Lower Helderberg or Waterlime Formation" and includes in it everything above the Niagara (considering that the Salina is not represented in the Ohio scale), and below his Upper Helderberg. It is exactly this series of beds which has been termed by Lane the Monroe beds. If the original New York Salina is really represented in the geological series of southeastern Michigan, as is very probable, there is no way yet of identifying its beds and separating them from the Waterlime division of the Lower Helderberg. The enormous beds of rock salt and gypsum which occur along the Detroit and St. Clair rivers would strongly suggest the Salina equivalency of these layers, but this cannot be positively asserted until we know the character of the limestones which overlie the Niagara. In Ohio the gypsum beds are underlain by several hundred feet of typical Waterlime dolomite and in New York the same thing occurs.

In the later reports of the New York Survey* the Waterlime beds are taken from the Lower Helderberg and added to the Salina. If this practice is followed in this western region, and it has received Orton's sanction for Ohio, the discussion of the geological equivalency of the Monroe beds is simplified, since then they would all be referred to the Salina. In the rearrangement of the New York series by Clarke and Schuchert the Salina and the Waterlime are each recognized and constitute the two lower members of the Cayugan, or Neontaric.

§ 2. General data.

The remainder of Monroe County, eastward from the basal layers of the Dundee, is underlain by the upper beds of this great series. This comprises over two-thirds of the county and includes the entire townships of Whiteford, Bedford, Erie, La Salle, Monroe, Frenchtown and Berlin, nearly the whole of Ash, Raisinville, Ida and Summerfield and one-half of Exeter. It thus forms a belt from eleven to seventeen miles in breadth and extends further eastward beneath

*Report State Geol., Vol. I, Geology, 1893.



Lake Erie and Detroit River. The beds strike northeastward as far as Stony Creek, where they turn eastward and, in the case of the lower beds exposed, finally southeastward. The dip of the beds varies considerably in direction and amount. Certain data indicate that from Toledo to Adrian this averages about 35 feet to the mile, but it is not regular, increasing in amount toward the west. This is shown by the narrowing of the outcrops of the beds beneath the drift in the southwestern part of the county and by the inclination of the strata seen in the quarries just over the Ohio line. The upper layers from the county line northwest of Ottawa Lake to Adrian dip at the rate of 56 to 57 feet to the mile. Measured upon the Trenton, which may be assumed to be conformable with the overlying beds, the dip from Monroe to Dundee is about 26 feet to the mile. From Monroe northward the direction of the dip changes from northwest to north and, as nearly as can be made out from the interpretation of the well records at Trenton and Wyandotte, equals 30 to 40 feet to the mile. The breadth of the outcropping belts, beneath the drift, is increased in the northeastern part of the county because of the increased thickness of the beds, and in spite of this greater dip. The Monroe beds lie nearer the surface than any of the preceding formations and are responsible for all the actual natural outcrops. The heaviest covering of drift occurs in the southeastern portion of Erie township, where it is from 90 to 100 feet thick. At the head of Ottawa Lake the highest elevation of the rock surface is attained, about 685 feet above sea level. From this point there is a very gradual slope of the rock surface in all directions, being greatest in rate and amount toward the southeast. In the southeastern corner of Erie township the elevation is about 470 to 480 feet, having dropped over 200 feet in 15 miles, or at an average rate of 13.3 feet to the mile. An inspection of the contours upon Plate I shows, however, that the slope is much steeper over the latter half of this distance, being equal to about 24 feet to the mile.

§ 3. Thickness.

The great breadth of the outcrops beneath the drift, of the Monroe beds indicates that we have a much thicker formation than any previously described. In Ohio the total thickness is 600 feet and borings in Michigan and Ontario indicate that it increases toward the north for a certain distance. In the five Trenton wells the average thickness is 1216 and in the Dundee well it is over 1000 feet. At

Wyandotte, in the well of the Eureka Iron and Steel Works the thickness appears to be 1375 feet. In the Solvay wells, at Delray, it is apparent that none of this thickness has been lost and it may have been considerably increased. Still further north, at Goderich, Ontario, according to Hunt, some 1517 feet of these beds were penetrated without reaching the bottom. Upon Plate V is recorded the section of one of the Monroe deep wells reprinted from Vol. V, which shows that the Niagara was reached at a depth of 700 feet. From the breadth of the outcropping layers and the dip it is estimated that about 200 feet of these beds are represented between Monroe and the base of the Dundee, so that the entire thickness of these beds in the middle of the county is not less than 900 feet. From what has been said, however, and from an inspection of the geological map, it will be apparent that the actual thickness to be penetrated in any given boring will depend upon its north and south position in the county and its distance southeastward from the base of the Dundee.

§ 4. Lithological characters.

So far as they are exposed within the county the Monroe beds consist of a series of gray to drab magnesian limestone (dolomite), embedded in which are strata of oölite, very sandy dolomite, and a friable bed of remarkably pure sandrock. These beds are so distinct, lithologically, that they have been of much service in the deciphering of the geological structure of the county and each will be separately described as fully as its importance seems to warrant. In the following chapter IV on quarries a still more detailed description will be given of the individual beds that make up the series. In general, it may be said that the typical dolomite layers show the normal proportions of lime carbonate and magnesium carbonate; from 50 to 55% of the former and 42 to 43% of the latter ingredient. The amount of alumina and iron together is generally less than one per cent, while the silica, in *insoluble* form, varies greatly at the expense of the carbonates. Bituminous matter is present locally but does not impregnate the rock as in the case of the Dundee. Near the top of the series, where weathered, the rocks become of almost a chalky whiteness and contain gypsum, but ordinarily they are gray to dark drab, sometimes running into a yellowish brown. In the deeper portions of the quarries they are sometimes blue. The rock responds only slightly to cold dilute acid, unless it is powdered, when the effervesence is brisk. In this way the Monroe dolomite is



to be distinguished from the Dundee limestone. Fossils are not abundant in the dolomite, except rarely in patches, and they are always in the form of molds, internal or external casts.

The rock layers are generally thin-bedded, rarely reaching one foot and usually less. Toward the lake, near Monroe, the beds have been much disturbed and the rocks shattered. In the Plum Creek quarry of the Detroit Stone and Supply Company, the bedding is described as being almost vertical, but could not be directly observed owing to the water present. North about two miles in the quarry of the Monroe Stone Company, the bedding is typical but the rocks seem shattered. In Monroe there is a tradition that about thirty years ago, one Sabbath morning, an explosion occurred in the bed of the river just above the city, which startled the entire region and very visibly disturbed the layers of rock in the river bed. There is wide-spread evidence that at a much earlier period than the time of the disturbances above referred to, probably while the beds were forming the rocks which compose them were broken into angular fragments and then recemented. Such brecciated beds are seen near Monroe and at Stony Point, and, according to Rominger, Orton, and Winchell, occur all over northwestern Ohio, the islands of Lake Erie, at Goderich and on the island of Mackinac. Thin slabs of dolomite showing ripple-marks and mud cracks occur in the Plum Creek quarries, characterize the Ohio beds, and extend into eastern New York. Immense concretionary bodies with finely laminated structure, regarded by Winchell at the time of the preparation of his first report as organic in their nature, are seen about Monroe and to the northeast. Their great convex surfaces bulge upwards through the floor of the quarry north of Monroe (See Plate IV); they are seen eastward on the lake shore, and are still better shown in the Patrick quarry on Grosse Isle, where they seem to be 12 to 15 feet in diameter in certain cases. It is very probable that they were formed while the dolomitic slime was still soft, through the action of the concretionary agencies which are as yet so little understood.

In the beds underlying Monroe and known only through samples of the well drillings, the dolomites are found to contain varying quantities of a form of calcium sulphate, known as anhydrite. Northward this mineral is found in distinct beds many feet in thickness and associated with pure rock salt, shales and sandstones. The section of the Noble well, at Monroe, as given on Plate V, shows a 230 foot bed of yellowish limestone, briskly effervescing with dilute acid, which was struck at a depth of 100 feet from the surface, or about 300 feet from the base of the Dundee. This seems to correspond in position with a group of limestones, 276 feet in thickness, containing corals, chert, and dolomite beds, reported by Hunt as occurring at Goderich, at the foot of Lake Huron. The series was struck at a depth of 357 feet from the surface and is overlain by 278 feet of dolomite, with thin limestone layers.* Hunt regarded this as an intercalation of Corniferous (Dundee) amongst the beds of Lower Helderberg (Monroe). The overlying dolomite was supposed to be continuous with the Lake Erie beds containing Waterlime fossils. The limestone itself is of the gray non-magnesian variety, rich in fossils, corals and chert. From fragments in the cores Hall identified *Favosites Winchelli* Rom., and *Favosites Emmonsii,* Hall, these being characteristically Devonian. This peculiar limestone series is underlain by dolomite containing gypsum.

§ 5. Lithological history.

It is evident from the variety of rock material represented as making up the extensive Monroe series that its formation must have taken place under widely varying conditions. The sea bottom was subject to repeated oscillations and the shore line advanced and receded, probably several times. Geologically it was a period of unrest, these disturbances in Michigan being but distant ripples from the agitation which brought the Silurian to a close and caused the advance in plant and animal life. The beds of sandrock and the conglomerate of Ohio and Mackinac were formed while shore conditions prevailed. The beds of shale, which occur toward the bottom of the series, represent the muddy accumulations of the off-shore. The beds of dolomite, which comprise the main bulk of the series in southeastern Michigan, seem to have been formed in a shallow, open sea, sufficiently distant from land not to get much sand and mud.† The paucity of fossil remains in such beds led Cordier, Hunt, Ramsey and others, to assign to them a chemical origin. If such a theory is accepted in whole, or in part, then this dolomite *dough* must be regarded as a chemical precipitate, to be described below. The oscillations of the earth's crust occasionally exposed patches of this

*Geological Survey of Canada, Report of Progress, 1876-77, pp. 221-243.
†Or the climate may have been dry and the land low and the sea shallow so that not much sediment was formed. L.



sea-bottom to the air and sun, which upon drying shrank and gave the mud cracks mentioned as occurring about Monroe, as well as elsewhere. These were later submerged, covered with soft slime and indefinitely preserved. Pressure, carbon dioxide gas and probably a low degree of heat have compacted these soft layers into firm rock.

The conversion of calcium carbonate into the double carbonate of calcium and magnesium, known as dolomite, has as yet received no entirely satisfactory explanation. The geological occurrence of dolomite gives no warrant for the theory of Von Buch that it represents limestone, in which some of the calcium has been replaced by magnesium, through the agency of magnesia vapors rising from beneath. Neither can it be maintained that thousands of square miles of heavily bedded dolomite have resulted from the action of percolating spring waters carrying magnesium salts in solution. Still less probable is the theory that the dolomitization is due to the action of molten magmas from the interior of the earth which have come in contact with limestone beds. In sea water there occur considerable quantities of magnesium chloride (10.878 parts) and magnesium sulphate (4.323 parts), in every 100 parts of the total salts, according to the analyses of Dittmar. By experiment it has been found that these salts, under high pressure, and above the boiling point of water, can convert limestone into genuine dolomite. An analysis of coralline limestone from the elevated coral island Matia, one of the Society group, according to Dana (Corals and Coral Islands, 1872, p. 357), gave 38.07% of magnesium carbonate, showing it to be in reality dolomite. Ordinary coral contains from 95 to 98% of calcium carbonate, with only a slight amount of magnesium carbonate. Dana concludes that this introduction of magnesium into the composition of the coral has taken place apparently in the sea water at ordinary temperatures and without the agency of any mineral waters except those of the ocean. "But the sand or mud may have been that of a contracting and evaporating lagoon, in which the magnesian and other salts of the ocean were in a concentrated state." These conclusions of Dana are accepted by Neumayr* and probably represent the consensus of geological opinion at the present time.

October 28th, 1844, Cordier deposited with the French Academy of Sciences a sealed packet, which after his death was opened and

*Erdgeschichte, 1886, p. 590.

found to contain a paper entitled "De l'origine des roches calcaires qui n'appartiennent pas au sol primordial."* In this the chemical origin of the great bulk of our limestones and dolomites is maintained, the carbonates being derived from the reaction of carbonate of soda upon the chlorides of calcium and magnesium in sea water. The supply of sodium carbonate he believed to be derived from the decomposition of feldspars, from alkaline springs and from plutonic emanations. Some three years before this information was made public, Hunt had published an elaborate account of his experiments on salts of lime and magnesio,† under the title "On Some Reactions of the Salts of Lime and Magnesia, and on the Formation of Gypsums and Magnesian Rocks," in which he had arrived at about the same conclusions. The source of the carbonate of soda, in all cases, he considered to be decomposing feldspathic minerals of the sedimentary rocks and the argillaceous beds are the correlatives of the limestones. The conclusion reached in this paper (p. 383) is that

"Dolomites, magnesites and magnesian marls, have had their origin in sediments of magnesian carbonate formed by the evaporation of solutions of bicarbonate of magnesia. These solutions have been produced by the action of bicarbonate of lime upon solutions of sulphate of magnesia, in which case gypsum is a subsidiary product; or by the decomposition of solutions of sulphate or chloride of magnesium by the waters of rivers or springs containing bicarbonate of soda. The subsequent action of heat upon such magnesian sediments, either alone or mingled with carbonate of lime, has changed them into magnesite or dolomite."

Hunt insists that calcium chloride must be absent, whatever the reaction, and that isolated and evaporating basins are indispensable conditions for the formation and deposition of magnesian carbonate.‡ An analysis of waters from the equivalent of these Monroe beds, in Western Ontario, at Chatham, Petrolea and Bothwell shows them to be derived from a bittern, "the result of the evaporation of the waters of an ancient sea."

One of the most recent discussions of the question is contributed by Dr. E. Philippi, of Berlin, in a paper entitled, "Ueber einen Dolomitisirungs vorgang an südalpinen Conchodondolomit."§ The author believes that dolomites in many instances, at least, result from a *leaching* of a lime rock which already contains a certain quantity of magnesium carbonate. The theory is based upon the supposition that the carbonate of lime is more readily dissolved than the carbonate of magnesium, and hence that under proper conditions

*C. R., Feb. 1862, pp. 293 to 299.
†American Journal of Science, 2d series, Vol. XXVIII, 1859, pp. 170-187, 365-383.
‡Chemical and Geological Essays, 1891, p. 92.
§Neues Johrbuch für Mineralogie, Geologie und Palæontologie, I Band, Erstes Heft, 1899, pages 32 to 46.



more of the former would be removed. The result of this would be to produce a rock which would show relatively greater and greater quantities of magnesia until the normal proportion of lime and magnesia might be attained. There is no reason to think that this theory can have any application in the case of our Monroe beds, where 900 to 1,000 feet of practically horizontal layers are evenly dolomitized. It would necessitate the destruction of unsupposably great masses of limestone, unless there is assumed to be present, from the first, considerable quantities of the magnesium carbonate. If such supposition is made then the difficulty of accounting for this carbonate is as great as is that of the original question. In ordinary corals which contribute so largely to the formation of limestones, there is present but a very small quantity of magnesia, *Isis hippuris* yielding Forchhammer the relatively large amount of 6.36%. Upon the supposition, however, that the magnesium carbonate is but one-tenth as soluble as the calcium carbonate, it is evident that in the process of leaching such a stone, the magnesium would have practically disappeared before the normal proportions for the two had been attained. There is no apparent agreement upon the part of supposed authorities however, in regard to the relative solubility of these two carbonates. Bischof found that a prolonged action of water, charged with carbonic acid, upon a limestone containing 11.54% of magnesium carbonate, dissolved out 4.29% of its calcium carbonate, but without appreciably affecting the magnesium.* With water containing three to four grams of magnesium sulphate to the liter, Hunt found that there would be dissolved 1.2 grams of carbonate of lime and 1 gram of carbonate of magnesia to the liter.

From his researches Dittmar concluded that in sea water carbonate of magnesia is far more freely soluble than is carbonate of lime. In all the above cases the water contained different ingredients but nothing which might not be present in the waters percolating through a bed of limestone. Additional evidence against the application of this leaching process to our Monroe beds is furnished by the complete conversion into dolomite of the granules of the bed of oölite. These were originally calcareous and, judging from the Great Salt Lake oölite now in process of formation, have not been appreciably reduced in size. There has taken place here a partial re-

*Lehrbuch, Vol. II, p. 1176. See also Treadwell and Reuter in Zeits. für Anorganische Chemie, Vol. XVII, 1898, pp. 170-204.

placement of the calcium carbonate with the carbonate of magnesium, this action occurring at the time of the formation of the beds and in sea water strongly charged with magnesium salts.

It seems necessary to conclude from these and still other considerations that a great inland basin had been formed in which the waters were greatly concentrated, while the open sea retained its normal composition. Hunt explains the intercalation of Corniferous amongst the beds of the Salina, by assuming that in the ocean the life had advanced into the Corniferous age, while that in the basin itself was still Silurian. A temporary influx of the sea into a part of this basin would bring in the higher forms and establish a new set of conditions, favorable for the growth of corals and the production of limestone. The cutting off of the direct supply from the ocean would in time exterminate the life in this particular region and by the opening of direct communication with the remaining interior basins, former and older geological and palæontological conditions would again prevail. Such basins would supply the necessary conditions for the deposition of gypsum, or anhydrite, and for the formation of rock salt found further north. Through the continued concentration of the water contained, after the point of saturation had been passed, there would be deposited a layer of calcium carbonate followed by one of calcium sulphate and later one of rock salt.* As evaporation progressed the water would be withdrawn from the margins of the basin and the deposits of salt would not extend shoreward as far as those of the lime carbonate and calcium sulphate. For this reason we find beneath Monroe more or less anhydrite, but no rock salt until we pass further north, in which direction numerous beds are developed, some of them attaining surprising thickness beneath Detroit. The deeper portions of the original evaporating basin then lay to the north of Monroe county, and the shore to the south. After the deposition of most of the calcium carbonate, calcium sulphate and salt there would remain in the central and deeper portions of the basin a solution, rich in chlorides of calcium, magnesium and sodium, and consequently intensely bitter to the taste. If complete evaporation took place these salts would crystallize, but if not the bittern containing them would impregnate thoroughly the beds formed later. Percolating waters would subsequently take up these salts again and give rise to the highly charged mineral waters that characterize the central portions of this great Silurian basin.

*See Vol. V, Geol. Survey of Mich.,Pt. II, pp. ix to xix. "The origin of Salt, Gypsum and Petroleum," Lucius L. Hubbard.



*Description of special beds.*

§ 6. Sylvania sandstone.

On account of their economic and stratigraphic importance it seems desirable to describe somewhat in detail two sets of strata which mark well defined horizons in the beds of dolomite. The chief characteristics of the latter rock will be presented in the following chapter IV upon quarries. Of these included beds the thickest, most important and most readily recognized one is the Sylvania sandstone.

This has been named from its occurrence southwest of the village of Sylvania, Ohio, where it has been quarried for the manufacture of glass. It enters the southwestern corner of Whiteford township (Sec. 5, T. 9 S., R. 6 E.) as a narrow belt scarcely more than one-half mile in breadth, owing to its steep westerly dip. It strikes northeastward across the county, broadening gradually to about four miles near the center, as seen upon the map (Plate I). Toward the Raisin, northeastward across Raisinville, the bed seems to narrow to less than a couple of miles as far as southwestern Ash, then turns to the east and maintains a breadth of two to three miles across Ash and Berlin townships. Upon entering Whiteford, from Ohio, it is covered by twenty to twenty-two feet of surface materials, which are reduced to ten feet, or less, in Sec. 28. Drift fragments of the harder portions of the rock occur in the vicinity, scattered over the fields, in the N. E. ¼, S. E. ¼, Sec. 5; N. E. ¼, N. E. ¼, Sec. 32; N. E. ¼, N. W. ¼, Sec. 33 and in the N. W. ¼, N. E. ¼, Sec. 29. From Sec. 28 the drift covering increases northeastward to twenty and then to thirty feet or more. In Raisinville the rock comes nearer the surface and forms the bed of the Raisin for a considerable distance. At the ford, near Grape, heavy building blocks for foundation walls have been removed. Where the rock is less coherent it has been scooped out by the river and only the harder strata appear in the ledges exposed during stages of low water. Just below the ford between claims 494 and 408 (South River Raisin), there is a bed of brown dolomite capped by six to ten inches of chert, while at the ford itself, blocks of sandstone were found which are either in place or have been shifted but a short distance. Opposite claim 275 (South River Raisin) dolomitic sand rock occurs.

The only natural outcrop of this sandstone occurs in the southwest quarter of Sec. 2, T. 6 S., R 8 E. (Claims 493, 484, North River Raisin.) Here extending over an area of eight to ten acres, to the north and west of the "Blue Bush Cemetery" the rock is directly exposed or covered by only a few inches of soil. Beneath an area of sixty acres the surface covering is said to be but two to three feet in thickness. Several pits have been opened exposing the bed to a depth of 12 to 30 feet, from which sand has been taken for shipment. In the eastern part of Ida township a trough is developed in the upper surface of this soft bed, extending its entire distance northeastward, as shown by the contours on the map (Plate I). The drift covering over the deeper portions of this trough in Ash and Berlin varies from 30 to 35 feet. The highest elevation attained by the bed is 673 feet above sea-level in Secs. 28 and 32 of Whiteford. The drop is gradual in the direction of the strike, giving an altitude of 610 feet A. T., in Ida, 613 to 588 A. T. in Raisinville and, finally, in Berlin a minimum of 560 feet A. T., or 13 feet below the level of Lake Erie.

Where it enters from Ohio the bed is probably not over 30 feet in thickness, but it increases gradually toward the northeast. At the cranberry marsh of Mr. C. W. Everett (S. E. ¼, Sec. 24, Summerfield) it showed a thickness of "40 to 50 feet," overlain by thirty feet of blue limerock (dolomite). In the deep well at Ida (N. E. ¼, Sec. 3) there were 45 feet penetrated. The breadth of the outcrop along the Raisin would indicate about the same thickness. The greater breadth of the belt in eastern Ida, western La Salle and southern Raisinville, does not seem to be due to increased thickness but rather to the position of the beds. At the sand pits, above referred to, three sets of cores have been taken out, giving a thickness of about 60 feet. There is a capping of four feet of a laminated dolomite here, which has escaped the general erosive agencies, showing that practically the entire thickness is represented by these cores. To the northwest, about three miles, at the Woolmith quarry (S. E. ¼, Sec. 29, Exeter), borings give the bed a thickness of 50 feet. The bed was penetrated at Gibraltar, Horse Island, in a 130 foot well belonging to Edmund Hall, but the record of the thickness could not be obtained. It is a matter of geological, if not economic interest, to know that this bed continues northward giving a thickness of 95 feet at Trenton, 130 feet at Wyandotte and, in the ten Solvay wells at Delray, an average of 99.4 feet.



Beds of essentially similar sandrock, but carrying considerable dolomitic matrix, occur both above and below the main bed, but separated from it by layers of dolomite. These secondary layers may be mistaken for the Sylvania proper, as was done by Rominger, and its thickness underestimated.* In the Davis quarry one and one-half miles west of the village of Ida (N. E. ¼, Sec. 4), a series of drill cores gives a compact white sandrock six feet thick, at a depth of 25 to 31 feet. Beneath this lies a silicious dolomite which caps the main bed struck at Ida. At the Lulu quarry (N. W. ¼, Sec. 16, Ida) one foot of similar sandrock is exposed with dolomite above and below. The same rock is seen in the floor of the Cummins' quarry (S. E. ¼, Sec. 2, Whiteford). At the mouth of Willow Run a layer of sandrock occurs which might easily be mistaken for the Sylvania, except that it is much coarser than the typical sandstone. It is overlain and underlain by beds of silicious dolomite, as seen in the Raisin bed and as indicated by adjoining well records.

Owing to the limited number of natural exposures the tracing of the Sylvania across the county had to be done largely from records of farmers and drillers. Such records were not always as abundant and definite as was desired and the breadth of the outcrop beneath the drift can be regarded as only an approximate one. Certain common expressions were found to characterize the bed in these records collected and much importance attached to them. The loose sand so frequently pumped from the wells over this belt was said to resemble "snow," "flour," "salt," "granulated sugar." The bed itself furnishes water throughout its extent and a very common report was that a thin crust of the bed had only to be punctured, when the water could be pumped or would rise to the surface. In numerous instances the sand-pump had to be used first before any considerable quantity of water could be obtained, thus testifying to the incoherent nature of the bed. Except in a few deep wells the bed is not entered far, so that we have comparatively few records of its thickness. In such cases it is said to cut the drill very badly, so that it would require very frequent sharpening. The reason for this will be apparent when the form of the individual grains is described. Some typical descriptions will serve as samples of the data, by means of which the bed was located upon the geological map.

Information secured from Barney Gay, a local driller of South Rockwood. At John Strong's S. E. ¼, Sec. 8, Berlin, struck 15 feet of sand, "white as snow," went

*Geol. Survey of Mich., Vol. III, Pt. I, pp. 27-29.

five feet in five minutes, and pumped sand for two weeks. At the blacksmith shop in the village, at a depth of 18 feet, "struck a funny kind of stuff," which was white. From all the wells in the neighborhood he secures white sand. Sometimes it has above it a hard crust. At the place of Joseph Borrow (S. E. ¼, S. E. ¼, Sec. 17, Berlin) it is twenty-four feet to a "shell-like rock," below which the drill drops four to six inches. This rock is a dark lead color. Before water will flow there must first be pumped out a snow-white sand of which there may be two to two and one-half feet. Has pumped out two to three wagon-loads. At Peter Donelly's (S. E. ¼, N. E. ¼, Sec. 19, Berlin) it is 32 feet to rock. Dug 14 feet and drilled 16 to 18, when the drill dropped three to four inches. The water rose into the dug portion and "spewed" white sand, covering the bottom to a depth of several inches.

Charles G. Peters, S. W. ¼, Sec. 8, Berlin (T. 5 S., R. 10 E.). Has two flowing wells, each 28 feet to a "shell-rock." In the well at the house the drilling was stopped for the night, no water having been secured. The next morning the water was found to be flowing, having brought up eight to ten bushels of sand, "white as paper," and giving the appearance of a snow bank about the mouth of the well. In the well in the woods he did not secure this sand, although a gray variety was struck. At the N. E. ¼, N. E. ¼, Sec. 18, Berlin, he put down a well in which rock was struck at 30 feet and entered 32 feet. It wore the drill considerably. In color it was "grayish, or dark like, whiter on drying." Considerable sand had to be pumped out, when the well flowed until a well was drilled at Howard Valrance's (N. E. ¼, Sec. 17, Berlin), since which time the water has had to be pumped. Still another well was put down in S. E. ¼, S. E. ¼, Sec. 7, Berlin (T. 5 S., R. 10 E.), at which place rock was struck at 30 feet. A very hard shell was first reached upon which the drill "rang like a kettle," and beneath this lay the same sandrock.

Charles M. Hood, N. W. ¼, S. W. ¼, Sec. 13, Ash. Here it is 32 feet to rock. Water rises to within four feet of the surface, is hard and contains iron. Just below the clay a hard "crust," a few inches thick, is struck. This has only to be punched through and the sand pump put in to secure water. From this well there have been pumped several wagon boxes of sand, which is used for scouring. When wet it packs very firmly. Has put down wells at eight different places in the neighborhood in each of which this same sand was obtained.

C. B. Loranger, N. W. ¼, Sec. 26, Berlin. Flowing well of sulphur water, with some iron and, at times, oil. After entering rock two feet a white sand was reached, looking "like flour." A few rods east is another well from which much sand has been pumped.

Augustus Dobberstein, S. W. ¼, N. W. ¼, Sec. 29, Ash., 35 to 36 feet to a very hard rock. Water stands 10 to 12 feet from surface and is considered "soft." A barrel of the water will sometimes yield a half barrel of white sand. This sand cut the drill badly and filled in the hole so as to prevent further drilling. Well becomes completely filled with sand and has to be reopened.

Peter Stumm, N. W. ¼, N. W. ¼, Sec. 32, Ash. 32 feet to a solid rock, above which water was secured. There was a "soft stuff" just above rock, which felt gritty on the augur. Jabbed through a crust two to three inches thick, when water rose rapidly in the well, standing about seven feet from the surface. The drill was cut badly and upon entering the rock "bounced."

Michael Strobel, N. E. ¼, Sec. 15, Ida. Rock was reached at 27 to 28 feet and entered 20 feet. An attempt to take out a core failed. No casing was put in and the hole filled with sand.

The chief characteristics of the Sylvania sandstone will be inferred from the above records. Typically it is a fine grained, sparkling, snow-white sandrock of remarkable purity. Usually it is very friable and incoherent, readily crumbling into sand in the fingers, or under the action of a drill. This is due to the lack of cementing material present with which to bind together the grains. Locally, considerable dolomitic cement may be present, forming a compact white sandstone, from which good cores may be removed by means of the "diamond drill." The beds exhibit only coarse stratification as observed at the pits and along the Raisin. At the Sylvania quarries, however, in some of the beds, there is quite a distinct lamination seen on weathered surfaces. Fossils are rare and very poorly preserved for the most part. Fragments of the sandstone taken from the Raisin near Grape furnished traces of trilobites, corals, brachiopods, lamellibranchs and gasteropods, but in an unsatisfactory condition for positive identification. At the outcrop the upper strata, to a depth of 8 to 10 feet, are discolored by percolating surface water. The stain is said to be due to organic matter, however, and not to iron. The following analysis of the rock at this locality is kindly furnished by W. H. Cowles, of Detroit, and shows the composition before it has been subjected to the washing process which prepares it for glass manufacture:



| | |
|---|---|
| Silica | 96.50% |
| Calcium carbonate | 1.50 |
| Magnesium carbonate | 1.04 |
| Iron oxide | .00 |
| Sulphuric acid loss and undetermined | .76 |
| Loss on ignition | .20 |
| | 100.00 |

Under the low-power of the compound microscope the individual grains, instead of being rounded, exhibit sharp points and edges, with plane faces. A close inspection shows that a very large proportion of them are, in reality, short hexagonal prisms, terminated at one or both ends with a hexagonal pyramid. They are thus more or less perfect quartz crystals. Examined with polarized light, a still more interesting fact is developed. The body of each minute crystal is an ordinary rounded sand grain, about which a thin shell of quartz has crystallized so as to give it optical continuity; as is evidenced by the fact that both granule and shell extinguish simultaneously, when revolved between crossed nicols. In the central granule Prof. C. H. Smyth, Jr., has identified crystalline inclusions of hornblende, apatite, tourmaline, rutile and zircon. Fluid inclusions, with bubbles, can also be seen with high power, showing that these grains do not differ from ordinary sand grains of the sea or lake shore. Upon the outside of the crystals are developed sparingly, minute rhombohedrons of calcite, or dolomite, probably judging from analysis above, the latter.

Perfect quartz crystals from the insoluble residues of limestones had been described in the early part of the century but their real nature remained unknown for many years. In 1880 Sorby described such sand grains as consisting of an angular or rounded quartz grain, with a secondary addition of crystallized silica, giving crystalline continuity.* In the New Red Sandstone of Penrith, he found

*Quarterly Jour., Geological Society, Vol. 36, p. 62.

upon the surface of the enlarged grains impressions due to the interference of contiguous grains. "Thus proving conclusively that the deposition of crystalline quartz took place after the nuclei were deposited as a bed of normal sand." (p. 63). In the case of the Vosges sand Daubrée had recognized such enlarged grains and believed them due to the local action of heated water. In the Fifth Annual Report of the Director of the U. S. Geol Survey,* Irving describes and figures similarly enlarged grains from our American rocks, showing that the secondary silica may serve as a cement and give rise to quartzites from sandstone. His investigations prove

"That most if not all of the ancient quartzites, as well as many of the quartziferous schists, are simply fragmental rocks composed in the main of the original fragmental material—unaltered save by some of the ordinary metasomatic processes—cemented together by a siliceous cement of secondary origin. This siliceous cement forms the only part of the rock that has crystallized *in situ*, the more or less intricate interlocking of its areas and its common optical continuity with the original quartz fragments giving rise to the deceptive appearance of complete original crystallization" (p. 221).

The discussion of the secondary enlargement of quartz grains was continued by Wethered in 1888,† and theories of their origin presented. He concludes that they cannot represent detrital matter, since there is no evidence of wave action, that they could not have crystallized directly from a solution of silica and that they are not the result of crystallization of amorphous or chalcedonic silica, but that they do represent additions of crystalline silica to a rolled or broken quartz crystal. This secondary silica he regarded as having been

"extracted from solution by the molecular affinity between the silica of the detrital quartz and the silica in solution" (p. 196).

With the results of these investigations in mind let us frame an explanation of the formation of this rather remarkable bed of sandstone. The stratification noted would prove that it was originally deposited in water, and the presence of marine forms in fossilized condition, proves that this water was the sea. Sand accumulates only in the region of the shore.‡ To account for the spreading of a shore deposit over such wide areas it is necessary to assume that the shore line was not stationary, that it was advancing landward, owing to subsidence, thus establishing shore conditions successively over wider and wider areas. Branner describes a beach deposit in Brazil, consisting of cobbles, pebbles and sand and attaining a

*1885, pp. 181 to 242.
†Quart. Jour., Geol. Soc., Vol. 44, pp. 186 to 199.
‡i. e. in the littoral belt, but sand as fine as that of Sylvania may be carried a good way by currents. L.



thickness of ten feet, which was thus made to cover thousands of square miles.* In this case, however, an elevation was in progress and the deposit attained only the ordinary thickness of beach material. The gradual subsidence of the sea bottom in southeastern Michigan, while the materials for the formation of the bed were accumulating, would permit a considerable increase in thickness. The lower strata would contain coarser particles, deposited while the shore was nearer; the upper strata would consist only of grains which were small enough to be carried some distance seaward by waves and currents. The silica for the sand grains was probably derived indirectly from the ordinary crystalline rocks and the grains were rounded and assorted by wave action. The mud was carried seaward and there should exist somewhere a bed of shale, the correlative of the Sylvania sandstone unless it was derived from the disintegration let us say of the Potsdam sandstone. Dolomitic slime derived from the disintegration of calcareous organisms, or precipitated directly from the sea water as previously explained, might be deposited with the sand grains and serve as a matrix. The proportion of sand and slime would determine whether there would be formed a dolomitic sandrock or sandy dolomite, such as underlie and overlie the Sylvania proper. Finally, when the shore line had sufficiently retreated the supply of sand would fail, only the formation of dolomite would continue and the epoch of the Sylvania would have closed. Subsequent to the complete formation of the bed, percolating waters, rich in alkaline salts and holding relatively larger quantities of silica in solution, saturated the loose sand, and about each grain a thin layer of crystallized quartz was deposited, owing to the "molecular affinity between the silica of the detrital quartz and the silica in solution." Experiments upon fragments of crystals suspended in saturated solutions of the same substance have shown that the crystalline accessions invariably yield crystalline, and hence optical, continuity with the original fragments. The molecules of the secondary silica simply dropped back into the places occupied by those lost from the original crystal fragments from which the sand grains were fashioned. The character of the percolating water soon changed, otherwise there would have been formed a quartzite as soon as the silica deposited began to firmly unite the grains. That the secondary enlargement of the grains

*"The supposed Glaciation of Brazil," Journal of Geology, Vol. I, No. 8, 1893, pp. 753-772.

took place after the formation of the beds is conclusively proven by an examination of those embedded in the adjoining dolomites. When fragments of these are digested in hot acid in order to remove the carbonates, the sand thus obtained is snow white and, under the microscope, shows also secondary additions of crystallized silica. Instead of getting perfect crystals, however, the surfaces are seen to be roughened with imprints of rhombohedrons of minute dolomite crystals, against which the crystals of quartz have grown.

The upper strata of the Sylvania sandstone, to the north of the Raisin, are about 70 feet below the base of the Dundee, this space being occupied by dolomites, more or less silicious, which cannot be separated lithologically, or palæontologically, from those lying beneath. The quarry rock at Ottawa Lake, the "sinks," Lulu, Ida, Raisinville and Woolmith, is all derived from these beds which intervene between the Sylvania and the Dundee. Thus embedded in the Monroe beds there is no reason yet known for assigning to it any different geological age than that of these Monroe beds themselves. At the time of the Newberry survey of Ohio the Sylvania was supposed to separate the Lower from the Upper Helderberg formations, and with an entire absence of fossils, it was very naturally correlated with the Oriskany sandstone of New York. Rominger regarded it as occupying this same geological position in our Michigan series and its correlation with the Oriskany as very probable. In his Biennial Report of 1860 and in his map of 1873, Winchell includes the bed in the Corniferous. In 1893 Orton first pointed out the fact that this bed in Ohio is overlain by typical Waterlime strata* said to be 200 feet in thickness. These beds are seen in the Sylvania quarries, lying to the west of the sand pits, and one mile farther north at the Cooper quarry, N. E. $\frac{1}{4}$, N. E. $\frac{1}{4}$, Sec. 18, T. 9 S., R. 6 E. The Sylvania sandstone must be regarded as part of the Waterlime group of the Salina.

§ 7. Oölitic beds.

Several beds of dolomitic oölite are known to occur, embedded in the dolomitic limestone. The upper one lies about 45 feet above the top of the Sylvania and hence about 25 feet below the base of the Dundee. It varies in thickness from three and one-half to four feet, as seen at the Woolmith quarry and in the adjoining excavation on

*Geol. Surv. of Ohio, Vol. VII, pp. 17-18. The correlation of this part of the geologic column is just now a subject of lively controversy. See two recent papers by H. S. Williams, pp. 333-346, and Charles Schuchert, pp. 241-332, of Vol. XI, Bull. Geol. Soc. of America.



the place of John Hoffman. The lowest bed exposed lies below the Sylvania at a distance of about 100 feet and in the neighborhood of 200 feet below the Dundee, giving a well defined horizon. This bed is most typically developed on Plum and Stony creeks as a light brown absorbent stone, gritty to the feel and showing a thickness of twenty inches to two feet. To the southwest of Monroe the structure becomes somewhat modified and obliterated and grades into a bed of brown dolomite, five to six feet in thickness, known locally as "bastard limestone."

Occupying the crest of the ridge it has been found in enough places in the county to permit the approximate tracing of it upon the geological map, whereas this was impractical for the uppermost bed. It enters the county from Ohio in Sec. 4, Whiteford (T. 9 S., R. 6 E.) and is first seen in the N. E. $\frac{1}{4}$, N. E. $\frac{1}{4}$, at a small quarry belonging to Stephen Young. Passing northeastward it is seen in the excavation along the roadside belonging to Nelson Bush (S. W. $\frac{1}{4}$, S. E. $\frac{1}{4}$, Sec. 25, Whiteford) and again some 80 rods eastward on Halfway Creek. It is next seen in the quarries about Little Lake in Bedford township. The best exposure is in the quarry on the farm of Mrs. White, where it is overlain by a few inches of loose dolomite. Upon the Dunbar farm to the northwest (S. W. $\frac{1}{4}$, S. W. $\frac{1}{4}$, Sec. 10, Bedford), the oölite is struck in a small field quarry about 100 yards east of the residence. At the center of Sec. 32, La Salle township, it was found in a small quarry belonging to W. W. Green, and again upon Otter Creek, claim 538, South River Raisin, where it is much compacted, light brown in color, having a gritty feel and might easily be mistaken for a sandstone. Still striking northeastward it appears in the bed of Tamarack Creek (property of Dennis Navarre, claim 498), and on the south bank of Plum Creek, claims 498 and 230, South River Raisin, in the Navarre quarries. The dip here is local and equals about six to seven feet in one hundred. Some 200 yards up the creek local flexures bring the bed to the surface, where the dip is 4° toward N. 22° W. At Brest, on Stony Creek, property of Mrs. Mary Emerson (claim 532, North Stony Creek), the oölite occurs in the best condition for study. The granules are very generally spherical and readily separate from one another in the fingers. From this point the bed strikes eastward and curves to the southeast, where it forms a submerged layer at Stony Point, Lake Erie. The gravelly beach from Stony Point to Point aux Peaux contains many partially worn fragments of this bed.

As seen on Stony Creek the component grains of the oölite are very regularly spherical and average about one-fiftieth of an inch (0.4 millimeter) in diameter. The cementing material is dolomite, which has formed a thin layer over the granules, showing minute crystal faces when examined with the magnifier. These granules have a concentric structure, being made up of a series of delicate, concentric, spherical shells. Occasionally when the granules are broken across some of their central layers drop out, giving them the appearance of having possessed a nucleus of some different material. With cold, dilute hydrochloric acid they effervesce slowly at first, but as they fall to pieces, the action becomes more rapid. When a considerable number are thus dissolved the acid becomes clouded and there settles to the bottom a dark brown, bituminous sediment. When single granules are treated with strong acid upon a glass slide, under the microscope they are seen to disintegrate into an immense number of minute, irregular dolomitic crystals, which dissolve only very slowly. There remains behind only the brownish slime and a few irregular birefractive fragments, none of which can, however, be regarded as a nucleus about which the concentric shells could have formed. In thin sections there is no trace of a solid nucleus, such as a sand grain, although the central portion sometimes appears darker and sharply defined from the remainder of the granule. These darker centers are more frequent in the Plum Creek sections than those from other localities from which material was sectioned and are apparently due to an accumulation of bituminous matter. Their diameter varies from one-sixth to three-fourths of that of the granule itself. Occasionally the central portion is lighter colored by transmitted light and a band of darker material lies outside, while in some instances a light band intervenes between the darker central portion and an outer darker band. In the preparation of the thin sections the central portion has occasionally dropped out, showing a surface of weakness between certain layers. When magnified the granules are seen to be made up of a great number of interlocking birefractive crystals of dolomite, which become well defined rhombohedrons, with their curved faces, about the outside surfaces of the grains. Toward the centers the crystals are invariably smaller. Except for this difference in color and size of the component crystals there is a very little trace of concentric structure when viewed with the microscope. Where the central mass has dropped out the margin appears rough.



Rarely dolomite crystals are arranged as a single concentric layer. There is no trace of a radial arrangement of the crystalline particles in any of the sections.

As has been stated the oölite shows considerable modification in its various outcrops and, indeed, considerable at the same locality. Typically it is made up of an immense number of subspherical bodies, cemented more or less firmly, and having the appearance of a mass of fish eggs, from which it derives its name. Upon Plum Creek these corpuscles are smaller than those seen at Brest, and the structure is not so apparent to the naked eye. Under the hand magnifier the darker central core is very conspicuous in all those which happen to be broken across near the center. Mingled sparingly with these spherical to ellipsoidal bodies are others which have about the same, or somewhat less, diameter but with a length of two to three diameters and are either straight or slightly curved. Their ends are rounded and they have the appearance of short, blunt sticks. Except for this difference in shape and bulk they exactly resemble the other bodies. At the White quarry, Little Lake, the granules are nearly all flattened and elongated to a length of about two diameters, while at the Dunbar quarry near by, the flattened forms are abundant with large numbers of the small subspherical type filling the spaces. The central darker core, with the outer lighter shell, gives evidence of the same structure as that described above. Under the microscope, in thin sections, they exactly resemble the structure of the more nearly spherical forms and they behave similarly with the acid. Still a third type of structure occurs in the oölitic rock, shown most beautifully and typically at Stony Creek and in the Dunbar bed, where it comprises nearly fifty per cent of the rock. These are flattened, tongue-like masses, varying much in size, from that of the flattened granules above mentioned to heavy masses four inches long, by three wide and one inch thick. Ordinarily their thickness varies from one to two millimeters, but their length and breadth are more variable, usually falling within five to ten millimeters. They are arranged in the rock with their flat faces approximately parallel with one another and with the bedding. They usually show evidence of having been broken into fragments and partially recemented, testifying to the disturbances which gave rise to the breccia in the adjoining beds and to the fact that they were *brittle* when the disturbances occurred. Their edges and corners are rounded, their surfaces somewhat undulating frequently showing rounded tubercles and irregular ridges. The smaller the bodies the more irregular and tubercular they become, unless, indeed, there are several types of these to be distinguished. Two hand specimens collected from Stony Creek and one from Bush's quarry, in Whiteford, show the portion of the bed sampled to be made up almost exclusively of this kind of material. These forms might easily be mistaken for frondescent *Stromatoporoids* or *Bryozoa*, so far as their external appearance is concerned, but in thin section they reveal none of the structure of these groups. Dissolved in acid they yield considerable bituminous sediment. Under the microscope they are seen to consist of a dense, interlocking mass of birefractive dolomite crystals, sometimes stained more or less toward the center.

It is evident that these three types of structures were all deposited simultaneously. It is very probable that they were *formed* simultaneously and not far from where they now occur. From their similarity in structure and composition and from their tendency to run together through intermediate forms, it is very probable that they were all formed by the same, or related agencies. The stratification of the bed and its gradual passage into dolomite, with marine fossils, shows that the accumulation took place in the sea. From the discussion which has preceded, it must be inferred that this sea was an inland one and rich in chlorides of sodium, magnesium and calcium. Any explanation of the formation of one form should, obviously, account for the formation of the others. The commonly accepted theory for the origin of the subspherical bodies of a typical oölite, viz., sand grains held in suspension by currents in a solution saturated with calcium carbonate, from which there are deposited concentric layers, will not apply here. In the first place there are no such foreign nuclei present and in the second, this explanation could not apply to the elongated and frondescent bodies. Through the kindness of Prof. I. C. Russell we have had an opportunity to examine some oölitic sand now forming about the shore of Great Salt Lake, and have found it surprisingly similar to our Monroe county product. It is made up of subspherical granules very largely, which average in size the same as those of our Plum Creek material, but ranging as large as those noted from Stony Creek. They are grayish white in color, consist of calcium carbonate, and show a darker central core with a lighter outer band when broken open. Occasionally they are stained with blue or red coloring matter. Exteriorly they are smooth and polished, the larger



ones looking like porcelain. Mingled with these bodies are numerous stick like forms, straight or slightly curved, with rounded ends, looking like magnified *bacilli*. Their diameter is less than that of the average subspherical forms, about equals that of the smaller, while the length ranges from two to five or six diameters. These have the same composition and external appearance as the others, including the occasional staining. Much less frequently than the rods, there occur irregular flattened masses, considerably larger than the other forms, with rounded edges and corners and carrying upon their broader surfaces small "tubercles." These are very similar to the structures so abundant at Stony Creek and at Little Lake and Bush's quarry. In the Great Salt Lake oölitic sand none of the larger mases described are represented in the samples. It is possible that these are present in the water of the lake but are not cast upon the shore by the waves, or only the smaller forms of this type may be forming. When dilute acid is applied to any of these bodies the effervescence is very rapid and the layers of calcium carbonate are quickly dissolved, leaving behind what appears as a nucleus in each case. An examination of this with the microscope shows a whitish, porous, brittle mass, having the general form of the spheroid or rod from which it was derived. The material shows no double refraction and refuses to be acted upon by even strong acid. About it there appears to be more or less slime with fragments of irregular crystalline fragments. In some cases a relatively good sized, rounded, quartz grain occurs. If we can assume that the nuclear body is organic, that the crystalline particles are not essential but only incidentally or accidentally present; then the Salt Lake oölite is practically identical with that of our Monroe county bed and they have both been formed under the same conditions and by the same agencies. In the latter granules we find the same crystalline fragments, but the organic structure is represented by only the bituminous matter and there is no apparent nucleus upon digestion with acid.

In the fall of 1891 Dr. A. Rothpletz, of Munich, visited the shore of Great Salt Lake and made an examination of the conditions under which the oölite is forming. He found that which had not yet been washed up from the shore bottom to be partly covered with a bluish-green mass of algæ in which he recognized colonies of *Glœocapsa* and *Glœtheœ*.* These forms secrete large quantities of

*Botanisches Centralblatt, Nr. 35, 1892. Translation in American Geologist, Vol. X, No. 5, 1892, pp. 279-282.

calcium carbonate in form of rounded tubercles, which are often massed together in larger irregular tubercular masses, inclosing dead alga-cells. In dissolving the oölitic granules of the beach in very dilute acid he was able to identify the dead and crumpled *Glœocapsa* cells. The rods and tubercular masses yielded similar cells, the former more abundantly than the oölitic grains. He concludes that

"The oölites of the Great Salt Lake are, therefore, indubitably the product of lime secreting fission-algæ, and their formation is proceeding day by day. * * * According to the present stage of my researches, I am inclined to believe that at least the majority of the marine calcareous oölites with regular zonal and radial structure are of plant origin, the product of microscopically small algæ of very low rank, capable of secreting lime."

In the case of the Woolmith bed of oölite the smaller components are much compacted and their structure nearly or quite obliterated. There is a light chocolate colored, dolomitic matrix in which they show as minute whitish points and streaks. The frondescent structures are abundant, arranged parallel to the bedding and with their creamy white color give a streaked and blotched effect to the rock. Locally it has been termed "liver rock." These structures are more abundant towards the upper part of the bed and occur more sparingly in the lower portions. A laminated layer at the top furnishes a transition from the oölite to the overlying dolomite. In the case of all the oölitic beds we must assume that the material was originally calcium carbonate and that it was altered to the dolomite, through the action of magnesium salts in a concentrated solution of sea water. Favorable conditions for the formation of these beds and their conversion into dolomite were several times established. A bed somewhat similar to that of the Woolmith quarry, but which seems to be situated at a lower horizon, is seen in the Rath quarries, claim 685, South River Raisin.

*B. Beds Reached by Borings.*

§ 8. Deep well records.

Ten deep wells have penetrated the Monroe series of rocks to a greater or less depth. Upon Pl. V there is shown graphically the beds beneath the city of Monroe, so far as they have been revealed by the driller's record and samples. A complete series of such samples was examined by A. C. Lane and the data upon the right side of the plate determined, from which the geological identifications were made. Aside from the 210 feet of limestone previously referred to as a possible interpolation of Upper Helderberg (Corniferous), there is seen to be a series of variously colored dolomites, with or without anhydrite, down to a depth of 700 feet.* These are all referred to the series of Monroe beds the base of which is at an actual elevation of about 110 feet below sea-level. This same series of beds was penetrated to a depth of 910 feet in the Newport well, situated in the N. E. $\frac{1}{4}$, S. W. $\frac{1}{4}$, Sec. 1, Berlin, (T. 6 S., R. 9 E.) upon the estate of C. H. Buhl. The elevation of the mouth of the well, as determined by the aneroid barometer, is 585 feet. Overlying the rock is three feet of a rusty pebbly clay. The following data were determined from a study of the drillings which averaged one sample for every twenty feet. Throughout the series there occurred rusty grains which stained the neighboring fragments. Occasionally one of these showed weak magnetism but usually were unaffected by the magnet. These are believed to represent oxidized fragments of the drill.



*Newport Well Record.*

| | |
|---|---|
| 0 to 3 feet. | Rusty pebbly clay. |
| 3 to 83 feet. | Drab dolomite, giving considerable muddy sediment upon being dissolved in acid. Fragments of calcite in thin crusts and considerable anhydrite. |
| 83 to 93 feet. | Light drab dolomite, with mingled dark shaly fragments. Considerable muddy sediment. Anhydrite and sand grains present. |
| 93 to 165 feet. | Samples not saved. |
| 165 to 195 feet. | Drab dolomite with carbonaceous flakes, which burn with flame. Cold dilute acid acts quite energetically upon the fine drillings. Anhydrite and sand grains present. |
| 195 to 220 feet. | Bluish-drab dolomite, drillings much compacted in vial. Anhydrite is present. Flow of fresh water secured at this level. |
| 220 to 247 feet. | Very similar to last, but rather more anhydrite and drillings more firmly cemented together. |

*For records of the three wells see Vol. V, Part II, pp. 69-70, and Vol. III, Part I, pp. 30 to 31, and below p. 74. The well recorded in Plate V is known as the Moore well.

247 to 305 feet. Samples are wanting.

305 to 315 feet. Bluish-gray dolomite, carrying anhydrite and some selenite. Much sediment left after dissolving in acid. Further flow of fresh water.

315 to 372 feet. Bluish-gray, argillaceous dolomite. Some anhydrite present throughout.

372 to 420 feet. Buff dolomite which leaves much yellow sediment after dissolving. The insoluble portion contains numerous rounded grains of quartz, some hornblende and some black non-magnetic grains, which are probably some form of titanic iron oxide. The rock also carries anhydrite.

420 to 435 feet. Bluish dolomite. Drillings are coarse and very firmly compacted in vial, as though set with mortar. Lumps of anhydrite are mingled with the fragments of dolomite.

435 to 448 feet. Quite similar to the bed 372 to 420 feet. Drillings are fine and looser as contrasted with the beds just above and just below. Much anhydrite is present.

448 to 467 feet. Practically identical with bed 420 to 435 feet. A bluish dolomite, drillings coarse and firmly cemented in vial. Anhydrite is present in lumps.

467 to 500 feet. Bluish, dolomitic shale. Action of cold dilute acid upon solid lumps is weak; brisk on heating for a comparatively short time leaving behind much bluish, muddy sediment. Drillings not compacted. Some anhydrite is present.

500 to 520 feet. Bluish-drab, argillaceous dolomite. Drillings not compacted in vial. Lumps of anhydrite occur and black flakes.

520 to 560 feet. Bluish, dolomitic shale, essentially similar to that occurring from 467 to 500 feet. Fragments of anhydrite mingled with those of the shale.

560 to 598 feet. Blue and drab dolomite. Drillings are fine and considerably compacted in the vials. Fragments of anhydrite.

598 to 615 feet. Drab to gray dolomite. Anhydrite and some sand grains. Lower portion of bed is more impure.



615 to 720 feet. Drab to gray dolomite, with varying amounts of anhydrite. Some of the samples of drillings compacted in vials.

720 to 815 feet. The five samples from this bed are all alike and more buffish than those from above bed. The rock is a dolomite also, containing seams of carbonaceous matter, fragments of anhydrite and scales of selenite. For some reason the rusty iron grains are exceedingly abundant in all the samples.

815 to 825 feet. Drillings have a gray color and under the magnifier look much like pure anhydrite. With heated acid, however there is considerable effervescence showing the presence of the carbonates of calcium and magnesium in large percentage. The rusty grains are not quite so abundant, but are numerous.

825 to 833 feet. The drillings from this bed are a purer white than above. In hot acid they effervesce vigorously for a short time only, leaving behind much anhydrite, which dissolves slowly and quietly.

833 to 844 feet. Gray to dray dolomite with fragments of anhydrite and scales of selenite.

844 to 860 feet. Samples missing.

860 to 910 feet. Bluish gray dolomite. Drillings relatively coarse and somewhat compacted, containing bluish flakes and fragments of anhydrite.

We may assume that the Monroe beds lying between the base of the Sylvania sandstone and the Plum Creek oölite have not materially thickened in passing northward this short distance and that the thickness equals about one hundred feet. The breadth of the outcrop of this belt, measured from Brest and to the west of Newport, is about five miles, giving an approximate depth of twenty feet to the mile to these beds. Noting the position of the Monroe and Newport wells, with reference to the oölite, it will be seen that the shaly dolomite, struck in the former well at a depth of 390 feet, corresponds very closely in position to the similar rock in the Newport well reached at a depth of 467 feet, and that this is presumably the equivalent in the Ohio scale of the Tymochtee slate (§ 9). The upper belt of shaly rock in the Monroe section is also represented in the Newport series but runs into the portion of the well from which samples were not saved. The supposed interpolation of the Corniferous (Dundee) should be found in the Newport well at about 157 to 387 feet. There is, however no trace of it here, the beds seem to be dolomitic and all contain anhydrite, so far as we may judge from the nine samples.

Three deep wells have been put down within the county of which it has been impossible to secure the record or any samples of the drillings. Just before the oil and gas excitement about Toledo, a party leased land of Oliver S. Bond, Toledo, Ohio, for the purpose of putting down a test well. This was located on the S. W. ¼, S. W. ¼, Sec. 29, Bedford, one mile south of Lambertville. The well is supposed to have reached a depth of 500 feet, where it was suddenly terminated by the withdrawal of the machinery for use in the Toledo field. During the latter part of the summer and the fall of 1896 a test well was drilled in the extreme northeastern corner of Sec. 33, Berlin, (T. 5 S., R. 10 E.) upon land belonging to John Frey. The work was done under the direction of E. E. Harris, of Detroit, from whom it was impossible to secure any data. The well is supposed to have reached a depth of 1300 to 1400 feet and according to newspaper reports, penetrated a bed of rock salt at about 1200 feet. The latest and most successful well within the county was drilled in November and December, 1898, upon the land of F. C. Potter, two miles southeast of Vienna. The well is located in the N. W. ¼, N. W. ¼, Sec. 22, Erie township and its mouth is about four feet above Lake Erie level. The Trenton limestone was reached at 1555 feet and penetrated 112 feet, making the total depth of the well 1667 feet. The yield of oil and gas from this well will be given in another connection, (Chapter VIII, § 9).

Somewhat fuller data were secured concerning the Ida deep well, upon the property of Simeon Van Akin N. E. ¼, N. E. ¼, Sec. 3. This was drilled during the summer of 1893 by George M. Brown, Bowling Green, Ohio; George M. Barnes, Toledo; and Simeon Van Akin, of Ada; contractor, M. E. O'Conner, Cygnet, Ohio. The elevation of the mouth of the well is about 640 feet above mean tide level. A pipe was driven twenty-two feet to the rock when the drilling began. Ten feet of "common limerock" were found to overlie forty-five feet of Sylvania sandstone. Gray limestone (dolomite) followed to a



depth of 320 feet from the surface, when a light bluish shale was struck, this constituting the "first break." The well passed through this "slate" and entered a "limestone" darker in color than the overlying beds. At about 480 feet the water "boiled as in a kettle" owing to the escape of gas. This was found to burn but had to be extinguished in order to prevent injury to the derrick. For a distance of sixty feet into the rock the flow of gas increased. At 700 feet a "light colored rock" was struck and found to be 100 feet thick. A handful of the drillings was saved by Mr. Van Akin and a sample submitted to a Chicago chemist, D. W. Chapman, who pronounced the material magnesium sulphate (epsomite) a very soluble substance, known as "epsom salts" and nowhere known to form beds of such thickness. It was stated to have been formed from the "oxydation of sulphuret of iron to a sulphate by the action of water and the decomposition of a bed of dolomite by the iron sulphate." A sample of the same substance was secured from Mr. Van Akin by the writer and it, indeed, proves to be magnesium sulphate. In its geological position in the Monroe series this bed corresponds to a one hundred foot bed of light colored dolomite carrying much anhydrite, which is shown upon Plate V, as occurring beneath Monroe at a depth of 500 to 600 feet. It is very probable that this is the equivalent of the Ida bed and that the sample of the epsomite collected just happened to come from a dry cavity in the dolomite, in which places the salt is occasionally found as an incrustation. The total depth of the well was 1200 feet when the drilling was suddenly stopped.

In the western part of the county two wells have been drilled to the Trenton limestone, each of which proved unsatisfactory so far as oil and gas are concerned. The first was drilled in 1887 in the old Christiancy quarry, upon the Macon, then owned by a Mr. R. H. Nogard. Owing to the secrecy maintained in regard to the results, it was inferred that the well had proven a success and a second one was drilled by citizens of Dundee the following summer (1888) upon the place of Alfred Wilkerson, one mile south of the village. Samples of the drillings are not available but the driller's logs are kindly furnished by Byron J. Corbin, of Dundee. They are valuable only as they enable one to infer the real nature of the beds.

Driller's record, Nogard well.*

Location, N. W. ¼, N. W. ¼, Sec. 8, T. 6 S., R. 7 E. Elevation of mouth, 660 feet.

| Formations. | Thickness. | Depth of top from surface. | Elevation of top above tide. |
|---|---|---|---|
| Gray limestone | 59 | 0 | 660 |
| Buff and white limestone | 100 | 59 | 601 |
| Blue limestone | 150 | 159 | 501 |
| Buff and blue limestone | 260 | 309 | 351 |
| Oil limestone | 100 | 569 | 91 |
| Buff limestone and brown marble | 600 | 669 | – 9 |
| Oil limestone | 151 | 1,269 | —609 |
| Snow white marble | 100 | 1,420 | —760 |
| Red, white and blue marble | 400 | 1,520 | —860 |
| Shale | 30 | 1,920 | —1,260 |
| Gray, black and brown slate | 200 | 1,950 | —1,290 |
| Trenton limestone | | 2,150 | —1,490 |

Total depth, 2150 feet.

Driller's record, Dundee well. (Sparks and Allen, Elgin, Ill.)

Location N. E. ¼, N. E. ¼, Sec. 25, T. 6 S., R. 6 E. Elevation of mouth, 680 feet.

| Correlations by Lane. | Formations. | Thickness. | Depth of upper surface. | Elevation of upper surface. |
|---|---|---|---|---|
| | Quicksand | 8 | 0 | 680 |
| Pleistocene. | Clay | 30 | 8 | 672 |
| | Gray oil limestone | 65 | 38 | 642 |
| | Sulphur limestone | 70 | 103 | 577 |
| | Dark limestone | 20 | 173 | 507 |
| | Fine gray sandstone (Gas) | 12 | 193 | 487 |
| | Blue gray limestone | 30 | 205 | 475 |
| Waterlime | Gray sandstone | 18 | 235 | 445 |
| | Fine limestone | 105 | 253 | 427 |
| | Hard shell limestone | 40 | 358 | 322 |
| | White sandstone | 7 | 398 | 282 |
| and | Dark limestone | 48 | 405 | 275 |
| | Hard shell limestone | 45 | 453 | 227 |
| | White putty limestone | 70 | 498 | 182 |
| Salina. | White putty limestone, very hard | 50 | 568 | 112 |
| | Buff limestone | 220 | 618 | 62 |
| | Alternating blue, gray and brown limestone | 315 | 838 | —158 |
| | Fine buff limestone | 10 | 1,153 | —473 |
| | Gray limestone | 7 | 1,163 | —483 |
| | Buff limestone | 23 | 1,170 | —490 |
| | Light gray marble | 15 | 1,193 | —513 |
| (Guelph dolomite.) | Snow white marble | 135 | 1,208 | —528 |
| Niagara. | Dark blue marble | 80 | 1,343 | —663 |
| | Red marble | 15 | 1,423 | —743 |
| | Pinkish gray marble | 35 | 1,438 | —758 |
| (Rochester shale.) | Blue slate | 30 | 1,473 | — 793 |
| | Gray limestone (Mineral water) | 60 | 1,503 | —823 |
| Medina. | Red slate | 60 | 1,563 | —883 |
| Hudson River. | Gray slate | 100 | 1,623 | —943 |
| | Blue slate | 110 | 1,723 | —1,043 |
| Utica. | Brown slate | 300 | 1,833 | —1,153 |
| Trenton. | | | 2,133 | —1,453 |

*Mr. C. S. Nims, the driller, told Mr. Lane that there was 1,640 feet of 4 to 5 inch casing to the "slates" and from 600 to 800 feet of them, the latter including probably the Medina, Lorraine and Utica shales. These figures agree better with those of the Dundee well. A tube of samples of the latter was kept, and shows selenite, but was shaken up. The record of the Dundee well was given in the Dundee Reporter, Dec. 7 and 21, 1888, and Jan. 11 and 21, 1889.



Entered Trenton 144 feet securing oil and gas in small quantities, both of which disappeared and no more water was secured. Total depth of well 2277 feet.

§ 9. Interpretation of records.

In addition to the 200 feet which comprise the upper part of the Monroe series and which are exposed in various parts of the county, there are about 700 feet in the vicinity of Monroe which are known only through these deep well records. As stated in previous sections the thickness is less towards the Ohio line and increases northward. These beds consist of variously colored dolomites, some carrying considerable quantities of anhydrite. At 390 and 450 feet of the Monroe section the dolomite contains some shale, which is very probably the horizon of the "Tymochtee Slate," of N. H. Winchell. This was described and named in the geology of Wyandot county.* In his report of 1893,† Orton calls attention to this bed as one of the few recognizable horizons in the Ohio scale and states that it occurs below the middle of the series and probably within one hundred to two hundred feet of the base. At Monroe the bed itself has thickened from the twenty-four feet found in the typical Ohio locality and its lower layers lie from two hundred to two hundred and fifty feet from the base of the series. The shale reported in the Ida well at a depth of 320 feet is too high up for the Tymochtee and seems to correspond with those shaly beds which comprise the upper part of the Monroe section.

Beneath the Monroe beds in southeastern Michigan there lies a compact, rather homogeneous mass of dolomitic limestone known as the Niagara or Guelph. This is typically fine grained, very light colored and free from anhydrite and salt, apparently formed in the open sea before the concentration of the sea-waters had begun which characterized the succeeding age. The Monroe section shows about 360 feet of this formation, which near its middle portion becomes arenaceous. In Ohio the lowest member of the Niagara is a light colored shale, with thin calcareous bands. In the Wyandotte well‡ ten feet of "slate" are regarded by Lane as the equivalent of the Niagara (Rochester) shale. Below the Niagara lies a bed of greenish and reddish shale, about one hundred feet in thickness, to be referred to the Medina of the New York series. These colored

*Survey of Ohio, Vol. I, 1873, page 633.
†Survey of Ohio, Vol. VII, page 16.
‡Geol. Sur. of Mich., Vol. V, Pl. LXVI.

shales pass into the bluish Hudson River (Lorraine) calcareous shales which show a thickness in the Monroe section of 400 feet. In southern Ohio the Hudson River consists of alternating layers of blue limestone and blue shale. Northward the amount of limestone diminishes so that it is all liable to be classed as shale in well records. According to Orton it also grows darker in color and difficult to separate from the underlying Utica. Towards the Ohio line the thickness becomes less, reaching in northwestern Ohio 300 feet. The Utica consists of a mass of brown bituminous shale, becoming black towards its base. Its thickness seems to be about 160 feet beneath Monroe. Part of the 300 feet assigned to the Utica in the correlation of the Dundee well belongs to the Hudson. Finally comes the coveted Trenton, the deepest bed yet reached by the drill in this portion of the state. At Toledo the top of the formation is struck at about 812 feet below mean tide level. In the Potter well near Vienna its elevation is 978 feet below tide. In the three Monroe wells the Trenton was found to be lower toward the west or northwest. In the Moore well, third ward, the elevation is—1154 feet; in the Long well, 2d ward, it is —1149 and at the brick yard in the west part of the city it was found to be —1160. The average of these three gives —1154 feet. In the Dundee well the elevation was stated to be —1452 feet and —1490 in the Nogard well. These data give a drop in the Trenton from Toledo to Monroe of seventeen feet to the mile and from Monroe towards Dundee of about 26 feet per mile. These beds are all known in outcrop to the south, in Ohio, and northward about the shores of lakes Michigan and Huron. In southern Ohio the Trenton consists of heavy beds of true limestone with interstratifications of shale. Towards the north the shale becomes less and the rock passes into a true buff colored dolomite in which condition it enters Michigan. From the general dip of the Trenton it is apparent that Monroe county is located on the western slope of the great Cincinnati anticline.

# CHAPTER IV.

## QUARRIES.

### *A. Dundee Formation.*

§ 1. Macon quarry.

This bed has long been known as the "Christiancy quarry," from the early owner, Judge I. P. Christiancy, formerly of Monroe. It is now owned by B. E. Bullock, of Toledo, Ohio. It is located in the former bed of the Macon River, from which the water has been deflected by an embankment, and extends for a distance of about thirty rods along the stream, with a main excavation of 450 by 200 feet. This is the most promising locality in the county for a high grade limestone, since the same beds are here exposed as at the now famous Sibley quarry, near Trenton. The quarry lies two miles northeast of Dundee, one-eighth mile from the Detroit and Lima Northern R. R. and three-fourths of a mile from the Ann Arbor Railroad. The nearness of the Macon interferes now with the quarrying of the deeper and heavier beds, but with an extension of the quarry northward, in which direction the stripping increases only slowly, the annoyance caused from the water would be gradually diminished. At present the water is pumped from the deeper portions of the quarry and drains slowly into the abandoned Nogard well. It thus seems likely that the deepening of the quarry will open up subterranean passages through which the quarry may be perfectly drained.

Four beds may be recognized in the quarry which may be designated as A, B, C and D in descending order. Bed A, the uppermost, consists of a rich, gray limestone from one to two feet in thickness, abounding in fossils. The limestone is relatively soft, glistens with cleavage faces of calcite and is thin bedded and more or less shattered. In the eastern portion of the quarry the top ledge of this bed has an elevation of about 660 feet above sea level. The second, or bed B, has a thickness of 4 to $4\frac{1}{2}$ feet and in places is nearly or quite without a seam. In other portions of the quarry it is divided into thick beds. The rock is a compact, brownish limestone which assumes a bluish gray color on weathered surfaces. Fossils large enough to be seen with the naked eye are not as abundant as in the overlying bed and the cleavage faces are smaller. The rock gives a strong bituminous odor and drops of oil are occasionally seen in fresh specimens. With dilute hydrochloric acid a brisk effervescence is always obtained when the cold acid is applied to the solid rock. Toward the bottom the bed becomes somewhat cherty and in places there is interposed between this bed and the underlying bed C a seam of impure chert, varying in thickness from one to two inches. At the same horizon there is also to be seen in places a one inch seam of blue clay, more or less charged with sand. The main excavation of the quarry has taken place in these two beds but two deeper ones have been penetrated and their characteristics determined. Bed C has a thickness of seven to eight feet, is a soft limestone of a dark gray color, either without seam or very heavily bedded. Beneath this lies a somewhat similar eight foot bed, which the analysis shows is richer in calcium carbonate. The following table shows the chemical composition of these four beds, as determined by Mr. G. A. Kirschmeier, of Toledo.

| | Bed A. | Bed B. | Bed C. | Bed D. |
|---|---|---|---|---|
| Calcium carbonate | 90.80% | 86.80% | 77.60% | 95.00% |
| Magnesium carbonate | 6.87 | 11.60 | 17.41 | 3.86 |
| Silica | .48 | 1.10 | 2.78 | .81 |
| Iron | .16 | .12 | .56 | .41 |
| Organic matter | 1.69 | .......... | 1.63 | .......... |
| Difference | .00 | .38 | .02 | —.08 |
| | 100.00% | 100.00% | 100.00% | 100.00% |

Mr. K. J. Sundstrom, of Trenton, General Manager of the Sibley quarry and chemist for Church and Company, has analyzed specimens of the two upper beds with the following results:

| | Bed. A. | Bed B. |
|---|---|---|
| Calcium carbonate | 98.10 % | 86.96 % |
| Magnesium carbonate | .63 | 10.08 |
| Silica | .70 | 1.86 |
| Iron oxide and alumina | .......... | .62 |
| Sulphur | .055 | .123 |
| Difference | .515 | .357 |
| | 100.000% | 100.000% |



From a careful study of the beds of the Sibley quarry it has seemed reasonably certain that the Macon beds are the equivalent of the deeper and better beds of that quarry. The analysis of the cores from the two test holes in the Sibley shows that their wonderful "9 foot bed" is from forty to fifty feet above the base of the series. The record of the Nogard well (Ch. III, § 8) shows at a depth of fifty-nine feet, a change from gray to buff limestone which probably marks the change from limestone to dolomite. If this is the correct interpretation, and there is much confirmatory evidence, bed D of the Macon quarry extends from thirty-eight to forty-six feet above the base of the Dundee formation. The actual difference in elevation between the top ledges of bed D and the "9 foot bed" is eighteen feet, this representing the amount of drop towards Trenton in the direction of the strike.

§ 2. Dundee quarry.

This consists of a rectangular excavation about 240 by 90 feet, upon the north bank of the Raisin, just back of the National Hotel in the village of Dundee. It is but a few feet from the water's edge, and as it is worked only in the late fall, was full of water at the time of each of several visits. Most of the information concerning the beds was obtained from Mr. Horace Pulver, the present owner, supplemented with a study of the blocks of stone piled about the quarry. The uppermost, or layer A, is two and one-half feet thick and consists of a rich, gray limestone, impregnated with oil and full of fossils. Fresh specimens are somewhat darker in color than those from bed A on the Macon, which it otherwise much resembles. Bed B is four and one-half feet thick and consists of a grayish brown limestone which gives a bluish effect on weathering. It shows but few fossils and is apparently identical with bed B on the Macon. The upper fifteen inches is said to be irregularly clouded and "gnarled." A third bed has been penetrated and found to be six and one-half feet thick. It is dark brown and bituminous and in the lower twelve to fifteen inches becomes cherty. Beneath this occurs a discontinuous seam of chert, carrying silicified fossils. It is of a light gray color, with brown streaks and is impregnated with black oil. It is very probable that this chert marks the same horizon as the similar seam in the Macon quarry and hence that bed B there is the equivalent of bed C in this quarry. Beneath the chert there occurs a heavily bedded five foot bluish layer, bed D, which becomes lighter colored towards its base. All the limestone in the quarry responds promptly to cold dilute acid upon the solid rock.

§ 3. Petersburg excavations.

No real quarry has been opened up in this vicinity so as to give a satisfactory rock exposure, but stone has been removed from the bank of the Raisin in ditching and also from the river bed. Mr. Jacob McCarthy, from a thirty year acquaintance with this region, was able to furnish the most complete information. In front of Spalding's flour mill, upon the river bank, just below the railroad bridge, a ledge of pure gray limestone was struck at a depth of about eight feet. A slab of this stone is now used as a horse block in front of the M. E. parsonage of the village. It is very probable that this is simply a drift mass of Dundee, similar to that described in § 3, Ch. II, as occurring upon the Stewart farm northwest of Monroe. In the river flats S. E. ¼, N. W. ¼, Sec. 4, Summerfield, farm of John Peters, ledges of limerock are said to be struck at a depth of five to six feet and it was intended to open a quarry here at one time. Upon land here, now owned by Louis Carman, a large block of Dundee limestone, eighteen to twenty inches thick, was removed while deepening a ditch. This block now lies in the barnyard of Mr. Carman's residence at the N. W. ¼, N. W. ¼, Sec. 31, T. 7 S., R. 6 E. where it is to be broken up and used as foundation stone. At the mouth of this ditch rock is struck with a probe at the depth of fifteen to twenty-four inches. Fragments have been removed here and the chips left scattered about indicate that it is a brown dolomite. According to Mr. McCarthy considerable stone has been removed from the river bed at this point and used for foundation walls in the village. Immediately below the dam the fall of water has cleared out a hole, laying bare the rock at a depth of fourteen feet below low water mark. This rock, Mr. McCarthy says, is blue-streaked limestone similar to that found in the Lulu quarry. So far as may be judged from the indications the break from the Dundee limestone to the Monroe dolomite is situated very near the village of Petersburg.

### *B. Monroe Beds.*

#### (*a*) *Quarries Above the Sylvania Sandstone.*

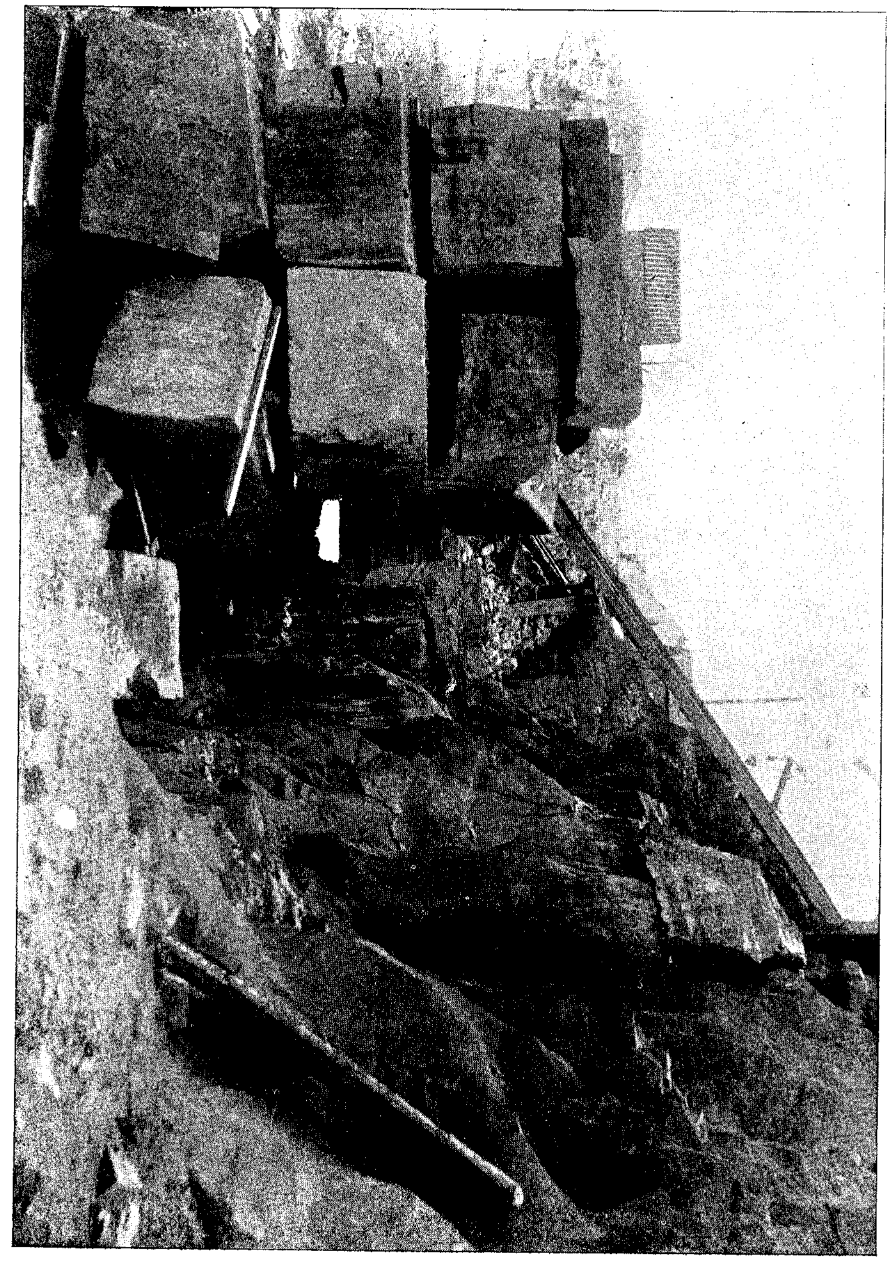
§ 4. Woolmith quarries.

These are located in Exeter township, about half way between Maybee and Scofield, N. E. ¼, S. E. ¼, Sec. 29. The chief one is owned by the Michigan Stone and Supply Company, headquarters in Detroit, Truman H. Newberry treasurer. During the past season it has been operated by George E. Currie, a contractor of Detroit. A short branch of the Detroit and Lima Northern enters the quarry ground and furnishes the necessary shipping facilities. A quadrilateral opening has been made, about 500 by 300 feet and to a depth of forty-five feet. A small amount of water trickles into the quarry, which collects at the southwest corner, from which it is pumped to the surface. One of the largest crushers in the state is operated in connection with the quarry, along with six gangs and one double gang of saws. The stripping consists of two to eight feet of blue boulder clay. This increases in thickness rapidly towards the east, south and west; but less rapidly to the north. Eastward just across the road, its thickness is fifteen feet; two hundred yards south it is twelve feet; while southwestward towards Maybee it is eighteen to twenty. Nine different beds, more or less distinct from one another, can be recognized and may be conveniently numbered in descending order, as was done in the previous descriptions. The direction of their dip is approximately W. 25° S. and the amount is two to three degrees. This is entirely local, the beds here being pushed upward into a knoll similar to that seen in the Sibley quarry. Bed A is a light colored, finely laminated dolomite, responding but slowly to cold dilute acid unless the rock is powdered. It is mainly of creamy white, but is blotched and streaked with dark gray to brown. Its thickness varies from two to four feet, being thinner in the eastern part of the quarry where in places it has been entirely removed by the great ice sheet, permitting the next lower bed to become glaciated. Its upper surface is smoothed, polished and striated. Where most weathered the rock becomes somewhat soft, mealy and gritty to the feel. In places it is porous and cavernous owing to the dissolving action of the surface water and sink-holes "large enough to take in a horse" were discovered when the stripping was first removed. When weathered the *Stromatopora*-like lamination becomes more apparent, and is similar to that observed in the Gibraltar and Grosse Isle quarries and in the upper part of the bed there occurs a similar stratum of gasteropod moulds and casts. Where nearest the surface the individual layers are thin, but become thicker toward the western part of the quarry where the rock assumes a bluish cast. Bed B is the three and one-half to four foot bed of dolomitic oölite previously described in § 7, Ch. III. Its lower surface is rendered very irregular by the hummocky nature of the upper surface of bed C. In conforming to these large hummocks the bed becomes laminated, a character which it does not elsewhere exhibit. Small cavities carry celestite, calcite and a little native sulphur. Bed C may be traced entirely around the walls of the quarry, varying from fourteen or fifteen inches to three feet in thickness. It is a drab to brown dolomite, in places almost as homogeneous, tough and campact as "lithographic stone," but in others it is open and cavernous the stone appearing soft and rotten. The large hummocks above referred to may be several feet in diameter, and the rock composing them consists of fine concentric laminae, convex upward. Large cavities contain celestite, calcite and sulphur and above and below the bed there occurs a thin seam of impure asphaltum. The underlying bed D is a dark brown to gray dolomite varying towards blue. It attains a thickness of five feet but may be reduced to one foot where the bed D is correspondingly increased. Its component layers are from two to eight inches thick and are, in places, plainly laminated with streaks of blue, gray or brown dolomite and delicate films of carbonaceous material. This character is more pronounced and the heaviest bedding occurs in the deepest, southwest corner of the quarry. Compared with the beds C and E this one is much more compact and free from the mineral bearing cavities, but it is more or less impregnated with oil. Locally it contains multitudes of a minute *Leperditia* and a miniature *Spirorbis*. Beneath this compact layer lies a much more open and cavernous one, bed E, from one to three feet thick, known locally as the "sulphur bed." It is a dark brown porous dolomite thoroughly impregnated with oil, giving it a strong bituminous odor and filling it with black blotches. Casts and moulds of simple corals, brachiopods and lamellibranchs are much more abundant than in the adjoining beds. Numerous cavities, more or less ellipsoidal in shape and in varying size from a fraction of an inch to two or three feet, are found throughout the bed. These cavities contain beautiful crystallizations of calcite, celestite and sulphur, intermingled in such a way as to indicate that they were simultaneously deposited from percolating water.* Upon a level with this bed there escapes into the quarry a stream of water from which sulphur is still being deposited; white, soft, and mealy looking at first but becoming

*Sherzer, Am. J. Sci., Vol. L, 1895, p. 246.







WOOLMITH QUARRY, SOUTH WALL, SHOWING MASSIVE BLOCKS OF SILICIOUS DOLOMITE.

yellowish upon exposure. Portions of the bed are compact and furnish building stone of a brown, bituminous character.

The five beds above described are essentially dolomitic limestones and sharply separated from the underlying beds F. G. and H, which consist of a mass of sand grains embedded in a dolomitic matrix. The uppermost, or bed F, varies in thickness from two to three feet and from its blue color it is one of the most conspicuous in the quarry. It has a gritty feel and becomes almost a sandstone in certain layers. It is permeated with vertical flexures, sub-cylindrical channels about three millimeters in diameter and several centimeters in length. These contain carbonaceous matter and oil and probably mark the position of seaweeds about which the sand and dolomitic slime accumulated. The channels are more abundant in the upper part of the bed and occur sparingly in the lower part. Near the top it becomes laminated with black, bituminous streaks. Towards the bottom the bed loses its blue color, becomes blotched with brown and merges into bed G. These blotches and streaks of chocolate brown fade out and we have a gray, highly silicious dolomite, from three to four feet thick. This passes without break into a beautiful sixteen foot bed (H) of light gray silicious dolomite, which is marketed as a "sandstone." This is so solid and free from seam that immense blocks may be cut out by means of steam chisels as shown in Plate II. When broken the rock gives a very coarse, conchoidal fracture. Occasional "glass seams" and dark streaks of grains of iron oxide somewhat disfigure the rock for building purposes. The dilute acid gives but slight action upon the solid rock, but upon the powder the acid gives brisk effervescence. Five grams of this powder give 1.37 grams of insoluble residue, or 27.4%, consisting of some alumina, with bituminous matter, but mostly of a white sand resembling that of the Sylvania bed. Examined under the microscope these grains are found to have been secondarily enlarged against the rhombohedrons of dolomite, giving them a roughened exterior and proving that the enlargement took place after the formation of the bed (see § 6, Ch. III). This series of silicious dolomites has a thickness of 21 to 23 feet in this quarry. Beneath lies bed I, a compact, even grained, gray dolomite heavily bedded. This has been penetrated fifteen feet and found to rest upon the Sylvania sandstone. Analyses of samples from the Woolmith quarry were made in 1895 by Prof. McDermott with the following results: