A STUDY OF THE MARSHALL FORMATION IN MICHIGAN

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THE Marshall formation was named from its numerous outcrops around the town of Marshall in Calhoun County; the upper phase of this formation has been called "Napoleon" from its typical section, which outcrops near Napoleon in Jackson County. According to Smith,[1] the Marshall should correlate with the Logan and Blackhand of Ohio and the Kinderhook of Illinois, formations which are Mississippian in age.

Glaciation and deposition have concealed the Marshall in almost all parts of Michigan, but there are good exposures in Cass River in northeastern Tuscola County, and also at Point Au Barques at the northern tip of Huron County. From these outcrops a meager amount of information about its character has been obtained. Rominger[2] merely mentions the fossils, but Winchell studied them extensively and showed that the Marshall was not correlative to the Chemung age,[3] as had been thought by Hall. This particular paper will be confined to the information we have obtained through well drilling and core testing.

In the summer of 1927 the Pure Oil Company saw the need of geological data on some shallow formation which could be used as a key horizon above the oil pay sands. Lane's description of geological structures was confirmed by intensive core testing in Huron and Tuscola counties.[4] In this paper Lane recognized faulting or

[1] R. A. Smith, *Mich. Geol. and Biol. Surv.*, Publ. 14, Geol. Ser. 11, p. 29. 1914.

[2] Rominger, C., *Geology of the Lower Peninsula. Geol. Surv. Mich.*, 3 (1873-76): 70.

[3] *Proc. Acad. Nat. Sci. Phil.* 15 (1863); 2; 17 (1865): 109; *Am. Journ. Sci.*, 41 (1866): 120.

[4] Lane, A. C., *Geological Report on Huron County, Michigan, Geol. Surv. Mich.*, Vol. 7, pt. 2.

of the Marshall will undoubtedly be made in the future, but at the present time this map seems to be more accurate than the old map based on the meager information available at that time.

In the eastern part of the state the Marshall sandstone, Mississippian in age, is our first key horizon penetrated. This lies almost conformably over the Berea, Traverse and Dundee formations. The data concerning the detailed structural conditions of the Marshall are more or less confidential, but we have plotted as nearly as possible the true picture of the Marshall section from about one hundred core tests which have penetrated the entire thickness of the formation. A large proportion of these wells show conclusively that the Marshall is not so uniform a sand body as had been thought originally.

From the information obtained on a few of our core tests and deep-well logs a graph (Fig. 13) has been constructed. In places erosion has been so pronounced on the top of the Upper Marshall that it has cut into the Napoleon proper, as is shown by the absence of the upper part of the Marshall section. The Napoleon sand in local areas retains an almost uniform thickness below the "break" or unconformity, though wells drilled in Huron County prove the Napoleon sandstone to be thicker on the Kilmanagh structure than on the structure passing through the town of Pigeon.

In a typical section there is a very thin veneer of greenish shale at the contact of the Michigan Series and the Upper Marshall. This shale is usually so fine that it passes through an 80-mesh-to-an-inch screen and the drillers made note on their samples that green water was present, but they were unable to catch any of the shale. This grades into a clear yellowish-white sandstone, of which there is from 5 to 25 feet. The drill then penetrates an unconformity, or disconformity, within the Upper Marshall. This is termed the "break," and is well marked in most places, except where erosion on the top of the Upper Marshall has cut into the massive sand of the Napoleon proper.

The "break" (by which we mean an interruption in the normal sandstone deposition of the Marshall formation) consists of a green shale, a coal, or a limestone from 1 inch to 35 feet in thickness. The green shale is perhaps more characteristic and Dr. Slawson

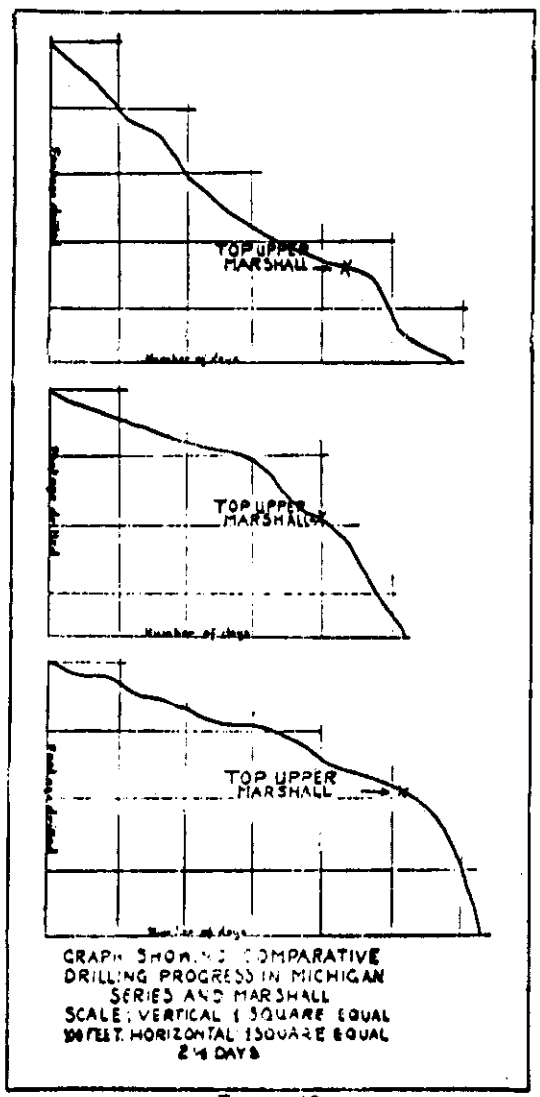
TOP UPPER MARSHALL
TOP UPPER MARSHALL
TOP UPPER MARSHALL
GRAPH SHOWING COMPARATIVE
DRILLING PROGRESS IN MICHIGAN
SERIES AND MARSHALL
SCALE: VERTICAL 1 SQUARE EQUAL
100 FEET. HORIZONTAL 1 SQUARE EQUAL
2½ DAYS

FIGURE 13

examined one of these samples, giving the following description: "This sample was essentially quartz, but there were a number of globular green masses. These masses consisted of many minute crystalline scales of chloritic material. The scales are so small that it is impossible to designate any member of the chlorite group. The aggregate index of refraction is approximately 1.59, which would be characteristic of any of the chlorites. All of the material appeared to me to be derived from a sandstone because of the preponderance of quartz. There is good deal of clay present and you may have washed out still more." As suggested, shale was present in these samples and, with the chlorite, it indicates an hiatus, differing greatly from the sand above and below.

The question may now arise whether this break should not be used as the contact between the Marshall and the Michigan Series. Further examination shows, however, that the sand above it closely resembles the sand below it, and the absence of gypsum from the sandstone also helps to identify it with the Marshall group in preference to the Michigan Series. Another point in favor of correlating this sand above the break with the Marshall is the similarity of the oil found above the break to that taken from the unquestioned Marshall. Both oils have an asphaltic base and register gravity of 24½ degrees Baumé. This oil is of such a heavy texture that it is practically impossible to pump, and its low gasoline content makes it of very little commercial importance at the present time. The oil of the Michigan Series is usually of a greenish color and lighter in texture than oil from the Marshall formation. Both oils examined were from the Midland-Isabella Oil Pool.

Below the shale, coal or limestone break, the section again becomes a white-yellowish sandstone, which grades into a peanut conglomerate near the base. Very often a band of marcasite is encountered at the top of this sand from one-half inch to two inches in thickness. The matrix binding the sandstone grains is a very soft Kaolin-like material; according to an analysis furnished by the Department of Mineralogy of the University of Michigan, this substance is gibbsite (AlO_3H_3), an aluminium hydroxide. There are from 45 to 110 feet of this sand.

The Lower Marshall contact is very definite. The sand of the Lower Marshall is a very fine gray micaceous sandstone alternating with gray shales, and red shales and sandstones. Where the red sandstones and shales are absent, the gray sand is extremely micaceous, often carrying muscovite, biotite and occasionally phlogopite in the same sample.

We have tried to describe the Marshall section in detail, as brought out by the drilling program, and we should like to suggest definite limits for the terms already in use for this formation. To date "Napoleon" has been used interchangeably with "Upper Marshall" to describe the section from the Michigan Series to the fine gray sand and red rock of the Lower Marshall. As the U. S. Geology Survey does not encourage the naming of a new formation unless it outcrops, no new name can be attempted at this time. Since we have this definite break or disconformity within the section formerly termed "Napoleon," it would seem best to limit the terms "Upper Marshall" and "Napoleon," and to give to each a specific meaning. "Upper Marshall" could be used to describe the sand from the base of the Michigan Series to the base of the shale, limestone or coal which indicates the disconformity. The name "Napoleon" would then be applied to the sand between the break and the Lower Marshall. The term "Lower Marshall" would still be used for the section from the base of the Napoleon to the blue-gray shale of the Coldwater formation. This is illustrated in the following section:

Michigan Series	Gray limestone, dolomite, calcareous shale, shale and gypsum
Upper Marshall	White to gray sandstone, gibbsite. Unconformity ("break") — green and gray shales, limestone and coal
Napoleon	Massive yellow-white sandstone, rather coarse grained, often peanut conglomerate at base, gibbsite
Lower Marshall	Fine-grained gray sandstones and shales, red sands and shales, very micaceous

Dr. Alfred C. Lane suggested the terms "Neo-Marshall," "Meso-Marshall" and "Eo-Marshall," instead of "Upper Marshall," "Napoleon" and "Lower Marshall," as used above.

In general the Marshall is thinner on structure than in the

synclines. Near the center of the Lower Peninsula it is usually thicker than around the rim of the basin. Near the rim the rate of dip is somewhat variable, but in general the beds dip 17 feet to the mile from the rim of the basin to the center, a short distance northwest of Mt. Pleasant, Isabella County.

On the western side of the state the Upper Marshall, Napoleon and Lower Marshall together attain a thickness of approximately 200 feet; in the Huron County area the thickness is between 450 feet and 500 feet. The color of the Marshall section on the western side is more red to pinkish; on the eastern side of the state the reds occur only in the Lower Marshall.

The color of the Upper Marshall suggests that the waters containing iron came from the old pre-Cambrian land mass of the Upper Peninsula. The iron material carried by the waters draining into the sea, which covered the Lower Peninsula, was precipitated in greatest quantities on the western side during the entire Marshall period. On the eastern side of the state there were alternations of the western waters and possibly the eastern waters, which contained very little iron material. This accounts for the gray shales of the Lower Marshall with only an occasional fingering of red. The distance from the source beds of the iron content may also be used to account for the depositing of lesser amounts of the heavier minerals on the eastern and southern sides of the state, when compared with the amount deposited on the western side of Michigan.

It would seem that the eastern waters free from iron sediments predominate throughout the Upper Marshall and Napoleon; in places we find no reds whatever in these formations on the southeastern side of the state. The center of the basin was evidently more influenced by the western drainage throughout the Lower Marshall period, since 80 to 90 feet of red sand and shales are common immediately below the Napoleon. During the Upper Marshall and Napoleon deposition, however, there seems to have been less iron content in the waters, since the reds are found only on the western side of the state, but the Upper Marshall and Napoleon of the center of the basin consist of a white sandstone with only an occasional streak of red sandstone.

The Marshall sandstone contains a brine from which the Dow Chemical Company of Midland has been producing for over thirty-five years. The constant drain on the Marshall water has lowered its static head, so that the wells on structure have a head of only 300 feet, but those off the axis have about 800 to 1200 feet, with an occasional flowing well. There is also a very noticeable demarcation in the sandstones in wells where the static head is low; the upper portion of the sand from which the brine has been exhausted shows considerable oxidation, though the lower 20 feet of the sand has the characteristic white of the Napoleon without any apparent change in color.

The bromine content of wells on structure is much less than that of wells drilled in the synclines, as shown by the following table:

	Percentage of bromine
Laura Root Number 1, Section 18, Greendale, Midland (T. 14 N., R. 2 W.)	0.0059
G. West Number 1, Section 25, Isabella, Isabella (T. 15 N., R. 4 W.)	0.0425
Shepherd Number 1, Section 23, Chippewa, Isabella (T. 14 N., R. 3 W.)	0.1777
Buck Number 1, Section 19, Geneva, Midland (T. 15 N., R. 2 W.)	0.1349
Isabella State Bank Number 1, Section 8, Denver, Isabella, (T. 15 N., R. 3 W.)	0.1536

The Root Number 1 and West Number 1 are on structure, the others are off.

The Marshall water is, in general, strongly saturated with chlorine compounds, and much might be accomplished from the analysis of waters throughout the state for correlation purposes were it not for the fact that the bittern seems to have a mixed source; it is usable, however, in most local areas. Undoubtedly there are fractures or faults between the Marshall and lower-lying beds which allow the waters to migrate from one formation to another.

The following is an analysis of the water from the Shepherd well (Section 23, T. 14 N., R. 3 W.) made by the Dow Chemical Company and shows a typical Marshall brine for the center of the basin.

Specific gravity	1.236
Bromine	0.1777
Calcium chloride	12.50
Magnesium chloride	2.77
Sodium chloride	10.50
Potassium chloride	0.76

The drilling through the Marshall has brought out some very interesting information which could be used by anyone planning to drill in the future. The Michigan Series contains an abundance of gypsum, limestone, dolomite and marcasite streaks which are very difficult to drill. To illustrate this, we have plotted the number of days required for drilling the Michigan Series as compared with the time it takes for drilling the Marshall formation. In doing this a record of the footage made each day was plotted on the vertical scale, the number of days drilling being represented by the horizontal scale (see Fig. 14). As the wells are drilled deeper, this curve in reality should begin to flatten out instead of becoming accentuated, or tending toward the perpendicular; the reason is that with depth more time is required for raising and lowering the tools in the hole and for replacing bits than is consumed for the same purposes when drilling near the surface.

Despite the rapidity of drilling in the Marshall, it is frequently a hazardous undertaking in fields where drillers are not accustomed to the formation. The following conditions are usually found: If the drillers' bit is not dressed out to gage, a "fishing" job often results when a new bit is run into the hole. Furthermore, the Marshall sandstone is very abrasive on the sides of the bit and at no time is it possible to run over a five-foot screw with safety unless the driller knows his bit is out to full gage. Near the base of the Napoleon the sand is so loosely cemented that the bailer is likely to become frozen. In spite of these difficulties, however, core testing in Michigan is successful on the whole, and much important information has resulted from the use of the diamond drill and the hollow rod.

In conclusion, the following summary seems to bring out the most important results of core testing in Michigan:

1. A slight unconformity or hiatus is found to be very per-

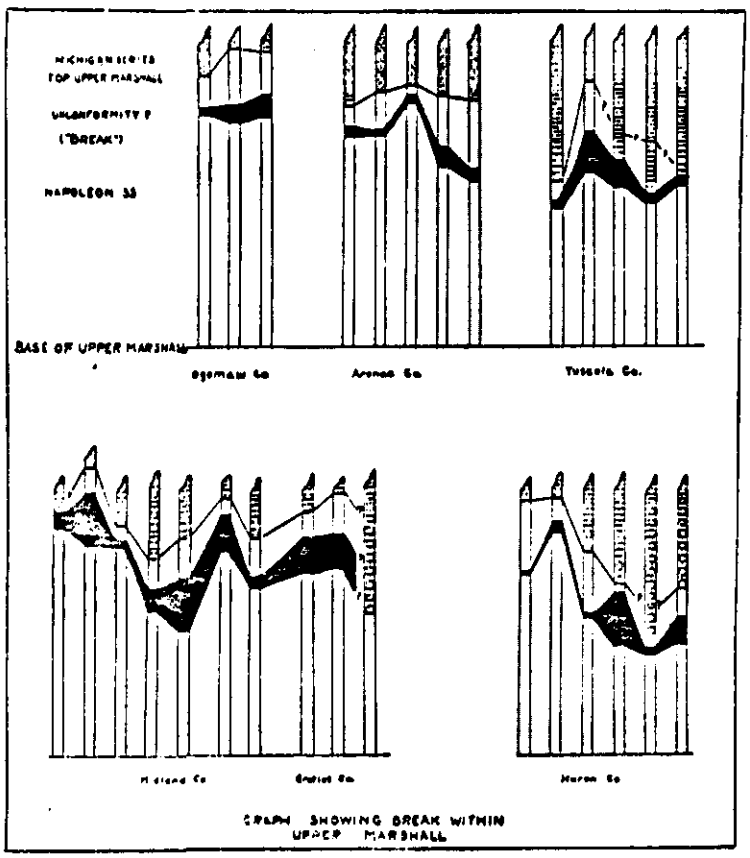

FIGURE 14

sistent in the section between the base of the Michigan Series and the Lower Marshall.

2. Because of the persistence of the break in the section formerly designated as "Upper Marshall" or "Napoleon," this section should be separated, and this paper has suggested calling "Upper Marshall" the part from the base of the break upward to

the base of the Michigan Series. The lower massive uniform sand, or the section below the break, we would call "Napoleon."

3. In some places the erosion on top of the Upper Marshall has completely cut out the Upper Marshall, the break and about 20 feet of Napoleon.

4. The Marshall on the eastern side of the state is conformable over the lower formations, but on the western side there seems to be a pronounced unconformity between the Upper Marshall and the underlying beds.

5. The source of the red color must have been from the northwest.

6. The use of brine analysis for correlation purposes is, in general, diagnostic over small areas.

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PURE OIL COMPANY
SAGINAW, MICHIGAN