STATE OF MICHIGAN
MICHIGAN GEOLOGICAL AND BIOLOGICAL SURVEY

THE OCCURRENCE OF OIL AND GAS IN MICHIGAN

By
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CHAPTER VI. CENTRAL MICHIGAN.

GEOGRAPHIC AND GEOLOGIC RELATIONS.

The central district of Michigan includes the Saginaw oil field, which has been deemed worthy of a separate discussion in the previous chapter. The central district is not only near the geographic but also the geologic center of the Southern Peninsula. The deepest part of the Michigan Basin is in the region of Isabella and Midland counties. In the immediate vicinity of the center of the Basin the Berea is 2000 feet or more below the surface. The Dundee is nearly 3700 feet below the surface at Mt. Pleasant, therefore the Trenton should be more than 5500 feet (Fig. 1) in depth at this place.

Surface Deposits. Northwest of a line from Midland to Grand Rapids, the drift is very thick, ranging from 250 to 600 feet. From Bay City, southwestward past Midland to Alma and thence northwestward to Manistee there is an old preglacial rock valley which accounts for the great depth of drift at Alma, St. Louis, White Cloud and Mt. Pleasant.

In the southeastern portion of the central basin, the drift is relatively thin, and, from Grand Rapids and Holland southeast to Jackson and beyond, bed rock in many places is at the surface or under a very thin cover of drift. From Jackson to Huron county the drift is generally less than 150 feet thick, and in much of the region rock can be reached from 40 to 100 feet below surface.
EXPLORATIONS.

The great depth to the oil horizons and the thick drift in the north-western half of the central district have been most effective in discouraging explorations for oil and gas. Deep drillings, however, have been made at Bay City, Midland, St. Louis, Alma, Gladwin, Mt. Pleasant, Grand Rapids, Charlotte, Delta, Eaton Rapids, Jackson, and near Morrice and Fowlerville, and at Ionia, St. Johns, Ithaca, Owosso, Durand, Perry, Blackmar and Flint.

BAY COUNTY.

Bay City. In North Bay City three or more deep wells have been drilled. One was bored by John Mason in 1885-6 to the depth of 2900 feet. The record indicates that the formations are about the same depth as in South Bay City, but that they are considerably different in character. The Coldwater apparently contains a number of limestone lenses, with a little black shale and sandstone at some distance above its base. The abundance of limestone in the Coldwater is unusual in the eastern part of the State, and possibly these "limestone" beds are only large iron carbonate concretions, which are common in this formation. C. E. Wright quotes John Mason as stating that the well at 2900 feet was in the same rock as the Morley well (Chap. IV) just north of Marine City. This indicates that the well may have been deeper than given in the record, and it is very probable that the record, which is only the driller's, is imperfect.

The information furnished by this record was valuable in indicating the character, depth and thickness of the formations, and number and depth of the water bearing strata, and the possible oil and gas horizons which might be expected to be encountered in drilling in the vicinity of Saginaw.
In the South Bay City well, water or brine was struck in abundance in the Coal Measures, the Parma, and the Upper Marshall. A strong brine was found in the Berea, in the Traverse, and very probably a highly mineralized brine was struck in the lower portion of the Dundee, although the latter is not noted in the record.

Strong signs of oil and gas were noted just above the Berea grit, but in none of the lower horizons except the Upper Traverse were noteworthy signs reported. The well penetrated the Dundee limestone 238 feet and the bottom of the well is probably close to the top of the Monroe dolomites since the Dundee is not known to be more than about 250 feet thick in Michigan.

**Kawkawlin.** At Kawkawlin, northwest of Bay City, salt' wells show that the Napoleon brine horizon occurs between 700 and 800 feet, or 150 to 200 feet higher than in Bay City. Since westward the same horizon is struck at Midland at 1205 feet a very strong fold must lie between Midland and Bay City. As noted On previous pages, the Saginaw anticline is conceived as running slightly west of north from Saginaw through a point two or three miles west of Kawkawlin. The connection between the anticlinal fold at Kawkawlin and Saginaw seems probable since the Coal Measures also show a strong upfold in the Ralston well near the old Bay Mine No. 2. The Marshall and the Coldwater in the Page Oil and Gas Company (see Chap V) well also appears to be higher than they are farther east along Saginaw river.

**FLINT WELLS.**

**Saginaw County.**

**Blackmar.** In the early 70's, a well reported to be 1764 feet in depth was drilled at Blackmar, Taymouth township, Saginaw county. Considerable gas and a strong brine appears to have been struck below 1545 feet. As a coarse sandstone corresponding to the Napoleon was struck at 360 feet, the sandstone below should be the Berea. As mentioned in the discussion of the Saginaw oil field, this depth appears to be much less than to the east or west of Blackmar, hence it is supposed that south of Saginaw the anticline veers to the east and runs through Blackmar towards Flint.

The depth of the well is given as 1764 feet but the record only adds up to 1677 feet.

**GENESEE COUNTY.**

**Flint.** At Flint there are many shallow borings, chiefly for coal. These indicate that the Maxville limestone is absent, probably eroded. In a deep well drilled many years ago a coarse sandstone was struck at 170 feet which yielded a "strong stream of sweet water." This, according to Lane, resembles the Marshall, and another sandstone at about 1200 feet containing a strong brine would therefore correspond to the Berea. The recent drillings for coal in the vicinity of Flint, however, indicate that the Marshall is more than 170 feet below the surface, hence the sandstone yielding the flow of fresh water is probably a sandstone belonging to the Coal Measures.

**MIDLAND COUNTY.**

**Midland.** At Midland, there are seven wells to the Marshall, which is struck at about 1200 feet or 580 feet deeper than at Saginaw. This represents a dip from South Bay City to Midland of about 20 feet per mile, and 30 feet per mile from Saginaw. The No. 1 was drilled for...
Larkin & Patrick in 1879. Others were drilled later for brominiferous brines by H. H. Dow and the Midland Chemical Company. The wells in the northwestern part of the city reach rock sooner than those in the southeastern part. The drift is much thicker than at Saginaw and Bay City but not nearly so thick as at Mt. Pleasant, Alma or Gladwin. Brine was struck in the Coal Measures, the Parma, and the Napoleon, the brine increasing in strength with depth. The record given below is representative of the character of the formations.

<table>
<thead>
<tr>
<th>MIDLAND WELL</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Elevation</strong></td>
</tr>
<tr>
<td>600 ft. A. T.</td>
</tr>
</tbody>
</table>

- **Pentreucene**: Surface deposits
- **Coal Measures**: Mosaic white sandstone, fresh water
- **Black shale**: 27 | 27 |
- **New Paris**: 90 | 90 |
- **Sandstone**: 20 | 20 |
- **Hard sandstone**: 70 | 70 |
- **Black shale**: 50 | 50 |
- **Carboniferous (FeCO3) shale**: 45 | 45 |
- **Black shale**: 60 | 60 |

**Saginaw**

In the No. 13 well of the Dow Chemical Co. red shale occurs at 1390 feet or above. (C. W. Cook, Pub. 15, Geol, Series 12, 1913.)

**GRATIOT COUNTY.**

**Alma.** At Alma, one of the deepest wells in central Michigan was drilled in 1895 for the Alma Sanitarium. It reached a total depth of 2865 feet and was bottomed in the Upper Traverse limestones where mineral water with a temperature of 98° F, was struck. A little gas also seems to have been found in the top of the Traverse.

In the No. 13 well of the Dow Chemical Co. red shale occurs at 1390 feet or above. (C. W. Cook, Pub. 15, Geol, Series 12, 1913.)

**St. Louis.** There are two or three deep wells at St. Louis which penetrate the Upper Marshall. The latter is reached at about 1330 feet and yields abundant brine. No definite records are available.

**Ithaca.** The Ithaca well, though not deep, has a carefully compiled record as published by a local newspaper. The drilling did not reach the Marshall and the 2 feet of light shale at the bottom of the well is probably the top of the Grand Rapids Group.

The drift was very thick, bed rock being struck at 500 feet. This is much deeper than at St. Louis and Mt. Pleasant. The Napoleon is about 375 feet higher than at Mt. Pleasant, thus indicating an abnormal dip of the formation from Alma to the north-northwest.
ISABELLA COUNTY.

Mt. Pleasant. In 1903, the city of Mt. Pleasant and the Midland Chemical Company drilled a well over 1550 feet deep penetrating to the lower Marshall; which was struck at about 1400 feet. This well indicates that the corresponding formations are from 200 to 600 feet deeper at Mt. Pleasant than at Alma, Midland, Bay City and Saginaw.

In 1913 W. F. Braun, an oil operator from the Pennsylvania and the Oklahoma fields drilled the deepest well in Michigan on the Riley farm near Mt. Pleasant in sec. 27, T. 14 N. R. 4 E. The record down to the top of the Traverse at 3082 feet is by Mr. Braun, but from that point his record has been supplemented by that obtained from an examination of a complete set of samples, which Mr. Braun kindly preserved and sent to the Michigan Geological Survey.

A comparison of the Alma and the old Mt. Pleasant well records with the new one shows that the rock formations are very similar even in many minor details. The depths to the Berea and the Dundee, however, are greater than calculated. In neither the Alma nor the Braun well is the Berea present in its typical phase as a sandstone. The "limestone and black sand" from 2568 feet to 2598 feet yielding oil at 2590 feet with a specific gravity of 47° Baume, may possibly represent this horizon. Some gas accompanied the oil. Another show of oil occurred in the Antrim black shales at 2632 feet.

In July the well reached the top of the Dundee at 3667 feet, but this formation yielded such a strong flow of water at 3680 feet that the well had to be abandoned. Generally the upper portion of the Dundee does not yield much water.

Deep drillings at Bay City, Saginaw, Gladwin, Alma and Mt. Pleasant indicate a remarkable uniformity in the character and thickness of the formations down to and including the Dundee, therefore if the formations below the Dundee are as regular in thickness, the Niagara should be found at about 5100 feet and the Trenton at 6200 feet or more. Such depths are so great that the cost of testing the oil possibilities of either one of these formations is out of proportion to the chances for success.

GLADWIN COUNTY.

Gladwin. A very deep well was drilled in 1913 at Gladwin for oil by Chas. G. McClure of Saginaw. According to the records of wells in the vicinity of Gladwin rock is from 200 to 400 feet, below the surface but, in the McClure well, the drift was found to be 600 feet in depth and great difficulty was encountered in getting the drive pipe down to rock. Much quicksand and water was found in the drift.
The elevation of this well is not known, but it appears to be about 780 feet above sea level, or nearly 200 feet higher than the Saginaw wells. Mr. MeClure, having drilled one well near Gera in Saginaw county and striking the Dundee between 2900 and 3000 feet, inferred that this formation should be struck at about the same depth at Gladwin. The Gera well is on the flat, eastern limb of the Saginaw anticline, and therefore the Dundee is 100 to 150 feet higher than it would be if the normal dip prevailed.

Since Gladwin is 200 feet higher and is not on an anticline, the depth to the Dundee should be several hundred feet greater than in the Gera well, and apparently this is the case. In May, the well reached the depth of 3043 feet, having penetrated the Traverse formation less than 100 feet and operations were temporarily suspended as the normal capacity of the drilling outfit had been exceeded. According to reports another drilling rig was brought in, but on account of the small hole, or other difficulties, the well was abandoned without reaching the Dundee oil horizon. Since the Traverse in the central part of the Basin is everywhere about 600 feet thick, the Dundee at Gladwin should be struck between 3550 and 3600 feet.

The record was made by the writer from a hasty examination of a set of samples in Mr. MeClure's office. The exact thickness of the various strata could not be determined from the data accompanying the samples, hence the record is more or less indefinite.
Assuming that the elevation of the Gladwin well is about 50 feet higher than the Braun well, the dip of the Napoleon from Gladwin to Mt. Pleasant is only about 5 or 6 feet per mile.

MECOSTA COUNTY.

Big Rapids. Near Big Rapids a well was drilled to the depth of 1400 feet by A. L. Clark a number of years ago. This well, known as the Red Cross well, entered rock at 600 (?) feet and struck water at 600, 800, 850 and 1300 feet. The brine at 1300 feet is very strong, and is probably from the Marshall. No record of the well is available.

KENT COUNTY.

Grand Rapids. The Grand Rapids Artesian Well Co. sunk a well for water to the depth of 2220 feet. An abundant of fresh water was found in the Upper Marshall sandstone, but it did not flow. Weak brines were struck in the Lower Marshall, mineral water in the Coldwater, a stronger brine from a sandstone in the lower part of the Coldwater, and gas and brine in the top of the Dundee. The black shales of the Anttrim yielded a strong smell of gas and oil.

IONIA COUNTY.

Ionia. A comparatively shallow well was drilled near the old sandstone quarries at Ionia many years ago. While it penetrated no oil horizon, the record is inserted as there are so few drillings in this part of the State giving any reliable information concerning the underlying rocks.

BARRY COUNTY.

Assyria. In 1899 a well was drilled near Assyria (sec. 14, T. 1 N., R. 7 W., about 870 A. T.) but no record is obtainable. According to the driller, John Brogan, the bottom of the Anttrim black shale was struck at 1875 feet. In 1903, another well was drilled at Assyria from which a good set of samples was preserved for the Survey by G. D. Connor and J. J. Callender. The latter located the well with an "instrument," but no oil was found, although the well passed through the Dundee. Apparently the well was deepened in the spring of 1904 to over 2300 feet, but no record was obtained of the lower part of the drilling.
EATON COUNTY.

Eaton County.

Charlotte. A well 2209 feet in depth was drilled at Charlotte many years ago by E. Shepard and F. W. Higby. The calcareous nature of the Coldwater shales is to be noted as this appears to be rather characteristic of the Coldwater in the western part of the State. The Berea horizon is represented by gritty red shales. This formation exists as a sandstone only on the eastern side of the Basin, being generally represented by red shales in the western half of the State. Brine was reported in the Dundee, but doubtless water was also struck in the Parma and the Marshall sandstones.

Grand Ledge. A comparatively shallow well was drilled at Grand Ledge a few years ago, but only a meager record is available.

EATON RAPIDS.

Eaton Rapids. In 1910 and 1911, two wells were sunk for oil in Eaton county, one at Smithville near Eaton Rapids, and the other about one mile south of Delta on the J. Hitchcock farm. The Eaton Rapids well reached a depth of at least 2005 feet for samples from 1510 to 2005 feet were preserved for the Survey. The samples above 1510 feet were never received. The well appears to have reached the Berea horizon, but no marked signs of gas and oil were observed at any horizon, according to reports. The well was not finished owing to legal troubles or other difficulties.
were wasted in casing off the numerous water bearing strata down to the Coldwater shales. According to reports, the casing was pulled and the hole reamed out 8 or 9 times before the last water horizon above the Coldwater was passed. The depth to the oil horizon appears to have been greatly underestimated, so that the drilling outfit brought in was inadequate for penetrating to the depth necessary to reach the Dundee oil horizon. Indeed, the drilling had to stop when supposedly within only a few feet of the coveted goal. Samples were taken and a log was kept by Mr. Ricker, owner of the well, but no record and only a partial set of samples reached the Survey. The following is the log compiled from verbal statements of one of the drillers and Mr. Ricker and from an examination of the partial set of samples.

DELTA WELL

Loc: One mile south of Delta on Courter Creek, sec. 10, Delta township, Eaton county. E. Hitchcock farm.

Elevation about 840 ft. A. T. | Thickness, feet | Depth, feet
--- | --- | ---
Surface | 40 | 40
Gravel, sandstone, and siltstone | 100 | 740
Dolomite, sandstone similar to 875 ft. at | 544
Calcareous sandstone | 100 | 720
Claystone | 100 | 760
Lignite, black, soft | 5 | 765
Upper Marshel: | 5 | 760
Flip white sandstone | 15 | 780
Mudstone | 50 | 500
Gravel, sandstone, and siltstone | 50 | 500
Calcareous sandstone, very fine | 40 | 480
Lignite, black, soft | 25 | 280
Coldwater shale | | 0
Lower Marshel: | | 0
Rincon clay, shale, and sandstone | 800 | 800
Sandstone, fine, dark gray | 800 | 800
Sandstone, very fine, blue gray | 800 | 800
Samples missing, probably blue and gray sandstone | 300 | 300
Grit, sandstone, and siltstone | 200 | 200
Samples missing, probably blue sandstone | 575 | 575
Mineral water from sandstone lens in Coldwater, 16-18 ib. per day | | |

Comparing the top of the Antrim black shale in the Charlotte and Delta wells, the depth is about 16 feet per mile to the north which is comparable to the dip of 17 feet per mile northeast from Kalamazoo to Charlotte. The striking fact is, however, that the black shale in the Eaton Rapids and Delta wells appears to be fully 1900 feet or more below the surface. Unfortunately no record of the rock strata penetrated in the old Magnetic well was kept. The record of the well at the State Industrial School is given below.

EATON RAPIDS AND DELTA WELLS

ININGHAM COUNTY.

Lansing. There are several drillings at Lansing from 350 to 1400 feet deep. The Hoffman well 700 feet and the old Lansing Magnetic 1400 feet in depth flow, but the water in both wells comes from the upper strata. Dr. Lane suggests that the latter well may have reached the Berea, but this is hardly possible for the Berea in the

MASON.

The E. Strope well at Mason is about 650 feet deep and flows a weak stream. The upper rocks down to 200 feet are mainly sandstone increasing in porosity with depth and yielding abundant water.

JACKSON COUNTY.
Jackson. At Jackson, three wells, respectively 2455, 2174, and 2100 feet in depth, have been drilled. The No. 1, or Worthington & Cooley Manufacturing Company well probably reached nearly to the bottom of the Monroe formation. An abundance of water was struck in the Marshall (including Parma?) with an "extra" flow at 218 feet, near the middle of the Coldwater, in the top of the Dundee, and at several lower horizons. According to the record, about 270 feet of "black slate" forms the base of the Coldwater, but only the last 28 feet is described as bituminous. The Berea is present, but it is very shaly. There is about 50 feet of blue sandstone at 660 feet in the Coldwater which, in Volume V, Dr. Lane correlated with the Marshall. The Antrim is characteristically black, the Traverse thin but typical with its calcareous shales or "soapstones," and the Dundee shows the exceptional thickness of over 250 feet.

The Woodworth well was drilled in the northern part of the city in 1883 and only a driller's (Fred Saeger) record is available.

GOGUAC LAKE WELL NO. 6.
Loc.: At Goguac Lake near Battle Creek.. Drilled in 1862 for Battle Creek. Water Works by Jim Coleman. Size of pipe & inches. Record by W. F. Cooper.

The Jackson No. 3 well was drilled near Francis and Milwaukee streets and was begun in 1863. Only a very incomplete record is available.

CALHOUN COUNTY.

Goguac Lake. The Marshall sandstone underlies the surface in Calhoun county throughout a belt extending from the northwest to the southeast. None of the wells for water at Albion, Marshall, and Battle Creek are over 500 feet in depth, as water is generally struck in abundance in the sandstone at shallow depths. A few of the test wells however, penetrate the Coldwater shale 200 or 300 feet. In the Goguac lake well near Battle Creek, traces of oil were found in these shales.

LIVINGSTON, SHIAWASSEE AND CLINTON COUNTIES.

Local Geology. A comparison of the wells from Genesee and from southeastern Saginaw county, southwest to Eaton and Barry counties across the southeastern part of the Central Basin indicates that the strata in northwestern Livingston and southern Shiawassee counties are higher than to the northeast or southwest, contrary to what should be expected. Unfortunately, the wells in these two counties are too shallow to reach horizons which can be definitely recognized, or their records are of such doubtful character, that the evidence indicating the presence of an anticline is inconclusive.

On the eastern side of the Basin, the Berea sandstone appears to have been struck at 1545 feet at Blackmar (610 ft. A.T.), 1500 feet at Columbiaville, and 1200 feet at Flint (723 ft. A.T.) West of the meridian of Jackson the Berea is apparently absent, but its horizon is usually represented by red shales, generally very sandy. At Jackson this red horizon occurs at 1410 feet, at Eaton Rapids (900 ± ft. A.T.) 1980 or 1995 feet, at Charlotte (906 ft. A.T.) 1680 feet, at Assyria (917 ft. A.T.) 1400 feet, and at Delta (830+ ft. A.T.) 1905 feet. The sandstone horizon at the bottom of the old mineral well at Lansing could not have penetrated this horizon at 1400 feet as shown by the Eaton Rapids and Delta wells.

Near Morrice close to the Looking Glass river (850 ft. A.T.) on sec. 25, T. 6 N., R. 2 E., C. W. Gale drilled a deep well in the 60's. The record obtained is one from memory, and it appears that the well was drilled to the depth of about 1135 feet and much black shale and also "blue clay" were struck. A strong brine was struck at the...
bottom which according to reports flowed and did not smell of sulphur. A little oil used to occur on the surface of the river.

Little dependence should be placed on such a record as drillers are careless in their observations and statements, and too often they pay little attention to the character of the horizons above the one which they desire to reach. The great amount of blue clay and black shale reported in the well, however, is similar to the Coldwater and the Antrim. It is also to be noted that in the Jackson No. 1 well, according to C. E. Wright, the upper part of the Coldwater is drab “slate” and the lower 270 feet including the Sunbury shale, “black slate,” but in the other wells at Jackson, however, there are only white shales according to the drillers’ records. The Durand and Howell wells and the Jason and Shumway well (1000 ft. A. T.) northwest of Fowlerville on the Grill farm, sec. 17, T. 4 N., R. 3 E., likewise show the same abundance of black or brown shales. According to Lane, the brown shales of the Jason and Shumway well may correspond to the Coldwater, the coarse brine bearing sandstone between 600 and 800 feet to the Berea, and the black shales beneath the latter to the Antrim. Lane argues that if this sandstone is the Marshall then there is an abnormal amount of black shale associated with it, for, as a rule, black shales are rarely found in association with this formation, but are nearly always associated with the Berea.

According to the village clerk, in the municipal well for water at Perry, Shiawassee county, drilled in 1914, blue shale extends from about 200 to 600 feet with about 30 feet of water “gravel” (conglomerate?) below 250 feet. The well was continued to 725 feet where brine was encountered. The Perry well is only about 7 miles northwest of the Jason-Shumway well and the brine horizon at 725 feet may correspond to that at 600 feet in the latter since the elevation of the two wells is about the same and the rock strata dip to the northwest. The preponderance of “blue rock” in the Perry well tends to throw doubt on the reports of so much black shale in the Jason-Shumway well. Quite possibly dark shale has been reported as black shale by the drillers. The 270 feet of “black shale” above the Berea in the Jackson No. 1, however, is comparable in amount to that in the Shumway well above the coarse brine bearing sandstone supposed to be the Berea, this sandstone may be the Richmondville or a stray sandstone in the Coldwater above the true Berea horizon. If this sandstone in the Morrice and the Jason-Shumway wells is the Berea, then there is a very pronounced arching of the strata in the vicinity of Fowlerville. (Fig. 2). If such is the case, it is difficult to explain the absence of the Marshall and a large part of the Upper Coldwater. Lane advances the idea that this uplift and arching preceded the deposition of the Coal Measures but not that of the Grand Rapids Series, in which case, the Grand Rapids Series, and locally the Marshall, and Upper Coldwater were either not deposited or were eroded away. This would bring the Parma sandstone directly above the Coldwater or above the Marshall. In the latter case, the Marshall and the Parma could not be distinguished, as they are very similar in appearance.

There is further evidence in support of Dr. Lane’s hypothesis of a pre-Coal Measure uplift and folding. From the studies of Dr. Sherzer in southeastern Michigan, the formations, down to the Traverse at least, are about 200 feet higher at Ann Arbor than they are on either side at Adrian and Pontiac. This fold, which is nearly 70 miles in breadth apparently pitches northwest in the direction of Livingston county, and perhaps is directly related to the supposed fold in the latter county, which, if it exists, probably runs northwest from Fowlerville through Laingsburg or its vicinity.

It must be admitted that the evidence, while highly suggestive, is not sufficient to draw a positive conclusion. A carefully made drilling to the Dundee in northwestern Livingston county, or in southeastern Shiawassee county would doubtless prove whether or not there is a pronounced anticline as indicated by the evidence.

LIVINGSTON COUNTY.

Fowlerville. The Jason-Shumway well, northwest of Fowlerville, though fall of strong pure brine and plugged, constantly leaked gas which came from the sandstone mentioned in the previous paragraphs. The abundance of black or brown shale is not unfavorable for the occurrence of oil and gas.

<table>
<thead>
<tr>
<th>JASON-SHUMWAY WELL</th>
<th>Loc.: Sec. 17, T. 4 N., R. 3 E., Grill Farm.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elevation of well 900 ft. A. G.</td>
<td>Thickness, feet.</td>
</tr>
<tr>
<td>Surface to rock (6-in. drive pipe)</td>
<td>95</td>
</tr>
<tr>
<td>Slag (or 129 ft. oil) at the hole</td>
<td>35</td>
</tr>
<tr>
<td>Shale (gas at 136 ft.)</td>
<td>65</td>
</tr>
<tr>
<td>Clay (dry well from 200-600 ft.)</td>
<td>25</td>
</tr>
<tr>
<td>Black shale (gas at 690 and 400 ft.)</td>
<td>600</td>
</tr>
<tr>
<td>Brown shales (gas at 600 ft.), capped at that depth with 5-7-in. casing</td>
<td>200</td>
</tr>
<tr>
<td>Coarse gravel with salt water (deres)</td>
<td></td>
</tr>
<tr>
<td>Black shale.</td>
<td>20</td>
</tr>
<tr>
<td>Brown shale.</td>
<td>150</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>FOWLERVILLE OIL WELL</th>
<th>Loc.: Two miles south and 2 3-4 miles east of Fowlerville in N. E. ¼ of sec. 6, T. 7 N., R. 4 E. Henry White farm. 1900.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thickness, feet.</td>
<td>Depth, feet.</td>
</tr>
<tr>
<td>Pliocene.</td>
<td></td>
</tr>
<tr>
<td>Clay.</td>
<td>30</td>
</tr>
<tr>
<td>Clay.</td>
<td>8</td>
</tr>
<tr>
<td>Gravel.</td>
<td>24</td>
</tr>
<tr>
<td>Sand.</td>
<td>24</td>
</tr>
<tr>
<td>Blue clay.</td>
<td>24</td>
</tr>
<tr>
<td>Gravel.</td>
<td>22</td>
</tr>
<tr>
<td>Sand and gravel.</td>
<td>22</td>
</tr>
<tr>
<td>Coal Measures.</td>
<td></td>
</tr>
<tr>
<td>Sandstone.</td>
<td>8</td>
</tr>
<tr>
<td>Blue shale with oil and gas, the flow being estimated at about one-half barrel per day.</td>
<td></td>
</tr>
<tr>
<td>There sandstone at 157 ft.</td>
<td></td>
</tr>
</tbody>
</table>

Fowlerville. In the northwestern part of Livingston county about 4 miles southeast of Fowlerville, oil was struck apparently in dark sandstone lens in blue shale at the depth of only about 157 feet. The oil horizon is in the Coal Measures, which underlie the northwestern half of
Livingston county. The well, if pumped, might have yielded half a barrel of oil per day.

SHIAWASSEE COUNTY.

Owosso. Four miles northeast of Owosso, C. W. Collyer in 1863, as it appears, drilled a well 1000 feet deep. The Marshall was struck at 556 feet, but, below 601 feet, white and blue shales with red horizons predominated. The Grand Rapids Group appears to be little represented, probably eroded or not deposited as it is absent farther east.

Durand. The rock strata in the Durand well are so variable in character, that it is hard to correlate them with the rock strata at Owosso. Lane thinks that, if the anticline mentioned on previous pages is present in Livingston county, the structure extends southeast to Durand, and the Marshall is not represented.

CLINTON COUNTY.

St. Johns. Near the Water Works at St. Johns are three deep wells ranging from 574 to 780 feet in depth. The record of the No. 3, obtained as this report went to press, shows that the Marshall sandstone occurs at 700 feet below the surface.

CHAPTER VII. THE SOUTHWESTERN DISTRICT.

A large number of deep wells have been drilled for oil and water at various places in the southwestern part of the State as at Kalamazoo, Assyria, Dowagiac, Berrien Springs, Bridgman, Benton Harbor, Niles, White Pigeon, Constantine, and Allegan.

ALLEGAN COUNTY.

Though oil and gas were struck in many of the wells, only at Allegan has oil been found in possibly commercial quantities. Nearly a dozen wells 1300-1400 feet deep have been drilled for oil and water at various places in the southwestern part of the State as at Kalamazoo, Assyria, Dowagiac, Berrien Springs, Bridgman, Benton Harbor, Niles, White Pigeon, Constantine, and Allegan.
feet in depth have been drilled in and about the city in the last twenty or twenty-five years.

WATERWORKS WELL NO. 2.


Jackson, contractor.

Allegan. About fifteen years ago the Allegan Gas, Oil & Mining Company drilled a number of wells at Allegan. According to Mr. J. G. Ellinger, president of the Company, their No. 1 well, which was located on the river flats near the Pere Marquette depot produced about 5 barrels per day natural, and this was not appreciably increased by shooting. The well was 1275 feet in depth, oil occurring in the sandy shales at 1245 feet and in a sandy limestone at the top of the Dundee at 1256 feet.

For six weeks their No. 2 yielded about 3 barrels of oil per day of 24 hours and nearly enough gas to fire the boiler.

The sand was struck at 1328 feet practically at the same level as in the No. 1, as shown on the contour map (fig. 13). Both of these wells were abandoned as not being worth operating. The No. 3 (?) well was absolutely dry although the "sand," according to the drillers, looked very promising. This well, 1411 feet deep, was located on the higher ground in the eastern part of the city.

In 1912, the Northern Oil and Gas Company drilled two wells, the first on "high ground" near the southwest corner of the N. E. ¼ of section 32, Allegan township, and the second in section 28 on the river flats, 1800 feet north of the No. 1 well of the Allegan Gas, Oil & Mining Company. The No. 1 well was drilled to the depth of 1387 feet the Dundee limestone, the "oil sand," being struck at 1318 feet, but very little oil was found even after shooting. There is an upper thin "sand," separated from a lower but much thicker one. In this well, the surface deposits were found to be exceptionally thick, rock being struck at 355 feet. Great quantities of water and hard "lime shells," probably chert beds and siderite nodules, were encountered. The cherty "lime" just beneath the drift is about 75 feet thick and, near its base, it yielded a heavy flow of water upon which the bailer "running at top speed" could make no impression. It took several months to complete the well.

In the No. 2 well, 1340 feet in depth, the surface deposits were found to be only 87 feet deep, and little or no water was struck in the bed rock except in the lower part of the Dundee below the oil horizon. No casing outside of the drive pipe would have been needed. Owing to the soft character of the rocks and the absence of water troubles the well was completed in 13 days.

Figure 13. Contour map showing the depth of the Dundee limestone below sea level in the vicinity of Allegan and the location of borings.

Roman numerals refer to the wells of the Northern Oil and Gas Company; Arabic to the older explorations.

Oil was struck at 1287 feet apparently in commercial quantity. The two oil "sands" separated by a few feet of gritty limestone consist of light buff to gray limestones of the Dundee. The well was shot December 6, 1912, with 120 quarts of nitro-glycerine, 60 quarts in each sand. Upon pumping, the well yielded about two barrels of oil per day and a little water.

The oil is dark reddish brown, smells of "sulphur" and tested about 36° Baume according to Mr. Mercer, president of the company. Little or no gas accompanied the oil.

Three of the wells drilled in Allegan yielded from 2 to 5 barrels of oil per well. If a group of such wells were drilled and operated from a central pumping plant as at Port Huron and in Ontario, probably, under the present high prices of oil, a fair return could be obtained upon the investment. As the oil horizons are twice as deep at Port Huron, the cost of drilling and operating the wells would be much greater.

Character of the Formations and Local Structures.

All of the drillings show consistently that the blue-gray shales of the Coldwater, with here and there a red horizon, predominate down to about 1150 feet where the black shales of the Antrim begin. The Antrim is composed of gray shales in the upper portion and dark
or black shales near the base. This formation is very thick but the Traverse is thin, the former being probably over 400 feet in thickness. The Dundee appears to be a cherty or sandy limestone very changeable in color with a shaly phase just below the top.

Through the kindness of Mr. C. F. Mercer, president of the Northern Oil & Gas Co., and Mr. Perry Fox, driller, the locations and altitudes of several of the former drillings were furnished together with all of the information available concerning the depth of the Dundee. In platting the wells according to sea level base, it is observed that there are irregularities in the general dip, and the most prominent structure is the apparent terrace or structural bench in sections 27 and 28 with the abrupt northward dip into the southern part of sections 21 and 22, Allegan township. The highest elevation of the Dundee occurs in the No. 2 well in section 32, yet this well yielded little oil or gas. The oil was found on the lower part of the terrace and on the steeper slopes to the north. It must be said, however, that some of the data may not be accurate. According to Mr. Mercer the Allegan Oil, Gas and Mining Co. well, Plate VI, Volume V, is located on the Kalamazoo river flats near the Pere Marquette depot, therefore could not have the altitude of 708 feet as given in Volume V. Owing to the doubtful location and elevation of some of these wells too much stress should not be placed on the structures as indicated by the records.

The following are the records of one of the older drillings and of the two wells drilled by the Northern Oil & Gas Co. The logs of the latter were made partly from memory and partly from notes by Mr. C. F. Mercer, president of the company, and Perry Fox, driller. The thickness of the various strata of rock are approximations. The depth to the Dundee, however, is accurate as it was carefully determined by steel tape measurements.

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vicinity of Bridgman, Berrien Springs, and Dowagiac, and a less well defined anticline northeast from near South Bend and Grangers in Indiana into Cass county 10 or 12 miles east of Niles. At Benton Harbor the base of the Antrim black shale is about 115 feet A. T., at Berrien Springs 30 feet A. T., at Dowagiac 0 feet A. T., at White Pigeon 227 feet A. T., and at Constantine 137 feet A. T. From this data it will be observed that from Benton Harbor to Berrien Springs there is a drop to the southeast of 85 feet in about 15 miles, and a rise of 160 feet from the latter place to Niles, a distance of 12 miles. The southern limb of this trough or syncline is much steeper than the northern. Southward the rise is pronounced from Berrien Springs to South Bend where the Antrim is nearly 350 feet higher, but south of South Bend the strata descends again, giving rise to the anticline (Fig. 14) mentioned above.

The territory in the vicinity of the Berrien Springs syncline may be classed as unfavorable for the occurrence of oil and gas, while the region from South Bend and Grangers, Indiana, northeast into Cass county may be worthy of exploration. This anticline seems to be related to the Kankakee uplift and therefore may have a much greater northeastward extension toward Jackson than indicated by present drillings.

Oil horizons. The Dundee oil horizon is comparatively shallow in the vicinity of the anticline, probably being nowhere more than 1000 feet below the surface. At Niles, 10 or 12 miles west of the axis of the anticline, it is only 580 feet below surface.

The next probable oil horizon beneath the Dundee, excepting perhaps the Niagra, is the Trenton limestone, which is not only deeply buried, but wholly unknown. It is in this part of the State that drillers from Ohio have confused the Traverse or Dundee limestone with the Trenton. In the southwestern part of the State the drift is underlain by the blue shales of the Coldwater and the Antrim black shales. After penetrating these shales and striking a limestone beneath some black or brown shale, drillers are deceived and believe that they have struck the Trenton. The black shale is the Antrim, and the limestone that of the Traverse or Dundee. It is doubtful that the Trenton has been penetrated in southwestern Michigan.

CASS COUNTY.

Dowagiac. The only boring which may have reached the Trenton is the Dowagiac well, which is known to be 1760 feet deep, and which apparently penetrated the Lorraine shales.

BERRIEN COUNTY.

Niles. At Niles, at least six wells have been drilled for oil and gas or water. One from 500 to 700 feet deep, drilled in 1865 close to the bridge, yielded some gas. Another, drilled about 1885 on Second street 20 rods from the railroad, yielded a large flow of water for some time after the drilling was completed. One of the drillers, also reported striking oil, claiming that, owing to outside influence, he had concealed the fact from the public. A third well was drilled about the same time near the C. C. & St. L. R. R. to about 1100 feet. No. 4 was located about one or two miles south of the city on a river terrace. A strong brine which rose nearly to the surface was struck at 546 feet and another in limestone, probably the Monroe, at about 850 feet. These were cased off, but fresh water was struck below 880 feet (Niagara?) and this rose as high as the first. Trenton rock was reported at 1000 feet, but the top of this formation must be several hundred feet deeper. Some gas was constantly given off, making the water "milky" or foamy. The well was abandoned apparently at 1438 feet, but it is claimed that the well was drilled to 1600 feet. Though this well is higher than those in the city, corresponding strata appeared to be struck at the same depth but this is what should be expected as the general
dip of the strata should be northeasterly. The No. 5 (Vol. V) well, drilled in 1899, was located across the river 200 feet from No. 4 and only two or three feet above the water. It was about 518 feet deep, and yielded brine at 504 feet. By the use of a packer, the water was shut off and some gas was obtained. In 1903, a sixth well 592 feet deep was drilled by the Niles Oil & Gas Company about a mile west of Niles on the old Baumann farm. A little oil with brine was struck in the Dundee at the bottom of the well.

Nearly all of the oil and gas in the above wells apparently came from the Dundee or "bastard" Trenton which also yielded an abundance of brine some distance below the top and especially in its lower portion. In the No. 3 and No. 4, a little oil was struck in the top of the Niagara. A good log of the No. 6, or Niles Oil & Gas Company well was kept by Mr. F. W. Cook of the Niles Daily Star and a copy furnished the Survey. The log below shows the general character of the rocks down to the Dundee. This record tends to substantiate the general correctness of the hearsay records of the earlier wells.

Berrien Springs. About 1900 a well 700 feet in depth (650+ ft. A. T.) was drilled at Berrien Springs about 60 rods north of St. Joseph river. The Hon. Roscoe D. Dix furnished an accurate record of the well as given below. As noted previously, the base of the Antrim black shale is respectively 160 feet lower than at Niles to the southeast and 85 feet lower than at Benton Harbor to the northwest, therefore Berrien Springs is near the bottom of the syncline. No oil was reported, but signs of brine were observed in the base of the Dundee, when drilling ceased.

Benton Harbor. At Benton Harbor a well was drilled for oil and gas by the Benton Harbor Natural Gas and Oil Co., but little or no signs of either were found. In 1904, the Salzman Mineral Bath Co. drilled a well at Benton Harbor near the corner of 5th and Park Streets.

ST. JOSEPH COUNTY.

White Pigeon. In 1903, the White Pigeon Oil & Shale Gas Co. drilled an 800 foot well near the northwest corner of the N. E. ¼ of sec. 22, T. 8 S., R. 12 W. The oil "sand" at 756 feet is a yellowish, cherty, fiercely effervescent limestone 75 feet below the top of the Dundee. At about 710 feet water was encountered which rose 400 feet. The well was shot "wet," i. e. without casing off the brine, at about 763 feet but without effect.

St. Joseph. In St. Joseph, across the river from Benton Harbor, Vincent and Blake drilled a well 820 feet deep penetrating the Dundee. The record compiled by A. C. Lane from a meager set of samples is given below. The
drift is much deeper in the St. Joseph well than in the Benton Harbor well. The record does not agree very well with that of the Benton Harbor Natural Gas & Oil Co. well and, according to Lane, the latter may be imperfect.

BENTON HARBOR NATURAL GAS AND OIL CO.

Record by C. E. Wright from samples. Samples from Fred Jordan.

Elevation about 600 ft. A. T. Thickness feet. Depth, feet.

Surface: Unidentified
130
130

Arbutus shale: Grauwacke, fine argillaceous shale. 5
135

Red shale: 5
150

Clausen argillaceous shale: 30 per cent of the shale is red, the rest being argillaceous and 5
150

Black shale: 5
170

Clay: 5
170

Clausen argillaceous limestone: 10
165

Grauwacke limestone: 20 per cent of the limestone is red. 10
665

Limestone, gray to white: 10
700

Possum shale: gray: 5
11
711

Dark shale: 5
750

Larger gray limestone: 5
750

Similar: 5
750

Light gray limestone: 2 to 10 per cent of the limestone is red. 5
788

Mount and Niagara Formation: 10

Limestone, dark: 5
815

Gray: 5
815

Dolomite: 5
832

Dolomitic limestone: 10
832

Dolomite: 5
940

FLINT ROCKS: 5
1285

SAZLEM MINERAL BATH CO. WELL

(U. S. Geological Survey Well No. 186.)

Loc.: Cor. 5th and Park Sts., Benton Harbor. Drilled in 1894.

Elevation 600 ft. A. T. Thickness feet. Depth, feet.

Surface: Fine grained, light, 0
130

Arbutus shale: 5
135

Light gray or gray siliceous shale: 5
215

Black shale: 5
400

Traverse (Hamiliton) Formation:

Limestone, dark: 5
400

Gray: 5
400

Dolomite: 5
620

Thus the Traverse is a very great distance below the surface of the well.

Record says: "Much limestone and a few shales."

ST. JOSEPH WELL

Levi Dodge, owner.

Elevation 803 ft. A. T. Thickness feet. Depth, feet.

Surface: Sand: 5
40

Blue clay: 5
52

Sand: 5
77

Blue clay: 5
100

Sand: 5
101

Sand: 5
101

Traverse and Dunes: 5
312

Limestone, coarse: 5
377

Pleistocene:

Quaternary, fine grit: 5
120

Gravel, pebbles, cobbles, quartz, sand, 5
140

150 ft. of sand, allowing for fresh water, 5
43

Compare surface to 33 or 36 ft. in the Constantine wells.

Clastic beds:

Shale, light gray or argillaceous: 5
31

Gray sand: 5
213

Quarternary, calcareous and from the varied character of its grains, 5
241

From sandy to fine sand, which must come from some vertical fissure, intru- 5

Clastic beds:

Shale, light gray or argillaceous: 5
31

Gray sand: 5
213

Quarternary, calcareous and from the varied character of its grains, 5
241

From sandy to fine sand, which must come from some vertical fissure, intru- 5

Gneiss: 5
750

Constantine. A well over 1080 feet deep was drilled many years ago at Constantine, and the record as correlated by A. C. Lane is given below.
KALAMAZOO COUNTY,

Kalamazoo. In 1887, the Kalamazoo Natural Gas Co. sunk a well 2250 feet for gas. A strong brine was struck in the top of the Dundee at about 1270 feet and brine and a little oil at 1490 feet near the top of the Monroe.

CHAPTER VIII. WESTERN MICHIGAN.

MUSKEGON COUNTY.

Muskegon. Along the shore of Lake Michigan from Muskegon north to Manistee and beyond, a large number of deep wells have been drilled since the early 70’s for salt, water, and oil and gas. At Muskegon, there are a number of wells, some of which penetrate the Marshall for fresh water, while others reach depths of 1400 to 2400 feet.

The oldest and farthest west of these deep wells is the Whitney or Truesdell, also called the Hacker well. It is located close to the lake at an elevation of about 586 feet. A.T. and according to reports is from 1230 to 1600 feet deep. Copious flows of water were struck at 330 feet, and also at 643 feet, the lower one being mineralized but of agreeable and refreshing taste. Strong brine was struck at the bottom, probably in the Monroe beds, but this did not rise and mingle with the water above.

The Mason well near the old Occidental Hotel, 613 ft. A. T., was begun 1872 and a depth of 2000 feet was reached two years later. In 1875, it was 2400 feet deep and was finally bottomed in the Salina at 2627 feet. An abundance of artesian water and brines was struck, and at 1200 feet oil and gas. At first, the quantity of oil was reported to be 75-100 barrels per day, but the flow proved to be mainly water mixed with a little oil. From the quality of the oil, the horizon then appeared to be that of the Berea grit, but later the much more accurate record of the Central Paper Company well indicates that the oil horizon is in some fine grained grits or sandstones in the base of the Coldwater, but at some distance above the Berea horizon. A strong brine resembling the Dundee was struck at about 2030 feet in rock containing thin beds of sandstone. No rocks typical of the Dundee were recognized and perhaps the formation is absent, since it is known to decrease in thickness toward the western part of the State, and it is absent at Milwaukee on the opposite side of Lake Michigan.
appears to be at about the same altitude as the Ryerson, and 10 feet lower than the Mason. A careful log was kept and a good set of samples obtained.

**RYERSON-HILLS WELL**

<table>
<thead>
<tr>
<th>Elevation 544 ft. A.T.</th>
<th>Thickness, feet</th>
<th>Depth, feet</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pleistocene: Sand</td>
<td>65</td>
<td>65</td>
</tr>
<tr>
<td>Rice</td>
<td>135</td>
<td>204</td>
</tr>
<tr>
<td>Hadelorn</td>
<td>59</td>
<td>298</td>
</tr>
<tr>
<td>Lower Marshall and Calcareous</td>
<td>200</td>
<td>498</td>
</tr>
<tr>
<td>Lime</td>
<td>4</td>
<td>282</td>
</tr>
<tr>
<td>Shale</td>
<td>9</td>
<td>523</td>
</tr>
<tr>
<td>Light shale</td>
<td>20</td>
<td>343</td>
</tr>
<tr>
<td>Jeep shale</td>
<td>5</td>
<td>545</td>
</tr>
<tr>
<td>Lime</td>
<td>40</td>
<td>382</td>
</tr>
<tr>
<td>Light shale</td>
<td>2</td>
<td>523</td>
</tr>
<tr>
<td>Hard line rock</td>
<td>2</td>
<td>523</td>
</tr>
<tr>
<td>White and blue shale</td>
<td>195</td>
<td>877</td>
</tr>
<tr>
<td>Red shale</td>
<td>8</td>
<td>888</td>
</tr>
<tr>
<td>Hard line</td>
<td>3</td>
<td>888</td>
</tr>
<tr>
<td>Dark and light shale</td>
<td>222</td>
<td>1110</td>
</tr>
<tr>
<td>Limestone</td>
<td>312</td>
<td>1427</td>
</tr>
<tr>
<td>Depth reported 2000 to 2200 feet. Report from 147 feet unknown.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**MICHIGAN OIL COMPANY WELL**

Loc.: Forty-four feet southwest of the Mason well.

<table>
<thead>
<tr>
<th>Elevation 542 ft. A.T.</th>
<th>Thickness, feet</th>
<th>Depth, feet</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pleistocene: Sand</td>
<td>60</td>
<td>69</td>
</tr>
<tr>
<td>Calcareous blue clay</td>
<td>163</td>
<td>223</td>
</tr>
<tr>
<td>Gravel in clay and till.</td>
<td>12</td>
<td>235</td>
</tr>
<tr>
<td>Upper Marshall:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sandstone</td>
<td>105</td>
<td>340</td>
</tr>
<tr>
<td>Lower Marshall (sandstone)</td>
<td>200</td>
<td>820</td>
</tr>
<tr>
<td>Harder shale with iron and lime: drilled 70 ft. in 10 hours.</td>
<td>80</td>
<td>709</td>
</tr>
<tr>
<td>Soft blue shale, calcarious, brown limestones.</td>
<td>24</td>
<td>914</td>
</tr>
<tr>
<td>Flagstones, shale with thin lamina of white sandstone and calcarious bands: drilled 40 ft. in 41 hours, and 6 ft. in 33 minutes.</td>
<td>361</td>
<td>1275</td>
</tr>
<tr>
<td>White and blue shale, shales, sandstone, and calcarious, yield oil.</td>
<td>18</td>
<td>1230</td>
</tr>
<tr>
<td>Sandy shale</td>
<td>18</td>
<td>1320</td>
</tr>
<tr>
<td>Shales, sandstone at horizon.</td>
<td>180</td>
<td>1569</td>
</tr>
</tbody>
</table>

Figure 15. Map of a portion of Marquette Lake, Mason county, showing location of salt blocks (after C. W. Cook.)

As the well is at a considerable distance from the Ryerson, the Mason, and other wells, determinations of the local dips and structures can be made. From Milwaukee, where the edge of the Traverse or Hamilton rocks outcrop at the surface, across Lake Michigan to Muskegon it is approximately 86 miles. At Muskegon, the Traverse appears to be 1700 feet below the surface, therefore the dip from Milwaukee eastward to Muskegon is about 20 feet per mile.

The base of the Antrim black shale occurs in the Central Paper Co. well at 1615 feet and in the Mason at 1700 feet. The latter well is about 10 feet higher in elevation, and, allowing for this, there is a drop in the strata of approximately 75 feet in about four miles. This gives a dip of nearly 20 feet per mile to the eastward, which corresponds with the general dip from Milwaukee to Muskegon.

In the Central Paper Co. well, a bed of red fossiliferous limestone occurs from 845 to 870 feet, and this also occurs from 890 to 904 feet in the well, drilled in 1900 near the old Mason well. In this case, the drop is about 45 feet in four and one-half miles or an average of only 10 feet per mile.

The Central Paper Company, Ryerson-Hills and Mason wells are not in direct line, but they are nearly so and, from the general eastward dip, the strata in the Ryerson should be lower than in the Mason well. On the contrary, the red horizon and other corresponding strata are higher in the Ryerson than in the well drilled in 1900 close to the old Mason well. This indicates a local disturbance in the rock strata, and, according to Lane, the chances for finding a pronounced anticlinal appears to be greater farther north along Muskegon lake, perhaps on the north side in sections 15 and 16. Unfortunately, the oil sand is so fine grained that probably the flow would be limited unless the oil stratum should be struck in a coarse phase.

Beneath this oil horizon, however, are those of the Traverse and perhaps the Dundee. The Traverse is well represented by an alternation of limestones and shales, the latter mainly blue. Possibly, as at Saginaw, some of the limestones may contain oil. As the Dundee is thin, or possibly not present at Muskegon, this formation does not offer great possibilities, but the porous brine bearing stratum at the point; where the Dundee should be expected to occur, may prove to be oil and gas bearing.

**CENTRAL PAPER CO. WELL**


<table>
<thead>
<tr>
<th>Elevation of well 584 ft. A.T.</th>
<th>Thickness, feet</th>
<th>Depth, feet</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pleistocene: Sand</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>Calcareous clay</td>
<td>183</td>
<td>283</td>
</tr>
<tr>
<td>Sandstone, red and calcarious clay</td>
<td>315</td>
<td>625</td>
</tr>
<tr>
<td>Limestone, greenish calcarious, very fine at the bottom: a typical Marshall gneiss.</td>
<td>77</td>
<td>319</td>
</tr>
<tr>
<td>Coldwater shale:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shales, sandstone, more or less calcarious.</td>
<td>315</td>
<td>625</td>
</tr>
<tr>
<td>Limestone, a clayey and dolomite water line, with sericite, blue mica, and hornblende.</td>
<td>35</td>
<td>600</td>
</tr>
<tr>
<td>Limestone and calcarious, greenish, calcarious, very fine at the bottom: a typical Marshall gneiss.</td>
<td>185</td>
<td>685</td>
</tr>
<tr>
<td>Limestone, red and white, sericite, and hornblende.</td>
<td>25</td>
<td>825</td>
</tr>
<tr>
<td>Beach, gravel.</td>
<td>530</td>
<td>1400</td>
</tr>
<tr>
<td>Sandstone, shales, sandstone, and calcarious.</td>
<td>80</td>
<td>1480</td>
</tr>
<tr>
<td>Antrim shale</td>
<td>180</td>
<td>1615</td>
</tr>
<tr>
<td>Traverse, Hamilton, Formation:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shale, blue, calcarous.</td>
<td>35</td>
<td>1650</td>
</tr>
</tbody>
</table>
**MASON COUNTY.**

**Fruitport.** At Fruitport in the southern part of Muskegon county, a deep well was drilled about 1903, but the samples preserved for the Michigan Geological Survey were carried away by mischievous boys and no record was kept by the drillers. 1

1Ann. Rept. 1903, p. 274.

**Ludington.** At Ludington, several deep wells (Fig. 15) were drilled to the Salina for salt by the lumber companies in the early days of the salt industry.

The Pere Marquette Lumber Company’s well at the north end of Marquette lake, 2220 feet deep, (490 ft. A. T.) and the Butters and Peters well on the southwest side of the lake, 2260 feet deep, penetrated rock salt in the Salina; but apparently no oil or gas was found.

In the Lyons No. 2 well, a showing of oil was reported at 1175 feet which should be near the base of the Coldwater, possibly in some of the thin strata sandy layers which in the western part of Michigan locally occur in this formation near the Berea horizon.

A few years ago the J. S. Stearns Lumber Company drilled a well 2304 feet in depth to the rock salt of the Salina. An accurate record and set of samples were kept from which it appears that an oily brown limestone occurs at 2085 feet in the upper part of the Traverse, while the middle Traverse is composed of 250 feet of pure limestone. Part of the latter may be the Dundee, but the recognition of this formation is not certain in this well.

**Anchor Salt Co.** has drilled five wells to the salt beds. The No. 3 well, 2360 feet in depth, shows the beds respectively 20, 9, and 8 feet thick and the No. 5, four beds 20, 12, 7, and 5 feet thick. The records of Nos. 4 and 5 are given below.

**The Anchor Salt Co.** has drilled five wells to the salt beds. The No. 3 well, 2360 feet in depth, shows three beds respectively 20, 9, and 8 feet thick and the No. 5, four beds 20, 12, 7, and 5 feet thick. The records of Nos. 4 and 5 are given below.

**MANISTEE COUNTY.**

**Manistee.** In the Manistee salt district, there are more than 35 deep wells scattered from the shore of Lake Michigan along Manistee lake to Filer City and Stonach, a distance of four or five miles. Below is a list of 29, giving locations and depths as far as obtainable. The records of many of them are very incomplete, only the depth to the salt or the total depth being known.

The Canfield-Wheeler well (592 ft. A. T.) near Lake Michigan (see Fig. 16), originally 1947 feet deep, was afterwards deepened some 500 feet by T. Percy to the white Guelph or Niagara dolomites. These outcrop on the opposite shore of Lake Michigan and, according to computations by Lane, the dip across the lake is not less than 20 feet nor more than 60 feet per mile. This dip is intermediate between the 20 foot dip from Milwaukee to Muskegon and the 60 foot one from Neebish Island to Cheboygan. A second well was drilled but only to 1926 feet.
Figure 16. Map of the Manistee salt district showing location of salt wells and the discordant dips of the salt horizon and depths of the same. Arrows indicate direction and numbers, amount of dip per mile.
Buckley & Douglass Lumber Co. drilled five or more wells, but only of the No. 5 was a complete record obtained. According to Mr. J. J. Hubbell, the record is as follows.

The above well is near Manistee Lake about 1¼ miles east of the Canfield-Wheeler, 610 ft. A. T. or about 18 feet higher, but the top of the salt at 1985 feet seems to be fully 70 feet deeper. Too much dependence must not be placed upon comparisons between these two wells as the record of the Canfield is probably not reliable, since the samples do not correspond with the log.

**East Lake.** The R. G. Peters Salt & Lumber Co. in East Lake is about three-fourths of a mile northeast of the Buckley and Douglass Lumber Co. The Peters Company drilled a well in 1886 and according to the record of this published in Volume V (PL XXXII) the top of the first salt bed occurs at 1988 feet, or practically at the same depth as in the Buckley and Douglass well. In the former, the base of the Antrim appeared to be at 960 feet, in the latter 940 feet. A soft shale from 1570-1680 feet may likewise be correlated with a similar shale in the Buckley-Douglass at 1490-1600 feet. The top of the salt in the Canfield and Wheeler well near Lake Michigan occurs at 1932 feet, hence the salt is about 70 feet deeper in the Buckley and Douglass well. This is equivalent to a dip of about 35 feet per mile slightly south of east. This dip is comparable to the average southeast dip of the Niagara of 39 to 50 feet per mile across Lake Michigan. From the Buckley and Douglass well northeast to the R. G. Peters well the dip is nearly if not quite flat (Fig. 16), assuming that the salt beds are the same in each well. Considerable oil and a great pressure of gas were encountered at 1905 feet in the old R. G. Peters well. Water and oil, according to reports, shot up 150 feet above the derrick, blowing off the top. Some oil was also reported in the Antrim shale at about 960 feet.
In 1908, another well was drilled by the R. G. Peters Salt & Lumber Co. to the salt bed and a set of samples and a log were preserved, from which the appended record has been compiled. According to Mr. R. A. Nickerson, general manager of the company, a considerable flow of oil was struck at 1925 feet, which was immediately cased off and the well continued to the salt bed, which was struck about 1980 feet.

Stronach. The Stronach Lumber Co. wells at Stronach (604 ft. A. T.) are a little over 3½ miles southeast of the Canfield-Wheeler and 2½ miles from the Buckley and Douglass wells. The salt bed, 1930 to 1964 feet is about as high as in the Canfield and about 30 feet higher than in the Buckley and Douglass or in the Peters at East Lake. The Bell (Marcellus) shale from 1450-1625 feet likewise is higher and signs of oil and gas were encountered directly beneath this shale. The Antrim black shale, however, is at about the same depth, i.e. 970 feet. Gas was struck in the top of the black shales at about 600 feet and oil and gas about 30 feet below the top of the Dundee, which is cherty, porous and perhaps brecciated as it caves in some of the drillings. In the Union Lumber Co. wells (605 ft. A. T.), the top of the salt, reported at 1949 feet, is apparently a little deeper. The bottom was supposed to be at 1982 feet, but the bottom of the brine cavity deepened to 2015 and 2025 feet. This indicates that the bottom of the salt was not reached in the drillings.

The average dip of the formations, as previously noted, is between 38 and 50 feet per mile to the southeast. From this one would expect that corresponding strata at Stronach and Filer City should be from 150 to 200 feet deeper than near Lake Michigan in the Canfield-Wheeler well. On the contrary they are nearly as high at Stronach and Filer City as in the latter well, and are even higher than in the Buckley and Douglass and Louis Sands wells, which, although not in direct line, are between the Canfield and Wheeler and the Stronach wells. This indicates that there is an upward fold or anticline near Stronach which may contain oil and gas in commercial quantity. As there are no deep wells southeast of Stronach, one cannot tell whether the axis lies at Stronach or farther to the south and east.

Plate III. The Onekama Gas Well, Manistee County.
In the vicinity of Portage Lake, Manistee county, considerable gas mixed with water has been struck in many artesian wells throughout an area of four or five miles long. In 1901, a well in sec. 22, Onekama township, was drilled close to the fish hatchery on the north side of the lake. A strong flow of gas under high pressure was struck which, according to reports, rapidly decreased in pressure and volume. According to Mr. W. W. Davis, a well driller and contractor, who has drilled a great many of the artesian wells in the Portage Lake district in the past twenty years, the well caved below the bottom of the casing, which did not reach to the gas horizon, and thus the flow of gas was shut off. Other wells yielding much gas with water have been struck since then. In 1913, Mr. Davis made a test well near the fish hatchery for Mr. H. Ward Leonard of Manistee. The well is located on the Northern Transportation Co. land about 25 feet from the old gas well. On January 27, 1913, gas with a pressure of about 185 pounds and free from water was struck at a depth of 437 feet in a sand or gravel bed. The casing is 2 inches in diameter and, in pulling out the well rods, the last 185 feet were blown free from the well and scattered around in the tree tops. The well was "blown" almost every day for several weeks from about 15 minutes to an hour and a half to prevent clogging. After it has blown for some time the pressure, measured by a registered steam gauge, gradually sinks to about 145 pounds but upon closing the valve the pressure is almost instantly back to 185 pounds or more. When the gas was lighted (PL III) the flame shot up 25 to 30 feet above the top of the casing.

The analysis of the gas, as furnished by Mr. Leonard, was made in 1913 at the Grand Rapids gas plant and indicates that the gas is of good quality and is free from sulphur.

**ANALYSIS OF ONEKAMA GAS.**

<table>
<thead>
<tr>
<th>Component</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon dioxide</td>
<td>0.2</td>
</tr>
<tr>
<td>Oxygen</td>
<td>1.1</td>
</tr>
<tr>
<td>Carbon monoxide</td>
<td>0.1</td>
</tr>
<tr>
<td>Nitrogen</td>
<td>11.7</td>
</tr>
<tr>
<td>Methane</td>
<td>86.0</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>100.0</td>
</tr>
</tbody>
</table>

**Heating power B. T. U. (cu.) 1070.0**  
**Candle power 3.0**

There is much water in the overlying sand and gravels but it is shut off from the gas sand, which appears to be just below a compact conglomeratic mass of shale fragments. The following is the log as given by Mr. W. W. Davis, the driller.

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**CHAPTER IX. NORTHERN LOWER MICHIGAN.**

**SURFACE DEPOSITS AND EXPLORATIONS.**

The northern part of the Southern Peninsula has few and widely scattered deep drillings and these are chiefly near the lake shore at Frankfort, Petoskey, Charlevoix, Cheboygan, Onaway, Alpena, Grand Lake, Harrisville, Killmaster, Oscoda, Tawas City, Prescott and Standish. The only ones in the interior are the Hanson wells at Grayling and the Cadillac well, now being drilled.

As noted on previous pages, there is a broad belt extending from Newaygo, Mason and Manistee counties northeastward into Otsego, Montmorency, and Alcona counties, in which the surface materials are very thick, ranging from 400 to more than 1000 feet, the average being probably about 600 feet. This has been, and will continue to be a most effective obstacle in discouraging explorations for oil and gas.

**BEDROCK GEOLOGY.**

The rock strata of this part of the State compose the northern segment of the Michigan Basin, consequently in passing around the lake shore from Frankfort, Benzie county, to Harrisville, Alcona county, the strata dip...
successively southeast, south, and southwest toward the center of the Basin. The formations beneath the drift form belts more or less concentric with the lake shore, and in passing form the lake margin to the central-basin the edges of the Devonian formations -- the Dundee, Traverse, Antrim, Berea, Coldwater, Marshall, the Grand Rapids Group, and the Saginaw Coal Measures are crossed in order.

Relations of surface signs to the oil and gas formations. Three of the oil horizons outcrop at the surface or lie beneath the drift cover in this part of the State. Locally as in southeastern Alcona county there are springs which, from the amount of gas given off, appear to be in a state of ebullition and one of these near Killmaster (center of sec. 26, T. 26 N., R. 8 E.) gave off so much gas that it led to the Killmaster drillings (see Fig. 18). Similar springs occur near Atlanta, Montmorency county. Gas is struck in wells also, as in Benzie county and around Portage Lake, Manistee county.

In the vicinity of Alpena there is a large area in which the Traverse formation and the Dundee limestone outcrop, or are under a light cover of surface materials. The Traverse has been carefully studied in northern Michigan by Grabau, and the outcrops around Little Traverse Bay and Alpena have received very careful study from limestone, cement, and chemical companies, which have extensively developed the deposits of the high grade limestones of the Traverse and the Dundee formations.

While no prominent anticlinal folds are known to exist in Alpena county, discordant and abnormal dips, noted by Winchell and Rominger, occur in several localities. The general dip is to the southwest, yet the rocks north and east of Alpena dip northeast toward Lake Huron. The Dundee limestone is much fractured and faulted locally and extreme brecciation is characteristic of the Monroe Beds throughout the northern and southeastern part of the State.

During the past few years Mr. Henry R. Hindshaw, former assistant State geologist of New York, has made an extensive study of the limestone deposits of possible commercial value in Alpena and Presque Isle counties. He observed the abnormal dips, local fractures, and the brecciation of the Dundee limestone, which near Rogers City, is so great that drilling with a core drill is very difficult.

In the Salina, in Alpena and Presque Isle counties, the salt beds aggregate 300 to 800 feet in thickness. According to the upward rise of this formation toward the northeast and east, it should form the bottom of the Lake Huron basin. Thin salt beds occur at Manistee and Ludington, and here too are to be observed abnormal local dips and a "vesicular" dolomite above the salt which caves in drillings and is very probably brecciated. The brecciation in the Dundee and the Monroe in the Frankfort well appears to be undoubted.

In limestone areas, much of the drainage is underground. In the limestone belt of northern Michigan there are relatively few streams as most of the surface waters drain into the numerous sinks. The Dundee, especially near its base, and the Monroe beds are very heavily water bearing, being filled with crevices, fissures, caverns, and underground water channels. The water channel struck in the Detroit salt shaft was more than five feet across. In many instances drill tools suddenly drop four or five feet into cavities. Again, in drillings, beds of dolomitic sand are struck in the Monroe which flow into the drill holes like thin mud. Such sands and oozes may be the residuum of other beds carried away by solution.

Mr. Hinshaw related these facts -- the abnormal dips, the brecciation of the Dundee and the Monroe beds, the large underground water circulation, the oozes, the relation of the margin of the Salina formation to the basins of lakes Huron and Michigan, and conceived the idea that these lake depressions are due in part to the ablation, or solution of the salt in the Salina and that the brecciation was caused by the slumping incident to the removal of the salt beds below. While the validity of all of the evidence has not been investigated, the theory as advanced contains elements of plausibility and is worth consideration.

It is obvious that if the salt in the outer edges of the formation should be removed by solution, there would be slumping in the beds above, which might very possibly cause brecciation in rocks like dolomites and limestones. The slumping would also explain the abnormal dips, observed near the lake shores.

According to Mr. Hindshaw's theory, marked disturbances in the rock strata are liable to be found along the margin of the southern Peninsula, excepting in those regions where salt was never deposited. Such disturbances are favorable to the accumulation of oil and gas, but the brecciated rock must be capped by some soft and plastic stratum such as shale, which would not readily fracture or these products would escape.

LITTLE TRAVERSE BAY ANTICLINE.

Along the south shore-of Little Traverse Bay, the limestones and shales of the Traverse formation outcrop in low bluffs. In the vicinity of Khagashewing Point (Fig. 2) there are numbers of low folds which pitch southward. While the folds are small, together they make up a structure sufficiently large to contain oil and gas in commercial quantity. A Mr. W. N. Norton, representing an eastern oil company, made a survey of the Charlevoix region and made preparation to drill a number of test wells in 1913, but for some reason the project was suddenly abandoned.

BENZIE COUNTY.

Frankfort. At Frankfort two wells respectively 1800 and 2200 feet in depth were drilled many years ago, but only a meager record of either was obtained. The first one, 1800 feet in depth, was abandoned on account of the
great flow of water from the brecciated Dundee limestone at the bottom. The second is 500 feet to the southwest, and, at 1800 feet, a sulphate brine testing 20 per cent salinometer was encountered. This brine appears to come from a horizon corresponding to the Manistee and Stronach salt horizon. The well was continued to 2200 feet and the brine decreased in strength toward the bottom, where an enormous flow of water was struck, probably in the Niagara.

EMMET COUNTY.

Petoskey. At Petoskey, a well was drilled nearly if not quite to the bottom of the Dundee limestone. Judging from the depth of the drift the well is in an old glacial rock valley for within a short distance on either side rock is only 5 feet below the surface.

Bay View. At Bay View, a well about 500 feet deep was drilled in 1895. This record and others show that the Traverse on the western side of the State is predominantly limestone, shale being very subordinate in quantity in contrast to the Alpena region. The only thick bed is the blue basin or Bell shale in which the drilling stopped, but thin shale beds have been struck in some of the shallow wells along the south shore of Little Traverse Bay.

A very hard layer was struck at 450 feet in which only 18 inches a day could be drilled. Water in great quantity was struck in the limestone below this shell. Nearly all of the limestone is hard as an average of only 10-12 feet per day could be made.

CHARLEVOIX COUNTY.

Charlevoix. In Charlevoix, three wells were drilled within 50 feet of each other. Only of No. 3 were samples obtained. The drift was found to be 230 feet in thickness, yet rock is at the surface to the east and west of the city. This indicates the presence of deep rock valley. Apparently the well was bottomed in the blue Bell shales at the base of the Traverse.

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accurate calculations of dip cannot be made. An approximation may be made, however, by assuming that the Traverse at Grayling (1140 ft. A. T.) is not over 600 feet thick, in which case, the top of the Dundee should occur at about 2880 feet at the latter place. The base of the Traverse in the Petoskey well occurs at 435 feet. Allowing for the difference in elevation of the two places, the base of the Traverse at Grayling is probably about 1905 feet lower than at Petoskey, representing an average dip of over 38 feet per mile slightly east of south.

WEXFORD COUNTY.

Cadillac. In 1913 the Cadillac Oil & Gas Company, C. R. Smith, president, and Bruce Smith, secretary, was organized and in the winter of 1914 began drilling a test well on the C. R. Smith farm near Cadillac. According to reports the well was located by means of an “instrument” invented by T. H. Cross, who superintended the drilling. Unfortunately the drift is very deep in the vicinity of Cadillac and considerable difficulty has been encountered in getting the drive pipe down. The upper 470 feet was entirely sand and gravel, and at last reports the well was still in drift at 712 feet. A good set of samples was preserved for the Survey from which the following partial record has been compiled.

CHEBOYGAN COUNTY.

Cheboygan. About 1900, one of the deepest wells in the Southern Peninsula was drilled at Cheboygan for rock salt. Rock outcrops to the west of Cheboygan, and on the adjacent islands, but the drift was found to be 380 feet in depth, indicating the presence of a deep pre-glacial rock valley. The first rock encountered was the Monroe instead of the Dundee as would have been the case if the latter had not been removed by erosion in the formation of the rock valley.

The well, 2750 feet in depth, was bottomed in dark drab shaly dolomite probably near the base of the Lorraine (Hudson river) shales, and did not reach the Utica or the Trenton.

CRAWFORD COUNTY.

Grayling. In 1901, R. Hanson of Sailing, Hanson & Co. drilled three wells at Grayling and one, the No. 3, reached a depth of 2800 feet. This well, though one of the deepest in the State, was drilled very quickly. Work began the last of January and, by May 6, the well was finished at a depth of 2800 feet. This well penetrated about 520 feet of Traverse limestones and shales, but did not reach the heavy shale (Bell or Marcellus) at the base of the formation.

ROSCOMMON COUNTY.

Roscommon. Many years ago a drilling was made for oil near Roscommon, but statements concerning it are so contradictory that nothing very definite can be asserted. It is not known that the well reached bed rock before it was abandoned, but it appears that the drift is at least 365 feet thick, and is mainly sand with some clay at 118 and 365 feet. Mr. Fred Johnson of Roscommon is authority for saying that he and others saw oil at the well, which was claimed to come from it. Many consider that the well was 'salted' and a fraud. One morning the well was found to have been filled with scrap and railroad iron, and the enterprise was abandoned.

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PRESQUE ISLE COUNTY.

Onaway. In 1913 the Presque Isle Development Company was organized, H. T. Moeller of Detroit, president, and Judge W. H. Martin of Saginaw, secretary. Drilling was started with the intention of penetrating the Trenton unless oil or gas should be struck before reaching that horizon. The well was bottomed in the Niagara at a depth of 3106 feet without encountering any noteworthy signs of either oil or gas.

The Monroe beds and the Salina show a remarkable development, the former being nearly 1150 feet in thickness and the latter, 1175 feet, including about 800 feet of rock salt. The combined thickness is several hundred feet greater than any thickness previously known in Michigan or Ontario. The Upper part of the Monroe appears to be composed largely of limestone or dolomitic limestone instead of dolomite and for 200 feet below the middle of the formation, the dolomite is very cherty and somewhat sandy. Most of the salt is red or tinged with red. The first salt bed, 145 feet thick, varies in color from a reddish pink to a deep brick red and the 225 foot bed at the bottom is nearly all white or gray salt. Below the salt beds there are 281 feet of hard white and gray limestone.

Notwithstanding the fact that shale everywhere overlies the Trenton limestone and that none had been penetrated in this well below the salt beds, the drillers, according to statements of the officials of the company, pronounced these limestones of Trenton age and barren of oil or gas. Upon this supposition, the well was abandoned.

The hard white limestones below the salt beds probably belong in part to the Salina, but, if they are considered as wholly Niagara and this formation has its normal thickness of 600 feet for the northern part of the State, there is still about 300 feet of Niagara limestone to be penetrated before reaching the top of the shale series which lies between the Niagara and the Trenton. This shale series in a descending order includes the Rochester, Clinton (generally dolomitic), Medina, Richmond, Lorraine and Utica and, while no close approximations can be made of the thickness of each of these formations, the total thickness is probably between 600 and 700 feet. From this it would appear that the bottom of the well is from 900 to 1000 feet above the top of the Trenton.

The company very kindly furnished the Michigan Geological Survey with a log of the well and a set of samples from which the following record has been compiled:
difference in elevation between Onaway and Grayling (1140 ft. A. T.), the base of the Traverse at the latter place is about 2250 feet lower than at Onaway. The distance from Onaway to Grayling is about 54 miles by map measurement, therefore the average dip south-southwest is nearly 42 feet per mile.

Grand Lake. A number of years ago, a well 1712 feet in depth was drilled by the Alpena Land Co. at Grand Lake. A careful record was kept and a set of samples preserved. This well was started directly in the Bell shales at the base of the Traverse and penetrated the Salina 425 feet, passing through salt beds aggregating more than 300 feet in thickness. Strong flows of salt water were struck at 1000 and 1257 feet. Fresh water was probably struck in the Dundee and Upper Monroe, though not mentioned in the record.

ALPENA COUNTY.

Alpena. The early borings at Alpena were drilled for salt. One of the deep holes was drilled about 1872 near the bed of Thunder Bay river and "salt," probably brine, was reported at about 1025 feet. The record shows 400 feet of Traverse limestone followed by 80 feet of blue fossiliferous Bell shales. Beneath the shales is 120 feet of Dundee limestone variable in color and hardness. Below the depth of 600 feet are light colored dolomite limestones.

Later, the Churchill well was drilled in Alpena close to the bay. A very careful record was obtained and a summary of the same is appended below. The top of the well is in the Alpena coral limestone of the middle Traverse, hence there are about 130 feet of Upper Traverse shales and limestones unrepresented in the record. Down to 444 feet there is a continuous succession of hard limestones and blue or calcareous shales. The hard and cherty Dundee limestone appears to be 99 feet thick, but perhaps the shale, and heavy limestone just below should be included with the Dundee. Farther north near Rogers City, Mr. Hindshaw reports the Dundee as being 215 feet thick. The Monroe beds down to 777 feet are alternations of relatively thin shale beds and heavy beds of hard limestone. Following this series is 480 feet of hard white limestone (dolomite).

The first flow of water in the rock was struck at 427 feet and a strong flow in the Dundee at 489 feet, which kept increasing down to 590 feet. This last flow was exceptionally strong. Other flows occurred at 605 feet and apparently at various intervals down to about 1050 feet. No oil or gas was encountered worthy of mention.

There are several other wells in the city or near it, but they only penetrate the Dundee for fresh water. Among these are C. Moench & Sons, the Tannery, and the Fletcher wells. (Ann. Rept. 1901, pp. 172-73).

Local structures. The Grand Lake well-is slightly west of north of the Churchill well at a distance of a little over 14 miles. The elevation of the former well is not given but from the indicated location it appears to be about 630 feet A. T. or higher than the Churchill well which is near the level (580 ft. A. T.) of Lake Huron. If this elevation is used in the calculations of dip the error probably will not be greater than a foot per mile. Since the Bell shales in the Grand Lake well are 50 feet thick, the top of the Dundee would come at the same level as the mouth (585 ft. A. T.) of the Churchill well in which the Dundee was struck at 444 feet. This figure therefore represents the amount of dip in 14 miles, or an average
dip of nearly 32 feet per mile a little east of south. This agrees fairly well with Grabau's determination, which is about 30 feet per mile. As the strike of the rocks is northwest-southeast and the above dip is along a line (see fig. 17), very oblique to the strike the above figure does not represent the maximum dip, which should be to the southwest. The 30 to 32 foot dip along the line from Grand Lake to Alpena should be equal to about 42 feet per mile to the southwest, and Grabau found that the average local dip, determined in several places, is approximately this figure.

Along the lake shore, however, northeast of Alpena, N. H. Winchell in 1870 noted marked dips toward the lake, yet at some distance from the shore he observed, in almost the opposite direction, a dip of 10° to the southwest. In the case of the Traverse beds, however, such dips may be due to the presence of the coral reefs, the dips being away from the reefs. Others have noted the same discordant dips. As noted on previous pages Mr. Wm. L. Hindshaw reports the same lakeward dips near Rogers City and associates them with the slumping of the formations due to the ablation of the underlying salt beds along the margin of the lake.

The distance from the Grand Lake well to Grayling, according to map measurement, is about 74 miles. Comparing the wells at these two places, the latter being about 510 feet higher, the average dip appears to be about 32 feet per mile. As Grayling is not in direct line with the center of the Basin, and apparently is to the west of the north-south median line, this figure must be less than the maximum dip, i.e., 42 feet. As will be seen later, the dip southward from Partridge Point, Alpena county, where the Antrim shale outcrops, to the Killmaster wells in Alcona county is approximately 35 feet per mile, and this should be equal to about 50 feet per mile to the southwest. From the foregoing approximations, it seems that the average southwest dip in the northeastern part of the Southern peninsula is between 40 and 50 feet per mile, 42 feet being about the average for the Alpena district.

While the Antrim, Dundee, and Traverse formations are bituminous, or contain bituminous horizons, yield a strong petroleum odor, and small quantities of gas in the northeastern part of the Southern Peninsula drillings have not shown any very promising signs of oil.

### ALCONA COUNTY.

**Relation of the rock formations to surface signs.**

Alcona county is underlain by the Marshall sandstone which crosses the southwestern corner, the Coldwater shales, the Berea sandstone, and Antrim black shale, the latter crossing the northeastern corner of the county. The strike of the formations is approximately northwest-southeast, therefore the dip is southwest toward the central part of the Basin. No rock outcrops are known in Alcona county. The Berea underlies the drift at Harrisville, as shown by the well at that place, and extends northwest toward Atlanta in Montmorency county and Vanderbilt in Otsego county. It is along the strike of this horizon and the Sunbury black shales that surface signs are most abundant.

There is another source of gas, however, and this is in the drift itself which contains an abundance of bituminous shale fragments, evidently from the Antrim. Apparently this bituminous material yields small but appreciable quantities of gas which collect in gravel beds in the drift.

In Alcona county, there are a large number of springs, some of which yield gas in considerable quantities. One of these near the center of sec. 26, T. 26 N., R. 8 E., yields so much gas that it led to the Killmaster drillings. According to reports, the gas from this spring when lighted will blaze up two or three feet above the water. There are several other similar gas springs in the same township as on secs. 14 (2 springs), 32, and 34. Gas springs also occur in sec. 15, (2 springs) T. 25 N., R. 8 E., and along the bed of the east branch of Pine river. Oil has also been noted on the Angus Cameron farm, sec. 12, T. 28 N., R. 5 E., and gas was struck in gravel, just above bed rock in the No. 1 Killmaster well.

Most of the county is deeply drift covered and there are no rock outcrops even in the deepest river valleys. Practically all knowledge of the bed rock geology has been obtained from the drillings.
been obtained from drill holes at Killmaster and Harrisville, and from wells in Alpena and Iosco counties.

**Killmaster.** Three wells were drilled at Killmaster. The No. 3 well, drilled in 1892, was the last and deepest (1530 feet). Some gas with a very small amount of oil was struck in the top of the Berea which yielded an abundance of brine lower down. The latter overcame the oil and gas, but according to reports some years ago the well was still yielding bubbles of gas. Below the Berea the hole was absolutely dry.

**Harrisville.** In 1904 a well 506 feet deep was bored at Harrisville at the courthouse striking the Berea sandstone directly under the drift (Fig. 19) at 230 feet. There were signs of oil in the drift at 100 feet, but no further signs of either oil or gas were observed at any other horizon in the well. The No. 1 well is about 80 rods from No. 3, a little east of south, and it is only 600 feet deep and stopped in a hard bed supposed at the time to be limestone, but it appears that this is only the hard upper crust of the bed at 570 feet in the No. 3 well. The formations are similar to those in No. 3 well except that there is a bed of gravel just above the rock which served as a reservoir for gas. (See Fig. 18), with a pressure of 103 pounds. The gas, however, was afterwards overcome by a large flow of nearly fresh water from the sandstone below.

**Conclusions.** The wells at Killmaster show that, locally, the Berea grit is not only a porous sandstone, but that it might contain gas and oil in commercial quantity if proper structural conditions were found. At Harrisville, however, the sandstone is too fine grained to be a free yielder and there was no showing of either oil or gas in the top of the Berea, although there is apparently an impervious cover of clay over the outcrop (see Fig. 18) which ought to have trapped small quantities of oil and gas in the top of the sandstone itself. Elsewhere along the outcrop, these products probably escape into the sands and gravels of the overlying drift as illustrated in Fig. 19.

As the drift is very thick over most of the county, there are ample chances for the accumulation of considerable quantities of gas in the drift, especially along the strike of the Berea grit and the overlying and underlying black shales. Such accumulations are more apt to be found northwest from Harrisville toward Hubbard Lake, Atlanta in Montmorency county, and Vanderbilt, Otsego county. In order to test the possibilities of the Berea, explorations should be made at some distance to the southwest of this line of outcrop and belt of leakage.

In Alcona county, the Traverse and Dundee formations are comparatively shallow and could be easily and cheaply tested. While the Traverse at Saginaw has three oil and gas bearing horizons, at Killmaster it was free from water and showed no signs of either oil or gas. The porosity of this formation, however, varies greatly in short distances and this is favorable for the occurrence of accumulations as in the so-called Saginaw sand in the Garey-Casamer No. 1 well at Saginaw.

Below the Traverse is the Dundee limestone which was not reached in the Killmaster drillings. Under favorable conditions, the Berea grit is not only a porous sandstone, but that it might contain gas and oil in commercial quantity if proper structural conditions were found. At Harrisville, however, the sandstone is too fine grained to be a free yielder and there was no showing of either oil or gas in the top of the Berea, although there is apparently an impervious cover of clay over the outcrop (see Fig. 18) which ought to have trapped small quantities of oil and gas in the top of the sandstone itself. Elsewhere along the outcrop, these products probably escape into the sands and gravels of the overlying drift as illustrated in Fig. 19.

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structural conditions oil may be found in considerable quantity in this formation, but the drillings are too few in Alcona county to indicate the presence or location of an anticline or structural bench, if either should exist. The oil and gas horizons beneath the Dundee, the Niagara, Clinton, Medina, and Trenton are so deep that the cost of testing them would be out of proportion to any reasonable chance of success.

Figure 18. Geological section from Alpena south through Alcona county to Oscoda, Iosco county. (Annual report Mich. Geol. Surv., 1901, Plate II.)

Figure 19. Diagrammatic sketch showing the possible occurrence of oil and gas along the strike of the Berea sandstone in Alcona county.

IOSCO AND OGEMAW COUNTIES.

AuSable and Oscoda Wells. In Iosco county at AuSable and Oscoda, eleven or more wells were put down by lumber companies for brines. The wells, all located within a radius of a mile, are in three groups which may be termed the Pack, the Smith, and the Loud. No detailed log of any of these wells is available, but from various sources the following information, which may be relied upon with a fair degree of confidence was compiled by Dr. A. C. Lane.

The Pack wells are from 20 to 25 feet above the lake, the Smith about 15 feet, and the Loud 6 to 8 feet. The drift, 90 to 100 feet thick, is mainly sand. The rock strata down to 200 feet, or more, are a series of sandstones and shales, apparently belonging to the Lower Marshall formation, which yields a very weak brine (one-half -- one per cent of salt). Below the Marshall blue shales with an occasional red horizon predominate down to the Sunbury black shale which overlies the Berea grit. The latter in the Pack wells was struck at 950 feet, in the Smith at 960 feet, and probably at a little greater depth in the Loud. The brine of the Berea is strong (90°-- 98° salinometer test) and pure, but the sandstone is so fine grained and shaly that there is not a free flow.

According to Mr. E. E. Holmes, the sandstone runs out to the north, yielding less and less brine. This can be the condition only for a short distance, however, as the sandstone is well represented at Killmaster and Harrisville. At Grayling, Alma, Mt. Pleasant, and in other places in the central and western parts of the State, the formation appears to be represented by shales, generally red or sandy.

According to the records of wells in various parts of the State the Berea, while locally coarse grained and porous, yielding an abundant flow of brine, is apt to be very fine grained or shaly as at Oscoda, Harrisville, Bay City, and Saginaw. In such localities, it cannot be a free yielder of oil and gas.

One of the Pack wells was drilled to a depth of about 1800 feet, reports varying from 1760 to 1850 feet. Only blue and black shales with thin streaks of limestone were penetrated below the Berea, and no water or signs of oil and gas were encountered. It is almost certain that the well did not reach the Dundee, but the bottom must have been very close to the top of this formation for the drill stopped in black shale, quite possibly the Bell (Marcellus) at the base of the Traverse. The hardness, light color, and the mineral waters of the Dundee would have been noted and remembered if the drill had reached this horizon.

At Harrisville the Berea is only 30 feet thick, being in part eroded. If it was originally as thick as it is at Killmaster, about 10 feet must have been removed, and the top of the Berea would have occurred at 220 feet instead of 230 feet. Using the first figure and allowing for the difference (35 ft.) in elevation of the mouths of the Harrisville and Oscoda wells, the Berea is approximately 765 feet lower at the latter place about 16½ miles to the south. This is equal to a dip of over 46 feet per mile, or about 8 feet per mile more than from Partridge Point, Alpena county, to Harrisville, or from Harrisville west-southwest to Killmaster. Computing the dip to the south-southeast from Killmaster to Oscoda, it is found to be about 30 feet per mile. If the black (Bell) shale at the bottom of the Pack well is the same as that at the top of the Grand Lake well, the dip southward from Alpena to Oscoda must be between 30 and 40 feet per mile.

From the above, the general or maximum dip for eastern Alcona and Iosco counties appears to be nearer south than southwest. From Oscoda south to Caseville across Saginaw bay in Huron county and south-southwest to Bay City, there is a decided flattening of the dip of the Berea, as the dip is only about 22 feet per mile toward the former and less than 20 feet per mile toward Bay City.

Tawas City. Several drillings have been made by the lumber companies of Tawas City for brine, which was struck in a coarse white or gray sandstone, apparently in
The general dip of the strata in Iosco county is apparently south-southwest at about 25 to 30 feet per mile. According to this the Berea should occur about 300 or 400 feet deeper at Tawas City than at Oscoda. Since the Berea is struck at approximately 950 feet in wells at the latter place it should be 1250 or 1350 feet below the surface at Tawas City. As the brine bearing sandstone at this place is struck at a depth of only 680 feet it appears that it is not the Berea but the Richmondville or some stray sandstone in the Coldwater shales 600 feet or more above the Berea horizon.

If the sandstone in question is the Berea proper, there is a very pronounced anticline in Iosco county with its crest near Tawas City.

**OGEMAW COUNTY.**

**Prescott.** In 1912 Mr. F. Jahncke of Alpena drilled a well for water near Prescott in southeastern Ogemaw county. The Upper Marshall was struck at 308 feet and the Coldwater shales were penetrated about 170 feet.

**ARENAC COUNTY.**

**Standish.** In Arenac county, there are a number of wells penetrating rock, but they are shallow excepting a 1900 foot well drilled by James Norn at Standish of which no log was kept but it appears to have reached the Berea (Sunbury) black shale just above the Berea grit. Below the Marshall, blue shales of the Coldwater which yielded a little brine, predominated.

The record given below has been largely compiled from notes and statements of persons connected with the drilling of the well, and may be taken as fairly representative of the general character and thickness of the formations penetrated.

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**CHAPTER X. NORTHERN PENINSULA.**

**THE PALAEOZOIC AREA.**

That part of the Upper Peninsula west of a line drawn from Marquette to Menominee is mainly underlain by pre-Cambrian rocks. Palaeozoic rocks from the Cambrian up to and including the Silurian occupy all of the area to the east of this line.

The Niagara limestone extends in an accurate belt along the western shore of Lake Michigan through Green Bay peninsula and along the northern shores of Lakes Michigan and Huron from Garden Peninsula to Drummond Island and into Cockburn and Manitoulin.
Islands, Ontario. The St. Ignace Peninsula, however, is composed of Monroe beds.

The Niagara in the Upper Peninsula is a massive limestone and dolomite formation with an average thickness of about 600 feet. The prevailing dip is lakeward from 40 to 60 feet per mile and this gives rise to low rocky shores with few deep harbors. Toward the interior the rock surface rises to considerable heights and the outer margin of the formation is marked by a prominent line of landward facing bluffs 100 to 200 feet high. The elevation of the interior and the lakeward dip of the rocks give rise to general artesian conditions along the lake shore. As a consequence much drilling for water has been done at several points but as water from limestones is nearly always very hard, some relatively deep drillings have been made in search of softer waters. These drillings, together with observations afforded by extensive outcrops, indicate that the Niagara contains very little bituminous matter and that in the Upper Peninsula it gives little promise of yielding oil and gas.

The Clinton, Rochester and Medina are doubtfully recognized in outcrops or in borings and can not be distinguished from each other. The Lorraine and the Utica are well represented and are easily recognized in drill holes. These shaly formations, being very soft, occur in a belt of depressions on the north side of the Niagara escarpment and outcrop in but few places. The Utica shale is exposed in the beds of streams on the east side of Whitefish river.

The Trenton limestone forms the western shore of Green Bay and Little Bay de Noc, turns eastward in Delta county, describing an arc through the Northern Peninsula, and crosses St. Mary’s river at St. Joseph Island into Ontario. Nowhere in the Northern Peninsula is the Trenton very deep, yet it offers certain oil and gas possibilities, for, aside from its bituminous and petroliferous character, it has a suitable cap rock, being overlain in most of the Peninsula by the impervious shales of the Utica and Lorraine.

The Trenton outcrops over a very large area and in general is under a very thin cover of drift in the vicinity of Rapid and Whitefish rivers. Wherever exposed, it shows signs of the former presence of oil and gas. The rock is bituminous and petroliferous and very frequently the cracks and fissures are found to contain dried oil residue or asphaltum "gum."

Comparatively little exploration has been done in the Upper Peninsula except for water. Thus far wells have been sunk at Marinette (Wisconsin), Menominee, Rapid River, Escanaba, Gladstone and Flat Rock, near Stonington, at Pickford, Neebish Island, and St. Ignace.

**THE WISCONSIN SECTION.**

**Milwaukee.** In order to show the relation of the eastern Wisconsin rocks to the Michigan Basin, the following log of the Lake Park well is given below. Comparing it with the western Michigan borings, it is to be observed that the formations in eastern Wisconsin are merely the western edges of the lower formations of the Michigan Basin. The dip from Milwaukee across Lake Michigan to Muskegon is rather flat, being only about 20 feet per mile. Farther north in the Northern Peninsula the dip toward the center of the Basin becomes much greater ranging from 40 to 60 feet, or even more per mile.

<table>
<thead>
<tr>
<th>Layer</th>
<th>Thickness (feet)</th>
<th>Depth, 1861</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hamilton (Traverse) Group:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Monroe beds</td>
<td>90</td>
<td>60</td>
</tr>
<tr>
<td>Saginaw</td>
<td>12</td>
<td>92</td>
</tr>
<tr>
<td>Delaware above</td>
<td>30</td>
<td>122</td>
</tr>
<tr>
<td>Waterline* Brown limestone</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Niagara limestone</td>
<td>30</td>
<td>152</td>
</tr>
<tr>
<td>Cincinnati shale (Medina to Utica)</td>
<td>120</td>
<td>470</td>
</tr>
<tr>
<td>Gladstone and Trenton limestone</td>
<td>380</td>
<td>958</td>
</tr>
<tr>
<td>St. Peters sandstone</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Potawatomi sandstone</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Marinette.** A number of wells were sunk in Marinette by the Hon. Isaac Stephenson, A. C. Merriman, and the city at the waterworks. The record of Mr. Stephenson’s well is incomplete, but the well apparently penetrated limestone and dolomite and a little light reddish sandstone, and a thin stratum of shale in the first 200 feet. A flow of water was struck in a crevice in the Calciferous (or the St. Peters) at 405 feet. At 410 feet, there was a large crevice, the tools dropping four feet and breaking the cable. The flow of water from this crevice was stronger and rose 21 feet above the surface. Below this point there was no increase in the amount of water though the well penetrated mainly lime rock until "granite" was struck at 716 feet. The granite, according to Lane, is probably a cherty or jaspilitic arkose quartzite which was struck in a later well drilled at the waterworks. 1

At Oakwood, three miles south of the city, it was claimed that a well reached a depth of 999 feet, but the samples at 860 (white sand) and at 920 feet do not resemble the Huronian rocks which should be struck at those depths. From a comparison with the records of other wells in the vicinity there seems to have been a mistake of 100 feet in the record.

A well two miles south of the Stephenson well was drilled in 1902-3 for oil and gas to the depth of 850 feet. This well may have reached the pre-Cambrian as red “sand,” similar to Huronian well samples from other wells, was struck at the bottom.

The first deep well drilled at the city water works was not completed as the tools were lost in the hole and could not be recovered. Another hole was drilled about 8 feet away and this struck the first hole at about 860 feet. Artesian water, struck above 860 feet in the second well, flowed out of the first after the intersection of the two. The tools were deflected on the old ones in the bottom of the first well and the hole was drilled to the depth of 978 feet, penetrating over 180 feet of Huronian rocks. The well yielded a little oil along with the water, but the oil...
probably came from the vugs or cavities in the limestone and not from the pre-Cambrian rocks as supposed by some. In the Rapid River well, Delta county, oil occurred in limestone in this way and at the same horizon.

**MENOMINEE COUNTY.**

**Menominee.** Several deep wells have been sunk in Menominee just across the river from Marinette. The records of all of the wells are incomplete and are of little value. A well drilled in 1895-6 at the residence of the Hon. S. M. Stephenson is reported to be 500 to 1000 feet deep. The water has a head of 15 feet and it is said to come mainly from sandstone, perhaps the Potsdam. A well on Mr. Stephenson's farm which, like the one at his residence, begins in the Trenton and perhaps reaches the pre-Cambrian. The water is hard, therefore it probably comes from limestone.

**DELTA COUNTY.**

**Escanaba.** In Delta county, there are several wells from 600 to nearly 1000 feet in depth. In 1890 the Escanaba Brewing Company drilled a well for soft water 730 feet in depth at Escanaba, but only a meager record was obtainable. The record below is given from memory by Nick Welch:

### ESCANABA BREWING COMPANY WELL

| Surface | 39
| Limonite | 150-160
| Sandstone | 500-600
| Struck, "open" at | 730

The Escanaba Manufacturing Company made a drilling to a depth of 972 feet for water, but no record was kept.

The Richter Brewing Company also drilled a well 810 feet and the record furnished by the brewmaster, Mr. Richter, is one from memory:

### RICHTER BREWING COMPANY WELL

<table>
<thead>
<tr>
<th>Elevation over 650 ft. A. T.</th>
<th>Feet</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pittsburg</td>
<td>9</td>
</tr>
<tr>
<td>Tufted shale</td>
<td>90</td>
</tr>
<tr>
<td>Potsdam</td>
<td>90</td>
</tr>
<tr>
<td>Graceful gray sand</td>
<td>44</td>
</tr>
<tr>
<td>Cardozo</td>
<td>16</td>
</tr>
<tr>
<td>Galesville</td>
<td>16</td>
</tr>
<tr>
<td>Trenton (undifferentiated)</td>
<td>10</td>
</tr>
<tr>
<td>Missouri gray</td>
<td>10</td>
</tr>
<tr>
<td>Rice Lake</td>
<td>10</td>
</tr>
<tr>
<td>Yellow</td>
<td>10</td>
</tr>
</tbody>
</table>

**Stonington.** A Wagner drilled two holes on his farm, three or four miles northeast of Stonington and, according to reports, the first was for coal and the second, a diamond drilling for iron. Mr. J. Wagner, present owner of the farm, furnished Mr. L. P. Barrett of the Survey with a record given from memory. A core was preserved but Mr. Barrett was not permitted to see this.

### A. WAGNER WELL

<table>
<thead>
<tr>
<th>Elevation over 650 ft. A. T.</th>
<th>Feet</th>
</tr>
</thead>
<tbody>
<tr>
<td>Potsdam</td>
<td>9</td>
</tr>
<tr>
<td>Raisin</td>
<td>20</td>
</tr>
<tr>
<td>Strone</td>
<td>20</td>
</tr>
<tr>
<td>Hocking</td>
<td>10</td>
</tr>
<tr>
<td>Delaware</td>
<td>10</td>
</tr>
</tbody>
</table>

**Gladstone.** The St. Paul and Ste. Marie railroad drilled a well for water at Gladstone, but the precise location is not given.

**Rapid River.** In the central part of Delta county, there are a number of water wells, mainly artesian, said to be from 250 to 900 feet in depth, as at Flat Rock, Lathrop, Maple Ridge, Parkins, Gladstone, and Rapid River. In some of the more northerly wells, it is only from 80 to
150 feet to the water bearing sandstones. At Rapid River, a dozen or more wells are supposed to be deep enough to go through the Trenton, which yields strong flows of water.

Seven miles north and two miles east of Rapid River, a well was drilled for oil. The set of samples taken for the Survey was stolen so that a very incomplete and perhaps inaccurate record can be given. The surface rock is the Trenton which apparently consists of about 300 feet of more or less oily and bituminous limestone. The rest of the well is largely in white sandstone, except at the bottom where decomposed schist of Huronian or Archean age was struck. There were strong flows of water, probably from the same horizons as in the Rapid River wells. A small quantity of oil was obtained in the Trenton. According to newspaper reports at the time, the flow, greatly exaggerated, was given as 400 barrels per day. The oil probably came from the vugs or cavities in the Trenton limestone rather than from the Archean rocks as was claimed at first.

The following record was made from scattered samples.

Rapid River well
Loc.: Two hundred paces W. 505 S. of N. E. Cor. of sec. 34, T. 42 N., R. 21 W.; 2 m. N. and 2 m. E. of Rapid River.

<table>
<thead>
<tr>
<th>Elevation 605 ft. A. T.</th>
<th>Thickness, feet</th>
<th>Depth, feet</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pleurocone or surface</td>
<td>13</td>
<td>13</td>
</tr>
<tr>
<td>Quick-burn</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Till (gray and brown)</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Sand and gravel</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Clay and limestone</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Total</td>
<td>13</td>
<td>13</td>
</tr>
</tbody>
</table>

Another well 1000 feet in depth was drilled a year or two later 7 miles northeast of Rapid River on the property of A. E. Neff. This record is more satisfactory than the foregoing one and shows that the pre-Cambrian is at comparatively shallow depths in the vicinity of Rapid River. The following record was compiled from samples.

Oil and Asphalt. In many places there is an asphaltic oil in the cavities of the Trenton limestone. The oil is a more or less semifluid, dark brown to almost black oil residue or asphaltic "gum." The "gum," according to Fr. Ruschaupt of Milwaukee, who made some analyses and tests, is odorless until heated and then gives an asphalt smell, foams at 185° F., fully liquefied at 200°, foams from 300° to 350°, slightly decomposes at 430° with an evolution of a small amount of empyreumatic matter and boils at 556°. After about one and a half hour's boiling the asphalnic gum thickens and the boiling point rises. Boiling the residue at 600° F. for three-quarters of an hour and then cooling to 70°, gave a hard tenaceous asphalt. There is no paraffin or petroleum in the distillate, asphalt being the only base. The results of two tests by Fr. Ruschaupt are given below:

<table>
<thead>
<tr>
<th>Analyses</th>
<th>No. 1. Percent</th>
<th>No. 2. Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distilled at 321° to 367° (mainly water).</td>
<td>25 ± 5</td>
<td>5.0 ± 0.5</td>
</tr>
<tr>
<td>Over 300° to 550° (mainly asphalt).</td>
<td>65 ± 2</td>
<td>45 ± 2.5</td>
</tr>
<tr>
<td>Balance crude or coagulation products.</td>
<td>10 ± 0.5</td>
<td>45 ± 2.5</td>
</tr>
</tbody>
</table>

Total: 100.00

Upon the supposition that a great pool of asphalt exists in a "synclinorium" in northern Michigan, a company was formed in Milwaukee to prospect for commercially important quantities but nothing came of the project. Oil might be found in quantity in the Trenton, especially in those regions where the formation is overlain by the Utica and Lorraine shales.

The wells of reliable record are so scattered in Delta county that there are no indications of favorable structures such as anticlines or benches. The general dip is southeasterly at from 40 to 50 feet per mile, but since no wells of accurate record on the opposite side of Lake Michigan reach any of the horizons represented in
the region under discussion, no exact calculations can be made.

**SCHOOLCRAFT COUNTY.**

**Manistique.** At Manistique, the flowing wells are from 200 to 800 feet in depth. At 800 feet in the Hiawatha House well, a flow was struck which lifted the drill head 30 to 40 feet and the water bearing stratum is in a "not hard, shell rock," probably the Trenton. The wells furnishing the municipal supply obtain their water from depths between 250 and 500 feet. The deepest well was drilled for salt but the tools were lost in the hole. The water is hard as it is from limestone. Possibly soft water could be obtained from the Potsdam, but the depth probably would be at least 1400 feet or much greater than at Escanaba.

In 1903 a number of new city wells were put down. Mr. Coleman, the driller, gave the following record:

**MANISTIQUE MUNICIPAL WELL.**

<table>
<thead>
<tr>
<th>Elevation 505 ft. A. T.</th>
<th>Thickness, feet</th>
<th>Depth, feet</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sand</td>
<td>21</td>
<td>2</td>
</tr>
<tr>
<td>Dolomite</td>
<td>15</td>
<td>5</td>
</tr>
<tr>
<td>Light dolomite</td>
<td>13</td>
<td>13</td>
</tr>
<tr>
<td>Bluestone dolomite</td>
<td>11</td>
<td>26</td>
</tr>
<tr>
<td>Bituminous dolomite</td>
<td>16</td>
<td>49</td>
</tr>
<tr>
<td>Baff crystalline dolomite</td>
<td>34</td>
<td>45</td>
</tr>
<tr>
<td>Light dolomite</td>
<td>16</td>
<td>63</td>
</tr>
<tr>
<td>Baff dolomite</td>
<td>7</td>
<td>70</td>
</tr>
<tr>
<td>Bituminous dolomite</td>
<td>7</td>
<td>80</td>
</tr>
<tr>
<td>This may be base of porosities, top of Byrum beds of Wisconsin, Remiinger's lower beds in Operator's No. 2 well.</td>
<td>10</td>
<td>225</td>
</tr>
<tr>
<td>White thin banded lithographic dolomite</td>
<td>10</td>
<td>225</td>
</tr>
<tr>
<td>Artic white limestone</td>
<td>15</td>
<td>240</td>
</tr>
</tbody>
</table>

All of the above wells are artesian and the flows are from the Niagara, with the exception of the Hiawatha House well, which probably obtains its flow from the Trenton. Usually, abundant water is found in the Niagara from 60 to 70 feet below the top as shown by other wells which penetrate this formation in Michigan and Ontario.

In the Manistique region, the Trenton, which is locally very porous, is overlain by the Utica, the Lorraine, and the Niagara, and, should favorable structures exist, oil and gas may occur in commercial quantities. The shallowness of most of the wells and the incomplete records of the deeper ones do not permit a close approximation of either the general or the local dip, and much less, a determination of the presence of local structures. From surface observations, however, the dip appears to be fully 40 feet per mile to the southeast.

**MACKINAC COUNTY.**

**St. Ignace.** In 1887, the Mackinac Lumber Co. drilled a well at St. Ignace to the depth of 919 feet. As the rocks on the St. Ignace peninsula are practically all of Monroe age, good water supplies are hard to obtain, the surface waters and those from bed rock being strong in sulphates. Plenty of good water, though hard, may be found in the Niagara. A cherty layer at the bottom of the well yielded some gas.

**ST. IGNACE WELL NO. 1.**

<table>
<thead>
<tr>
<th>Elevation above 606 ft. A. T.</th>
<th>Thickness, feet</th>
<th>Depth, feet</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surface</td>
<td>15</td>
<td>15</td>
</tr>
<tr>
<td>Marine formation</td>
<td>16</td>
<td>40</td>
</tr>
<tr>
<td>Red beds</td>
<td>25</td>
<td>120</td>
</tr>
<tr>
<td>Red and blue sandstone</td>
<td>30</td>
<td>230</td>
</tr>
<tr>
<td>Red and blue sandstone</td>
<td>30</td>
<td>230</td>
</tr>
<tr>
<td>White sandstone</td>
<td>30</td>
<td>230</td>
</tr>
<tr>
<td>White sandstone</td>
<td>30</td>
<td>230</td>
</tr>
<tr>
<td>White sandstone</td>
<td>30</td>
<td>230</td>
</tr>
<tr>
<td>White sandstone</td>
<td>30</td>
<td>230</td>
</tr>
<tr>
<td>White sandstone</td>
<td>30</td>
<td>230</td>
</tr>
</tbody>
</table>

**St. Ignace Well No. 2.** Well No. 2 at St. Ignace is about two miles north of the old well, 300 feet from Lake Huron, and only about 10 feet above lake level. A comparison of the two wells show that the beds dip rather steeply, the dip being over 40 feet per mile. Neither of these wells show the Medina, Lorraine, or Utica. The Lorraine and Utica are known to exist in the Upper Peninsula and from the Neebish well the total drop of the formations must be over 1200 feet in 30 miles, or over 40 feet per mile. If 500 feet is allowed for the thickness of the shaly beds, above the Trenton, the total drop would be over 1700 feet, which would be equal to a dip of about 55 feet per mile from Neebish southwest to St. Ignace. As the general dip is nearly south and not southwest, the maximum dip is probably 60 to 65 feet to the mile.

**CHIPPEWA COUNTY.**

**Neebish.** A well was drilled on St. Joseph's Island to the depth of 200 feet and, according to reports, it penetrated the Huronian without striking oil. No further details are known. On Neebish Island, near Sailor's Encampment and close to the water, a well over 527 feet in depth (563 feet according to the Michigan Miner), was...
drilled by A. W. Palmer for the American Alkali Company. It appears that the drilling began in the top of the Trenton, but if this is true the Trenton must be very thin.

Dr. Lane considers that the bottom of the well is in conglomeratic Potsdam and that the limestone is in part Trenton. The white sugary sandstone appears to be Calciferous, and, in that case, the St. Peter is absent as at Pickford. The top of the Potsdam is locally very similar to the St. Peters, and if the Calciferous is absent the two may be easily confused.

The record given below is chiefly that of the driller. Notes on the samples and the record are given in brackets. The correlations are by W. Alden of the U. S. Geological Survey.

**NEEBISH WELL**

**Loc.:** Near Saige's Encampment, Neebish Island, or across the west channel on the main, land opposite Tromby's and about 1000 ft. south of mouth of Tromby's about metric.

**Elevation about 507 ft. A. T.**

<table>
<thead>
<tr>
<th>Depth, feet</th>
<th>Thickness, feet</th>
</tr>
</thead>
<tbody>
<tr>
<td>51</td>
<td>51</td>
</tr>
<tr>
<td>93</td>
<td>93</td>
</tr>
</tbody>
</table>

**Trenton limestone**

- Limestone, hard
- Limestone, calcareous, soft
- Limestone, gritty, soft
- Limestone, flinty, 7 ft. 8 in. thick (111-38 light colored)

**St. Peter limestone**

- Limestone, hard (148-148 light colored)
- Limestone, soft
- Limestone, hard, next above, some sandstone
- Limestone, hard, calciferous, some sandstone
- Limestone, calciferous, calciferous, some sandstone
- Limestone, calciferous, some sandstone
- Clay, shale, sandstone, sandstone, sandstone
- Clay, shale, sandstone, sandstone, sandstone
- Clay, shale, sandstone, sandstone, sandstone
- Clay, shale, sandstone, sandstone, sandstone

**Formation**

- White sand rock
- Clay, shale, sandstone, sandstone, sandstone
- Clay, shale, sandstone, sandstone, sandstone
- Clay, shale, sandstone, sandstone, sandstone
- Clay, shale, sandstone, sandstone, sandstone
- Clay, shale, sandstone, sandstone, sandstone

**Surface**

- Clay, loam, sand

**Thickness**

- 51 feet
- 93 feet

**Depth**

- 1200 ft.

**FURTHER WELL**


**Elevation about 760 ft. A. T.**

<table>
<thead>
<tr>
<th>Depth, feet</th>
<th>Thickness, feet</th>
</tr>
</thead>
<tbody>
<tr>
<td>110</td>
<td>110</td>
</tr>
<tr>
<td>132</td>
<td>132</td>
</tr>
<tr>
<td>128</td>
<td>128</td>
</tr>
<tr>
<td>260</td>
<td>260</td>
</tr>
<tr>
<td>215</td>
<td>215</td>
</tr>
<tr>
<td>475</td>
<td>475</td>
</tr>
<tr>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>525</td>
<td>525</td>
</tr>
<tr>
<td>275</td>
<td>275</td>
</tr>
<tr>
<td>800</td>
<td>800</td>
</tr>
<tr>
<td>600</td>
<td>600</td>
</tr>
</tbody>
</table>

Concerning the interpretation and the correlations, Dr. Lane makes the following statements:

"Down to the top of the Trenton, the record is verified by samples and agrees perfectly with other holes; below that, it must be made out by statements from memory, and the only thing of which one can be reasonably sure is that it struck the red Potsdam above 1360 feet and probably at 800-900 feet and did not penetrate the Huronian. The most that can be said of the correlation above is that there is nothing known to make it impossible. The Neebish Island well shows that there is about 400 feet more between the Utica and the red sandstones there; at Wagner's well (near Stonington) there was 310 feet. And here, there is (525 to 800 or 900 ft.) 373 feet or less. This must then include the Trenton, St. Peters, Calciferous, and perhaps the upper white part of the Lake Superior sandstone, affiliated with the Calciferous.

The water at 600 feet is hard, a regular limestone water and does not suggest the St. Peters. There will hardly be less limestone than in the Neebish well and along St. Mary's river and it makes a conspicuous ridge to the north. The dip seems to be about 66 feet to the mile to the south and, with any such dip, the Trenton must be 200 feet or so thick, judging from the breadth of the outcrop. Not only that, but the Neebish well shows a good thickness (Alden thinks 112+ ft.) for the Utica does not show, and the Manitoulin Island wells also show 250 feet, which is assigned to the Trenton. It seems most likely that the Calciferous has been eroded and the St. Peters and Potsdam cannot be separated."

Assuming that the Niagara has its average thickness of 600 feet at Pickford, if it were not eroded, the dip of the Niagara, as calculated from its projected top toward the center of the Basin, would be about 50 feet per mile instead of 66 feet as suggested by Dr. Lane for the lower beds. As the Lorraine thins toward Cheboygan the dip would be greater for the Trenton. In any case, the dips of the strata in the Northern Peninsula are prevalingly greater than in the Southern.

**Pickford.** In 1906-1907, a deep well was drilled for oil at Pickford, Chippewa county. A heavy flow of water with a 25 foot head was struck somewhere below 1000 feet, probably about 1400 feet. There was some water between 500 and 800 feet, but it would rise to the top of the casing only on standing over night. Very little signs of oil and gas were struck anywhere, though an oily sandstone was encountered toward the bottom of the well. The record, compiled by Dr. Lane from a partial set of samples down to 1000 feet, is as follows:
MANITOULIN ISLAND, ONTARIO.

Gore Bay. In 1904-05, several oil wells were drilled on Manitoulin Island, and the record of one is given by M. J. L. Ward. Some oil was struck at 425 feet, about 85 feet below the top of the Trenton.

<table>
<thead>
<tr>
<th>Gore Bay Well.</th>
<th>Thickness, feet</th>
<th>Depth, feet</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pleistocene at drift</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Niagaran</td>
<td>40</td>
<td>40</td>
</tr>
<tr>
<td>Lower Carboniferous;</td>
<td>69</td>
<td>165</td>
</tr>
<tr>
<td>Upper Carboniferous;</td>
<td>1</td>
<td>150</td>
</tr>
<tr>
<td>Limestone;</td>
<td>29</td>
<td>166</td>
</tr>
<tr>
<td>Limestone;</td>
<td>1</td>
<td>156</td>
</tr>
<tr>
<td>Slate;</td>
<td>00</td>
<td>256</td>
</tr>
<tr>
<td>Coal;</td>
<td>60</td>
<td>216</td>
</tr>
<tr>
<td>The following;</td>
<td>15</td>
<td>381</td>
</tr>
<tr>
<td>Limestone;</td>
<td>15</td>
<td>381</td>
</tr>
<tr>
<td>Oil at 45 ft.</td>
<td>250</td>
<td>581</td>
</tr>
</tbody>
</table>

APPENDIX A. THE REGULATION OF DRILLINGS AND CARE OF DEEP BORINGS.

In all oil and gas fields a larger or smaller percent of the wells drilled are dry holes or holes with a yield which is too small for profitable operation. In "spotted" fields, such as in Randolph county, Indiana, 40 per cent of the wells may be dry. In many fields, such wells are abandoned without plugging with the result that water, which is generally encountered at one or more horizons, makes its way into the oil and gas sands with disastrous consequences. Sometimes the casings are left in the wells but this is only a temporary protection as the corrosive action of the brines or mineral waters generally will destroy ordinary casings in two to five years.

Most oil and gas bodies are surrounded by salt water but this water, known as "edge water" invades the reservoirs only as the oil and gas are withdrawn (providing these products are not withdrawn at too rapid a rate), so that a maximum recovery is possible. When water is introduced directly into the productive portion of a field through an uncased, or improperly cased well, the oil is forced back into the sand, so that pumping may produce nothing but water. As the sheet of advancing water reaches other wells, their production becomes partly, or entirely water, and the final result will be the ruin of the entire field.

In the older oil and gas fields of the country, little or no attention was given to abandoned and unplugged wells and the life of many pools has been greatly shortened or abruptly terminated by the flooding of the sands by water. In California, investigations by the State Mining Bureau has disclosed the fact that the productivity and life of many of the oil fields of that state are menaced by water from improperly cased and unplugged wells. Reports obtained from 41 per cent of all the wells in operation show that 25 per cent of these wells produce from 10 to 50 percent or over of water. Similar menacing conditions exist in most of the fields of the country, and had proper means and methods been used in the drilling and care of wells, these conditions could have been largely avoided.

Abandoned or improperly cased wells are not only a menace to productive wells in an oil and gas field, but they are a source of pollution to potable waters or valuable brines and mineral waters. Brines or mineralized waters from one horizon may invade another containing fresh water, or, vice versa, fresh water may find ingress to brine bearing or mineral water strata. In the first case, supplies of potable water, the most valuable of the natural resources, are destroyed and in the second, the quality of the brines or mineral waters is injured or ruined.

Along Saginaw river, most of the former supplies of fresh water in the surface deposits have been ruined through leakage from the abandoned salt wells unplugged or improperly plugged. In the vicinity of Grand Rapids, drillings for salt and gypsum have permitted the sulphate brines of the Michigan Series to percolate down into the underlying Marshall, and, locally, the former supplies of fresh water in this formation have been destroyed. As these old test holes and many others scattered over the State are still unplugged, the injury to valuable supplies of brine and fresh water grows greater from year to year. The above cases are not exceptional but are rather typical of conditions obtaining in many portions of the country.

Many oil and gas fields are located in coal fields, particularly is this the case in Pennsylvania, West Virginia, Ohio, Indiana, Illinois, Kansas and Oklahoma. Oil and gas wells penetrating workable coal seams or active mines add greatly to the hazards of mining on account of the danger of the escape of gas or oil into the mines with the consequent danger of explosion. The casings may be improperly placed, breached by the corrosive action of brine or mineral water, broken by the caving or subsidence of the overlying strata subsequent to the mining of the coal, or removed upon abandonment of the wells. In several instances, severe explosions of natural gas from this source have occurred in coal mines, and many others have been narrowly averted.

In Pennsylvania, there are over 50,000 oil and gas wells in coal territory, and it is estimated that 3000 new wells are drilled each year, 2000 of which are abandoned. Most of the latter are abandoned without being properly plugged or charted. Many of these though not producing commercial quantities of gas, yield enough to cause explosions and fires, if it were to leak into a mine. In some localities, the oil and gas wells are so numerous and close together that they not only seriously interfere with mining operations but cause much loss of coal through the large pillars which must be left to protect the wells. Owing to the close drilling and the number of unplugged and uncharted wells, the leases on certain coal properties in Pennsylvania have been surrendered on the ground that the estimated recovery of coal is too small and the hazards too great to pay for mining. In
addition to the danger from gas and the loss of coal noted above, water from unplugged and uncharted wells may flood the mine workings. This has happened in a number of cases. Water, under a head of 400 feet, broke into two mines in Illinois in 1912 and caused much trouble and expense before it was controlled.

Since many of the older oil and gas fields have been redrilled from one to three times and tens of thousands of holes are being drilled in coal territory, hitherto unprospected for oil and gas, the situation between the coal and the oil operators has become acute. A number of states have passed laws with the aim of protecting and conserving the oil and gas resources, but only in Ohio, Indiana, and Illinois have measures been enacted to protect the coal mines and coal reserves from the dangers of the promiscuous drilling of oil and gas wells. The laws, however, in all of these states are inadequate.

On the other hand, mining operations are a menace to the oil and gas wells. As noted previously, the slumping of the strata after the removal of the coal or other minerals may bend or break the casings and ruin some of the wells. The broken casings in the case of abandoned mines also permit the entrance of water to the sands with consequent injury to the field.

As a result of these conflicting interests, a bitter antagonism has grown up between the coal and the oil and gas operators. Manufacturing concerns utilizing brines and mineral waters also look with disfavor upon drillings which endanger the purity and strength of their supply of these substances.

It is most regrettable, that in the past the public at large has displayed only an apathetic interest in the conservation of the potable water supplies. Owing to the wave of agitation for the conservation of the natural resources, which has swept over the country during the past few years, strong efforts have been made in many states to secure adequate laws regulating the drilling and care of oil and gas wells or other deep borings, more particularly those for oil and gas. In certain states, opposition on the part of the oil and gas interests has been successful in defeating every attempt at securing much needed legislation on this subject. Oklahoma, California, Wyoming, Illinois, and a number of other states, however, have passed remedial and protective measures. Unfortunately, in some states, the measures are rendered almost nugatory through failure to provide for proper administrative machinery, sufficient funds, or adequate penalties for violations of the law.

In Pennsylvania and West Virginia, the law requires that abandoned wells must be plugged, but there is no competent executive officer to see that the requirements of the law are properly complied with. In Ohio, owners of wells must notify the Salt Mine Inspector ten days prior to the contemplated abandonment of a well so that, at his discretion, he may notify a district mine inspector to be present when the well is plugged. A man may be an efficient mine inspector but incompetent to supervise the plugging of an oil or gas well. Moreover, mine inspectors, beyond the protection of the coal mines have little interest in the protection of oil and gas sands or water and brine horizons. In the California laws, there is no provision for a central executive authority. The drilling and care of wells is left to the county well commissioner, who is appointed at the request of three or more oil companies operating in the country. The Indiana laws of 1903 require owners upon the abandonment of a well to plug the same according to certain specifications and file an affidavit signed by two witnesses, describing in detail the manner in which the well was plugged. Since the law does not require that the State Natural Gas Supervisor shall be notified, this official has no means of knowing when a well is to be plugged or when the law has been violated, except through information furnished by outside parties. "Fly-by-night" operators take advantage of this, "pull" their casings, and seek more promising fields in other states without plugging their wells.

In Wyoming, the laws prohibit the waste of oil or gas from a well beyond a limit of thirty days, specify the manner in which wells shall be plugged, and provide penalties and liabilities, but there is no central authority to enforce the provisions of the law. No legal action is taken except on the formal complaint of an interested party.

The Illinois statutes provide that all fresh water, during the drilling and after the completion of a well, shall be kept cased off from the oil and gas sands, in addition to the requirement that abandoned wells shall be plugged. The law fails of its purpose as there is no provision for adequate administrative machinery. The only protective measure in Michigan is a law requiring that, in Saginaw and Bay counties alone, salt wells shall be plugged upon abandonment. In short, in none of the states do the existing laws relative to the regulation of the drilling and care of oil and gas wells secure the desired ends.

In order to fully protect the rights of all parties concerned, a law regulating the drilling and care of oil and gas wells or other deep borings must provide for, (1) a competent administrative body having adequate executive powers, sufficient funds and trained assistants to properly carry out the provisions of the law; (2) definite methods of (a) casing and protecting wells through beds of coal, clay or other mineral deposits, and through horizons bearing valuable brine and mineral or potable water and, (b) of plugging wells, (3) the collection and filing of all information bearing on the geologic conditions, i. e.; the character, thickness, and depth of the various formations, the water and the oil and gas horizons, (4) the formal and accurate (a) location and recording and (b) the formal abandonment, plugging, and inspection of wells; (5) the coop ration of all parties concerned; and (6) adequate penalties and liabilities for infractions of the law and for damages.

The chief difficulties in framing a workable and satisfactory law regulating the drilling and care of oil and gas or other deep borings arises from the (1) conflicting interests and (2) the variety of conditions which may be
met. A law which will adequately protect the coal operator and minable coal beds may work undue hardship upon the oil and gas prospector. In some districts, there are several coal seams, some of which are of workable thickness under present conditions and others not. The term "workable" thickness is a relative one. Whether a coal bed is workable or not depends upon several factors besides that of mere thickness, viz., quality of coal, mining and labor conditions, nearness to markets, and competition. In Wales, veins of coal under 14 inches in thickness and in Missouri and Kansas beds 12 to 20 inches are operated at a profit, while in some coal fields no beds under four feet thick are being mined. With further exhaustion of the coal reserves, or with the development of new markets or cheaper methods of mining, some of the beds too thin to mine now may become workable.

The churn or percussion drill is generally used for oil and gas explorations, and, with this type of drill, it is very difficult to determine the exact thickness of coal beds and many drillers pass through workable beds without recognizing their presence. In Michigan, there are a dozen or more seams of coal, extremely variable in thickness and extent. Apparently only a few of the beds contain areas thick enough to be mined under present conditions, and these areas are very local. From this, it follows that there is no absolute way of distinguishing the different seams of coal, and it would be impossible in many cases to determine what seams should be protected. To require a driller to case off and protect each coal bed encountered would not only entail prohibitive expense, but it would be practically impossible in many cases on account of the size of the hole which would be required. The same may be said of the water and brine horizons, since, in some regions, there are a number of water or brine horizons, each yielding a water or brine differing in quality from any of the others.

The capping of oil and gas wells within a definite time limit to prevent waste may be very difficult or even impossible as in the case of the great oil wells in the eastern Mexico fields and the gas wells of Texas and Louisiana. It cost $3,000,000 to put out the fire and cap the great Dos Bocas well No. 2 near Tampico. In many instances the plugging of a gas well too small to be operated is very difficult especially where the rock pressure is very high, and it may cost several thousand dollars. To case off the salt water which occurs between the two productive oil sands in the Midway-Sunset field of California costs about $10,000 additional per well, yet it must be done to protect the oil sands.

The designation of a specific method for the casing and plugging of wells is unsatisfactory as no one method is adequate to meet the different conditions which may be encountered in different parts of a state, or even in the same field. A given method may secure the desired results in one case, but may fail of its purpose in another. Two or more efficacious methods, however, may be outlined to meet the conditions more commonly occurring, but certain discretionary powers as to what coal beds and water and brine horizons shall be protected, and what method and means are to be used in a particular case should be given the administrative official or body, but arbitrary power over the casing and plugging of wells should not be placed in the hands of a single individual.

One of the greatest difficulties in intelligently applying the remedial and protective measures of a law lies in the lack of an organized body of information concerning the character, thickness and depth of the (1) formations, (2) the oil and gas horizons and, (3) coal beds or deposits of other minerals and mineral substances having present or possible future value. In some fields where the sands are little disturbed, regular in thickness and character and continuous over large areas, the problem of drilling and caring for wells is comparatively simple, but in fields where the sands are numerous, variable in character, discontinuous and much disturbed, and where there are several water bearing strata, some of which lie between the productive sands, the problem demands the fullest knowledge of the geological conditions and taxes the ingenuity of the most highly trained geologist-engineer.

The usual penalties prescribed in the laws of the several states are nominal fines from $100.00 to $500.00, or both fines and imprisonment. In those states where the maximum fine is but $500.00 and the cost of repairing the casing of a well or of plugging a well is several thousand dollars the fine is ridiculously small in comparison. To obviate this difficulty some states have made the fine cumulative according to the length of time that the offender fails to comply with the requirements of the law.

For many years the drilling and care of oil and gas wells has been the subject of much study and investigation. During the past few years the United States Bureau of Mines has made an exhaustive study of this subject with special reference to the danger to life and property from drillings for oil and gas in coal territory. In order to secure information bearing on every aspect of the subject, the Bureau of Mines has been in the practice of conferring from time to time with students of the subject and representatives of all interests concerned. The information has been collected with the view of formulating and recommending changes in the present practices in the drilling and care of wells, and also changes in the state laws which might prove effective by being "both reasonable and enforceable." As a result of these separate conferences, a general conference was held February 7 and 8, 1913, between representatives of the coal operators, the oil and gas companies, the geological surveys of the various states, and the Bureau of Mines of the United States. At this conference, problems, arising particularly from the interrelations of oil and gas wells and coalmines, and tentative suggestions for the legal regulation of drillings in coal regions, were discussed at length. The tentative regulations were referred to a committee of twenty composed of three representatives from each of the interests: coal, natural
gas, petroleum, state geologists, state mine inspectors, and the Bureau of Mines, together with the president and secretary of the conference. This committee met on March 1 and 10 and made a revision of the proposed regulations which was presented to the general conference on March 11. The proposed regulations as drafted by this conference are in the form of an outline of desirable legislation, to be developed in proper legal form to meet the industrial needs of each state.

The essential features prescribed in the proposed regulations are six in number, viz:

(1) Accurate and formal location and recording of wells.
(2) Cooperation of the several parties interested to obtain a safe location.
(3) Designation of efficacious methods of casing and protecting wells through coal beds.
(4) Formal abandonment of wells.
(5) Safe methods of plugging wells.
(6) Adequate inspection.

The proposed measure placed the administrative power in the hands of a single individual, the Chief Well Inspector of the state, and this is one of the objections strongly urged against it. According to R. P. McLaughlin of the State Mining Bureau of California, experience has shown that the arbitrary power to order repairs or the abandonment of a well should not be wielded by a single individual. Other investigators hold that the control of drilling and plugging of wells should be in the hands of a commission composed of the State Geologist, the head of the State Mining Board or Inspector of Mines, and a third member chosen from the oil and gas operators. A second criticism refers to the framing of specific regulatory measures designed to protect coal mines and coal reserves without adequate protection of potable waters, valuable brines and mineral waters, deposits of clay, gypsum, limestone, shale, or other minerals or mineral substances. A third criticism may be made as to the lack of explicitness regarding the control of the chief inspector over the kind of geologic records to be kept of each drilling. This is most necessary to the intelligent application of the remedial and protective provisions of the law, and the information contained in a log made by the average driller is far from reliable. The Chief Well Inspector should have power to prescribe the kind of record to be kept and to demand, as circumstances warrant, sets of samples of the well drillings and samples of the waters and brines encountered.

In 1912-13, the Saginaw Development Company drilled a number of wells for oil in close proximity to the salt wells in Saginaw and the operators of salt blocks were alarmed lest these borings should be abandoned without being properly plugged. The law requires that only those wells drilled for salt in Saginaw and Bay counties alone must be plugged, hence the Development Company was not legally bound to plug their borings upon abandonment. The company, however, of their own accord plugged all their wells which were near enough to contaminate the brines utilized by the salt blocks along Saginaw river.

In order to protect the fresh and mineral water, brine, coal and other resources of Michigan from the danger of promiscuous drilling and of improperly cased and unplugged wells, an attempt was made during the session of the legislature of 1913 to pass a general law covering the subject of drilling and care of wells, but the bill was permitted to languish in committee. Later, the members from the Saginaw Valley districts introduced a bill to protect the salt industry of the State but this also failed of passage. Michigan has no law governing the drilling and care of deep borings, other than the salt wells in Saginaw and Bay counties.

APPENDIX B. BITUMINOUS OR OIL SHALES.

Before the great oil fields of the United States and Canada were discovered, the extraction of oil from bituminous or oil shales was an industry of considerable importance in the United States. Prior to the Civil War, there were 50 or 60 plants¹ in the United States distilling oil from shales and coals, high in volatile and liquid hydrocarbons. Some of the companies imported special kinds of coal but most of them used shale and coal from Pennsylvania, Ohio, Virginia, Kentucky, and Missouri. Twenty-five oil-shale plants were in Ohio and ten in western Pennsylvania, but most of the plants in the country were of small capacity and the greater number were hardly in operation before the discovery of the great oil fields of Pennsylvania and other states forced them out of business. The oil-shale industry was practically destroyed by 1865, but the operating companies in many cases saved themselves from ruin “by converting their oil factories into refineries, which was done with very little trouble.”

In Scotland², unsuccessful attempts to extract oil from coal and shale began more than a century ago, and in France the distillation of shale began even earlier. James Young discovered a process of distilling oil from bituminous and petroliferous substances and began the distilling or refining of petroleum found in a coal pit. Later he experimented with various coals and, finding Boghead coal or Torbanehill mineral suitable for distillation, began work on a commercial scale at Bathgate, 1850. The deposit of Boghead mineral was exhausted in 1862 and then the extensive deposits of bituminous shale west of Edinburgh were utilized. The Torbanehill mineral yielded from 116 to 125 gallons of

²Bull. No. 65, U. S. Bureau of Mines, Oil and Gas Wells through Workable Coal Beds, 1913
crude oil per ton, but the black shales only 40 to 45 gallons. The oil-shale industry was carried on for many years with varying success but, with improved methods of mining and distillation, and with more attention to the value of the by-products, especially ammonium sulphate, now much in demand as a fertilizer, and paraffin, the industry has become very profitable, some of the companies paying annual dividends of 50 per cent or more.

In 1904, the production of oil shale in Scotland was 2,709,840 tons yielding 63,000,000 gallons (Imperial) of crude oil and, in 1913 3,150,000 tons of shale were mined from which about 65,000,000 gallons (Imperial) of crude oil was obtained. From these figures it follows that the average yield of crude oil is from about 20 to 23 gallons (24 to 28 gal., U. S.) per ton. During the same years, the average amount of sulphate of ammonia produced per ton was from 35 to 40 pounds.

In Saxony, chiefly brown coal or an earthy lignite is used in the distillation of oil, and the industry, began more than half a century ago, has become very important. In 1880, the amount of lignite mined for the production of crude oil was over 9,000,000 tons but later statistics are not available. The oil-shale industry is carried on in a number of localities in New South Wales, which has some of the largest and most important deposits in the world. The material is called by different names, viz.: kerosene shale, torbanite or Boghead coal, cannel and parrot coal, etc. The yield of crude oil per ton from some grades is over 100 gallons.

Extensive deposits of bituminous and oil shales occur in eastern Canada, particularly in New Brunswick, Nova Scotia, and Quebec. The oil shales of New Brunswick are known as the Albert shales of the Perry formation of early Carboniferous age. The petroliferous character of these shales led to much fruitless drilling for oil and the high oil content of some of the bands of shale resulted in a thorough test being made under the direction of the Department of Mines of Canada to determine their commercial possibilities. Some 45 or 50 tons of material were sent to the Pumperston Oil Company near Uphall in Mid-Calder, Scotland and the shale, upon distillation, yielded about 48 gallons (U. S.) of crude oil and 77 pounds of ammonium sulphate per ton, or twice the average yield of oil and ammonia from the Scottish shales.

The value of oil-shale depends not only on the oil but also upon the ammonia content. The by-products, particularly ammonium sulphate and paraffin are the chief sources of profit. The failure of many of the early companies was due to the fact that they recovered the oil but not the ammonia. Investigations show, that, in general, as the content of oil decreases, the ammonia increases. From this fact, shales low in oil but high in ammonia can be made to yield a large profit and the low average yield of 20 gallons of oil per ton from the Scottish oil shales is due to the utilization of a greater amount of the “lean” oil-shales, high in ammonia. Some of the latter yield only 10 or 15 gallons of oil but from 60 to 70 pounds of ammonium sulphate.

The value of the crude-oil according to 1910 prices would be $0.025 per gallon and of the ammonium sulphate $0.29 per pound, therefore the value of the products of distillation, i. e., 48 gallons of oil and 77 pounds of ammonium sulphate would be $3.43 per ton. The cost of mining the shale is estimated at $1.00 per ton and the retorting of the shale and the manufacture of the sulphate $0.86, or a total of $1.86 per ton, giving a profit of $1.57 per ton, no allowance, however, being made for depreciation of plant and equipment and for interest on the capital invested. This profit may be materially increased through the refining of the crude oil itself, especially if it is rich in naphtha, burning oil, and paraffin.

The by-products resulting from the present methods of retorting and refining of oil shale are numerous and there is still much chance for improvement in methods and means of treatment. The latest types of retorts have greatly increased the recovery of ammonia from the shales. As stated previously, the average yield of ammonium sulphate for the past few years from the Scotland shales is from 35 to 40 pounds and, with the improved retorts, 60 to 70 pounds have been extracted from the same shales. The common products of manufacture and their principal uses are:

1. Permanent gases, mainly used for fuel.
2. Shale naphtha used for lighting and heating or power purposes.
3. Burning or lamp oils, especially adapted for continuous burning lamps.
4. Intermediate oils used for gas making.
5. Lubricating oils.
6. Solid paraffin, used for water proofing, insulation, and metal protection.
7. Still grease, used for grease making.
8. Still coke, used for fuel where smoke is undesirable.
9. Sulphate of ammonia, used chiefly as a fertilizer, especially for the growing of sugar beets. With the exhaustion of the guano deposits of south America and the impending exhaustion of the nitrate beds of Chile, ammonium sulphate is becoming of great importance as a fertilizer, especially as it contains about 20 per cent of nitrogen, or 4 per cent more than nitrate of soda.
10. Liquid fuel -- the acid and basic tars together with the dregs and other residues are generally used as liquid fuels in the stills. These tars with further refining would probably yield a number of tar products.
11. The oil from some shale yields vaseline, but this substance is not contained in the Scottish oil shales.
12. "Spent" shale. The shale after it has passed through the retort may be used in the manufacture of Portland cement, brick, and road metal.
The future value of the bituminous or oil-shale deposits has been recognized by the British Government and, according to reports, the British Admiralty has purchased a large tract of oil shale in New Brunswick to be held as a reserve for supplying the British navy with fuel oil when the present sources are exhausted. Recognizing that the present and growing demands made upon the oil fields of the continent must sooner or later exceed their capacity of production, the U. S. Geological Survey has made an investigation of the oil shales of Utah and Colorado to determine their possibilities as a future source of oil. The results of this investigation will be issued as a bulletin, which is now in press. According to the Press Bulletin of the Survey of January, 1914, the tests and analyses of the oil shales of these states show that they contain from 10 to 61 gallons of oil per ton with a probable average of a barrel per ton for the better grades. This is practically two and one-half times the average yield from the Scottish shales and compares favorably with the better grades of shales of New Brunswick. Apparently, the investigations did not extend to the nitrogen content of the shales which, as previously mentioned, is of the utmost importance in exploiting oil-shales on a commercial basis since much of the profit comes from the ammonium sulphate, the coming substitute for the guano of South America and the sodium nitrate of Chile.

In Michigan, there are a number of formations containing bituminous or oil bearing shales. The Antrim shale, 300 to over 480 feet in thickness, locally is composed almost entirely of black bituminous shales. In certain parts of the State, however, it contains much light colored shale. In Alpena and Charlevoix counties, this formation is easily accessible as it outcrops at a number of points and is under a light cover of drift in many localities. Even where the drift is of considerable thickness, as in southeastern Michigan, the shales could be easily mined for the formation generally contains little or no water.

In the Northern Peninsula the Utica black shale is about 50 feet thick and outcrops, or lies beneath a thin cover of drift in many places on the east side of Whitefish river, Delta county. In the Southern Peninsula, the formation is thicker, but is too deep to have economic possibilities. From 1851 to 1861, near Collingwood, Ontario, the Utica shales were used for the distillation of oil with fair success until the discovery of the Petrolia oil field.

Numerous black shales also occur in the Coal Measures associated with the coal beds. Some of the coal seams are too thin or of too low grade for profitable mining, but it is possible that the coal, usually high in volatile matter, and the black shales, or the bone, cannel, and "blackjack" coals could be mined together for their oil and ammonia content and made to yield a substantial profit. Certain parties from New York investigated the Michigan coals last year with the view of establishing a coal and shale oil plant and reported that some of the coals high in volatile matter were very suitable for the manufacture of oil and ammonium sulphate, but as yet nothing has come of the project.

The amount of oil or bituminous matter recoverable as oil in the sediments is many times that contained in the accumulations known as pools, and, in contrast to the latter, the amount of oil in a given area of bituminous shale can be estimated within close limits. The average yield of oil from the better grades of Colorado and Utah black shales is estimated at 53 gallons per ton or about 71.5 gallons per cubic yard. A square mile of such shale three feet thick would yield over 1,800,000 barrels of oil, and 300 feet thick 180,000,000 barrels, or more than 75 per cent of the total production in the United States for 1913.

If the oil is present in amounts of only one per cent, a square mile of rock 300 feet thick would contain 15,000,000 barrels of oil. While no extended tests and analyses have been made on the Antrim shales to determine their average oil content, the two analyses given below indicate that locally the content of oil is about 6 per cent, equivalent to at least 90,000,000 barrels per square mile, 300 feet thick. In any case, the amount of oil in the Antrim shale alone forms a reserve practically inexhaustible which can be drawn with the exhaustion of the oil fields of the country.

**ANALYSIS ANTRIM SHALE.**

Sample from a depth between 1575 and 1700 feet in the No. 2 Assyria well, Barry county. Analysis by a student under the direction of M. A. Cobb, laboratory of Lansing High School, October 22, 1903.

<table>
<thead>
<tr>
<th>Percent.</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Moisture</td>
<td>6.595</td>
</tr>
<tr>
<td>Volatile carbon</td>
<td>6.025</td>
</tr>
<tr>
<td>Fixed carbon</td>
<td>3.95</td>
</tr>
<tr>
<td>Ash</td>
<td>83.435</td>
</tr>
<tr>
<td>Total</td>
<td>100.00</td>
</tr>
</tbody>
</table>

**ANTRIM SHALE.**

Sample from near Alpena, Analyst, W. H. Johnson, Alpena.

<table>
<thead>
<tr>
<th>Percent.</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Volatile matter (water between 5 and 10 percent)</td>
<td>17.96</td>
</tr>
<tr>
<td>Fixed carbon</td>
<td>6.49</td>
</tr>
<tr>
<td>Ash</td>
<td>75.55</td>
</tr>
<tr>
<td>Total</td>
<td>100.00</td>
</tr>
</tbody>
</table>

While there are no satisfactory analyses showing the oil content of the Utica shale, the table of analyses taken from a report on the geology of Wisconsin shows the bituminous character of the shale.

<table>
<thead>
<tr>
<th>Clay and sand</th>
<th>I.</th>
<th>II.</th>
<th>III.</th>
<th>IV.</th>
<th>V.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>38.45</td>
<td>34.60</td>
<td>37.26</td>
<td>48.27</td>
<td>73.57</td>
</tr>
</tbody>
</table>
No I is a brownish black, very fine grained rock from Cape Smith Lake Huron.

No II from an island to the north of Maple Cape, Lake Huron and is blackish-brown, fine grained, and of earthy texture, with a laminated structure, and contains no fossils.

No. III from St. Anne, Montmorency, is a dark brown shale, and contains graptolites.

No. IV is from Gloucester, near Ottawa, and is a black shale filled with fragments of trilobites and crinoids. In these analyses, the carbonates of lime and magnesia, with the alumina and oxide of iron were removed by solution in acids, and the elements of the organic matter were determined in the insoluble portion.

No. V is that of a pyroclast from this formation in the lead region of Wisconsin.

Dr. T. S. Hunt's account of the attempt to exploit the Utica shale for oil in the vicinity of Collingwood, Ontario, gives a general idea of its possibilities as a source of oil.

"These shales contain very variable amounts of combustible matter, and they give when distilled, besides inflammable gases, portions of oily matter, which in the shales of Collingwood, the richest yet examined, are equal to 4 or 5 per cent. Though the final results of the retorting of these shales are not now available the following details of operations at this place may be given (Geol. Can. 1863, p. 784):

In 1859, works for obtaining these oils were erected on the locality of this shale, near the town of Collingwood. Twenty-four longitudinal cast-iron retorts were set in two ranges, and heated by wood, of which 25 cords are said to have been required weekly. The shale, broken into small fragments, was heated for two or three hours, from eight to ten charges being distilled in 24 hours. In this way, it is said from thirty to thirty-six tons of shale were distilled daily, and made to yield 250 gallons crude oil, corresponding to about three per cent of the rock. By a further continuance of the heat, a small additional proportion of oil was obtained from the shale; but it was found more economical to withdraw the charge after 2½ hours. The bed of shale available for the purpose adjoins the works, and was furnished, ready broken, at twenty-cents per ton. The cost of the crude oil from the shale was stated by the manufacturers to be fourteen cents per gallon. When rectified and deodorized, it gave from 40 to 50 per cent of burning oil, and from 20 to 25 per cent of pitch and waste, the remainder being a heavy oil fitted for lubricating purposes. After two or three unsuccessful trials, and the repeated destruction of the works by fire, they were at last, in 1860, got into successful operation, and a ready market was found for the oils. Data, however, is wanting to show whether the enterprise was remunerative; and it was after some time abandoned, partly, it is probable, on account of the competition of the petroleum of Enniskillen, which was about that time brought into the market in large quantities, and at a very low price. Should it, however, at any time be found advantageous to renew the experiment of distilling the bituminous shales of this formation, those of Collingwood offer very favorable conditions, from their accessibility, and also for the ready means of transport afforded both by the lake and the railway."

The following tables largely taken and adapted from the Joint Report of Mines and Survey Branches Nos. 55 and 1107 illustrate the difference in the analysis in the yield of crude oil and ammonium sulphate from various oil shales and oil coals.

<table>
<thead>
<tr>
<th></th>
<th>Moisture</th>
<th>Volatile Hydrogen</th>
<th>Fixed Carbon</th>
<th>Ash</th>
</tr>
</thead>
<tbody>
<tr>
<td>Torbanite, Scotland</td>
<td>71.17</td>
<td>7.95</td>
<td>21.18</td>
<td></td>
</tr>
<tr>
<td>Albertite, N. B.</td>
<td>64.39</td>
<td>46.44</td>
<td>8.17</td>
<td></td>
</tr>
<tr>
<td>Guadalupian oil-shale, N. S. Wolfe</td>
<td>60.37</td>
<td>52.16</td>
<td>7.58</td>
<td></td>
</tr>
<tr>
<td>New Renfrew bitumite</td>
<td>66.50</td>
<td>50.12</td>
<td>8.26</td>
<td></td>
</tr>
<tr>
<td>Kentucky Cannel Coal</td>
<td>66.13</td>
<td>52.12</td>
<td>8.45</td>
<td></td>
</tr>
<tr>
<td>Chattanooga, New York</td>
<td>63.45</td>
<td>50.25</td>
<td>9.85</td>
<td></td>
</tr>
<tr>
<td>Antion shale, Barre Co.</td>
<td>63.24</td>
<td>50.10</td>
<td>11.87</td>
<td></td>
</tr>
<tr>
<td>&quot;Cumberland&quot; Ace Co</td>
<td>63.05</td>
<td>50.30</td>
<td>11.87</td>
<td></td>
</tr>
<tr>
<td>W. Charleston, Sartigue Co</td>
<td>63.15</td>
<td>50.30</td>
<td>11.87</td>
<td></td>
</tr>
<tr>
<td>English Cannel, Wigan</td>
<td>63.27</td>
<td>49.64</td>
<td>15.87</td>
<td></td>
</tr>
</tbody>
</table>

The figures given in the table below refer to the U. S. wine gallons and are the approximate equivalents of the figures given in the above report which refer to the Imperial English gallon.

<table>
<thead>
<tr>
<th>Crude oil</th>
<th>Ammonium sulphate, pounds.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Geo. Irving seam, N. B. (shale retorted in Scotland)</td>
<td>48</td>
</tr>
<tr>
<td>Albertine, N. B. (shale retorted in Scotland)</td>
<td>48</td>
</tr>
<tr>
<td>Eel River seam, N. B.</td>
<td>48</td>
</tr>
<tr>
<td>South Bend seam, N. B.</td>
<td>48</td>
</tr>
<tr>
<td>Torbanite, Scotland</td>
<td>48</td>
</tr>
<tr>
<td>Eel River seam, Scotts.</td>
<td>48</td>
</tr>
<tr>
<td>South Bend seam, Scotts.</td>
<td>48</td>
</tr>
</tbody>
</table>

In conclusion it may be stated that Michigan has an abundance of oil-shale and oil-coal which, with the increasing demand upon the oil fields of the country, probably exceeding their capacity of production within a very short time, and with the exhaustion of South American guano and nitrate deposits, will become of very great economic importance as a source of oil and ammonium sulphate.
BOARD OF GEOLOGICAL AND BIOLOGICAL SURVEY,
1912.

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