PROGRESS REPORT NUMBER TWO

STATE OF MICHIGAN

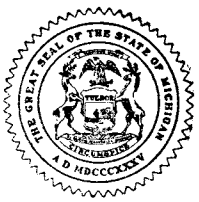
DEPARTMENT OF CONSERVATION
P. J. HOFFMASTER, Director

GEOLOGICAL SURVEY DIVISION
R. A. SMITH, State Geologist

Geology of Ogemaw County and West Branch Oil Field

By

E. A. NEWMAN
Petroleum Geologist



August, 1936

GEOLOGY OF OGEMAW COUNTY AND THE WEST BRANCH OIL FIELD

By E. A. Newman*

Introduction

Ogemaw County has become of especial geological and economic interest due to the discovery and development of the West Branch Oil Field. Exploratory work in search for oil has shown new structural trends and sufficient information relative to glacial and structural features has been obtained to make possible a progress report of the County.

Surface Geology and Physiography

Geologically Ogemaw County covers a part of a segment of the northeast rim of the Michigan Basin but the bed rocks of the area are almost wholly covered by a thick mantle of glacial drift, there being but three discovered rock exposures. The irregular deposition of the drift gives the County a rolling or hilly to undulating surface.

During the last ice invasion the region of Ogemaw County was covered by the Saginaw ice-lobe of the continental glacier which moved slowly southwestward along the axis of Saginaw Bay. Accumulation of ice on the cap of the lobe caused a pressure-differential movement of the sides of the lobe or northwestward in this region. Advance and retreat of the ice developed hilly belts or moraines along the edge of the lobe which therefore north of Saginaw Bay have a general northeast-southwest direction. The high moraine (Plate 1) in the western and northern part of the County is part of an outstanding topographic feature in the Saginaw Basin - the West Branch moraine. From its position along the front of the ice in Isabella County, the moraine extends diagonally northeast bisecting Clare County, across the southwestern corner of Roscommon County to the northeastern corner of Ogemaw County where it swings north-northwest roughly in the form of a question mark into Oscoda County paralleling the Au Sable River. The moraine has a width of from three to six miles; changes in elevation are great and rapid, as much as 200 feet in a square mile.[1] Elevations on the moraine range from one thousand to over fourteen hundred feet. This moraine provides the artesian head for numerous water wells in the vicinity of West Branch, Rose City and Edwards.

The gently rolling area west of the moraine is an outwash plain of sand and gravel laid down by water issuing from the ice front. A rather narrow plain extends from Lupton through Rose City southwestward to West Branch and Edwards. This is a till plain or ground moraine made of loamy material laid down under the ice sheet during a stage of its retreat.

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*Assistant Petroleum Geologist, Geol. Survey Division, Dept. of Conservation

[1] Frank Leverett; Report on the Geology of Ogemaw County, Michigan, 1925

The gently rolling belt in the eastern part of the County is the northern end of the Port Huron moraine and is less prominent than the West Branch moraine and has a more or less north to south direction. The change in morainic trend is apparently due to a retreat of the Saginaw ice-lobe along its main axial movement followed by a minor advance. The eastern moraine is hemmed in by an outwash plain on the west and bordered by the till plain on the east.

A broad flat area extends from West Branch southward and southeastward interrupted only by minor broken moraines. This flat area is sandy material laid down on the borders of glacial lakes that were formed by the damming effect of the Saginaw ice lobe. The lowest elevation on this plain is found at 700 feet above sea level in the valley of the Rifle River at the south line of the County. Variation in elevation from this low plain to the highest points on the western moraine is therefore over 700 feet - from 700 feet above sea level in Mills township to over 1400 feet in Foster and Klacking townships.

Thickness of the glacial drift varies from nothing in the bed of the Rifle River where bed rock is exposed, to over 500 feet in the West Branch moraine.

Before the discovery of oil the glacial drift was an important economic natural resource of the County. The moraines are a source of gravel and furnish an artesian head for the artesian wells of the County and also provide water for other wells and for the clear cold streams and lakes which head in or obtain water from the moraines and drift. Rather extensive beds of bog lime (marl) are located at Edwards Lake, Chatham Lake, De Voe Lake, and North Lake.[1] The marl was originally limy material in the drift; surface waters leached out the lime carbonate, carried it to the lakes where it was precipitated and deposited by action of the warmer water and the alga chara.

Three important rivers flow through the County, the Tittabawassee, Rifle and Au Gres. The immediate courses of the streams are influenced by the moraines which are the drainage divides. All three rivers drain southward into Saginaw Bay. It is interesting to note that at one time when its course was blocked by ice as described by Leverett, the Rifle River drained into the Tittabawassee by way of the low area north of Greenwood in Horton township.

Areal Geology

Areal geology in contrast to surface geology in a drift covered area describes the rock surface which would be exposed if the drift were removed. In the following discussion therefore the bed rocks are referred to as if they were not buried under the clay, sand and boulders that were laid down by the ice sheet.

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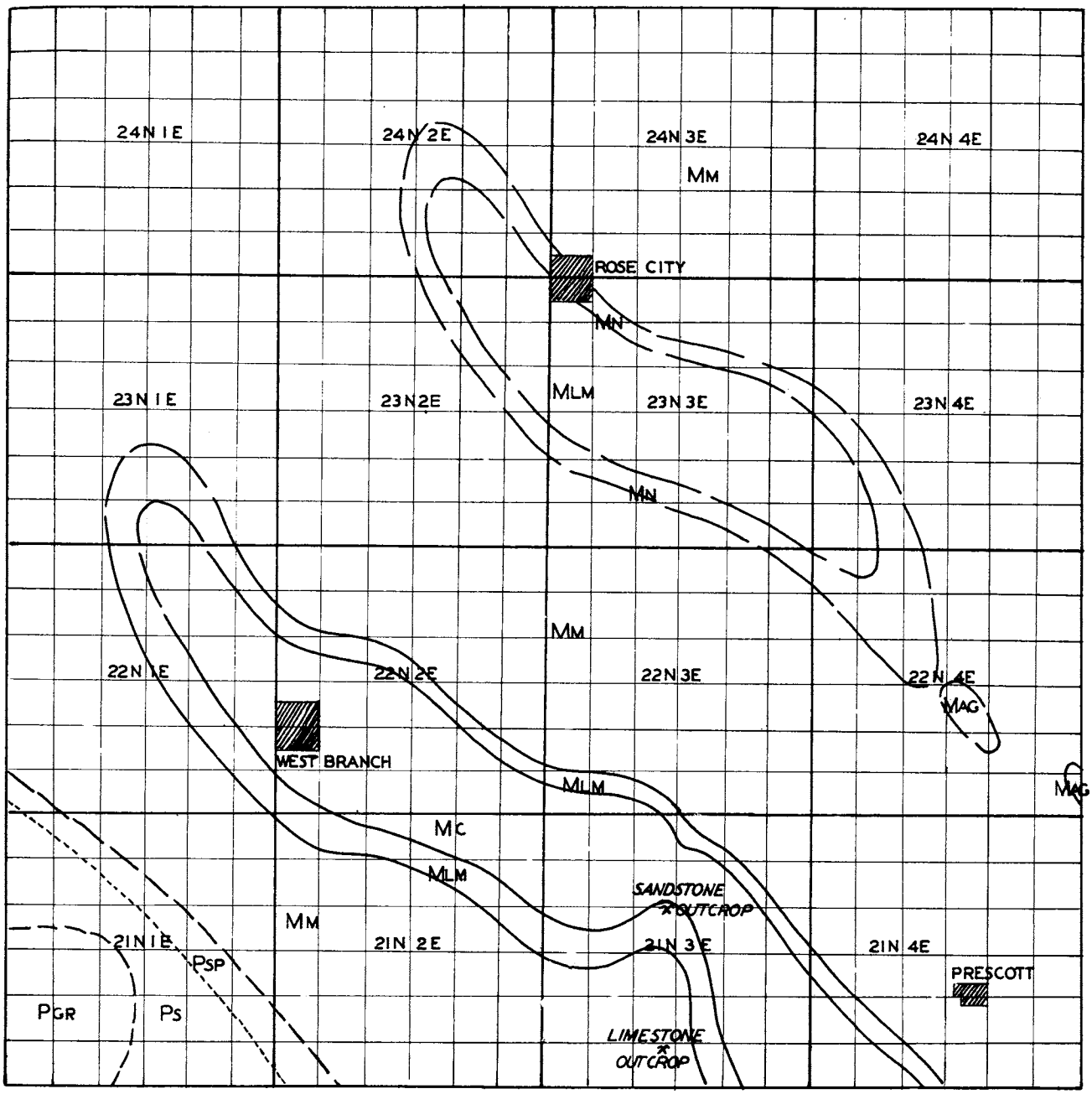
[1] L. R. Schoenman - Peat and Marl, Surface Geology of Ogemaw County, Mich. 1925



MAP OF OGEMAW COUNTY

SHOWING

AREAL GEOLOGY

AFTER HELEN M. MARTIN

SCALE

0 1MI. 2 3

LEGEND

PENNSYLVANIAN

PGR- GRAND RIVER GROUP
PS - SAGINAW GROUP
PSP- PARMA FORMATION

MISSISSIPPIAN

MAG- AUGRES (BAYPORT) LIMESTONE
MM - MICHIGAN FORMATION
MN - NAPOLEON FORMATION
MLM- LOWER MARSHALL FORMATION
MC - COLDWATER FORMATION

PLATE 2

The outcropping bed rocks of the County (Plate 2) are of Pennsylvanian and Mississippian age. Pennsylvanian rocks outcrop in the southwestern corner of the County and successively older rocks are found northeastward across the County. In the southwestern corner of Edwards Township are fifty or more feet of red shales and sandstones of the Grand River Group (Pennsylvanian). However the upper shales may be of the so-called "Red Beds" or "Permo-Carboniferous". Below the Grand River and outcropping farther northeast are the white and light gray micaceous sandstones of the Saginaw formation with the characteristic dark gray shale at the base. The Saginaw formation is about 100 feet thick. The contact between the Saginaw and Grand River almost bisects Edwards Township from the southeast to the northwest corners. Below the black shale is the Parma sandstone 100 feet thick, a hard gray to white quartzose sandstone, conglomeratic at the top, outcropping in a band diagonally northwest southeast across the township.

Rocks of Mississippian age cover the rest of the county. The highest or youngest in the series is the Bayport or Au Gres limestone which is in scattered outcrops of small areal extent. Below are the [illegible] sandstones, limestones, gypsum beds and limestone "shells" of the [illegible] each a combined thickness of

Errata

Page 3, paragraph 1, line 11, change Grand River to Parma
Page 4, paragraph 3, line 6, change North Creek to North Eddy Creek.

will be more fully described in [illegible]
ure.

It was long supposed that in crossing Ogemaw County from southwest to northeast successively older rocks would be traversed. However drilling has shown that this is not the attitude of the Mississippian rocks. Reference to the map of the areal geology (Plate 2) and to the cross section (Plate 4) will show that the older Coldwater shale surrounded by Marshall sandstone outcrops through the younger Michigan formation in Ogemaw, West Branch, Horton and Mills Townships and that the Napoleon and Marshall outcrop through the younger Michigan in Cummings, Klacking and Foster townships, which is evidence either that the younger formations were deposited around hills of the older formations or more probably that all were uplifted in folds and the younger formations eroded from the tops of the hills thus causing outcrops of older rocks surrounded by rocks of a later age.

Actual exposures of the bed rocks of the county are found in the bed of the Rifle River. Gregory[1] reported an outcrop of sandstone in the bed of the Rifle at the bridge over the river on the south line of section 9, Mills Township. The sandstone is exposed for about a third

[1] W. M. Gregory - Preliminary Report of Arenac County. Annual Report 1901 Mich. Geol. Survey

of a mile and is greenish gray in color, cross bedded and weathered. The strike of the ledge is northwest and the apparent dip to the southwest. Rominger[1] described a sandstone outcropping in the Rifle River in Section 16 Mills Township, "The rock is coarse grained, whitish or greenish, with ferruginous spots, moderately soft and irregularly stratified in discordant bedding....The strata dip southward....." These sandstones are correlated with the Marshall sandstones. Farther south along the south line of Section 28 in the bed of the Rifle River a dark calcareous rock underlying 6-8 feet of crystalline dark gray limestone is exposed. Some geologists correlate the upper limestone bed as Bayport or Au Gres and others place it lower in the Michigan formation.

Relationship of Glacial Features to Subsurface Structure

Surface geology in an area of glacial drift often reflects subsurface structural conditions. Information accumulated from completed wells seems to show a more or less definite relationship between surface features and subsurface structure in Ogemaw, a relationship too close to be merely coincidental. Land surface features that existed prior to the ice invasions must have influenced ice movements, and the resultant deposition of moraines, till plains, and the formation of stream and lake patterns. Had there been but one ice invasion, surface expression would have been more pronounced, but repeated ice movements tended to obliterate features left after earlier invasions. Comparison of the surface, areal, and structure maps shows the close relationship of structural and surface features in the County.

The areal map (Plate 2) and the structure map (Plate 3) show a marked structural development on the Marshall sandstone. The Coldwater shale outcropping under the glacial drift in Ogemaw, West Branch and Mills townships is bordered by an escarpment of Marshall sandstone. The surface map (Plate 1) shows that the West Branch of the Rifle River and North Creek appear to follow the Marshall escarpment from Ogemaw Township southeastward into Mills Township. North of the structure the drainage pattern becomes haphazard as it is more influenced by increasing altitude towards the moraine than by underlying structural conditions. The main Rifle River swings to the southeast in Section 23, Churchill Township, conforming to the projected escarpment of the Marshall sandstone. In the central part of Mills Township the river crosses the anticline above a saddle in the underlying structure. It is interesting to note also that the glacial course of the Rifle River into the Tittabawassee follows the structural syncline south of the West Branch structure.

There is a decided break in the moraine northwest of West Branch. There the Marshall escarpment and the structural dip may have influenced the ice movement and thereby provided the drainage channel

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[1]Rominger, C., Mich. Geol. Sur. Vol. III, 1876

for the West Branch of the Rifle River. Structural conditions evidently affected deposition of the drift also, as the drift thickens down dip on both slopes of the West Branch structure.

Since glaciation, the northern part of North America has been slowly rising, not in an even rise, but up-canted like a trap door, developing lines of uplift known as "hinge lines". In the areas of drift north of the hinge line it is reasonable to assume that pre-existing structural folds have been to some degree intensified by the uplift. Uplift must also have caused some adjustment in the unconsolidated drift overlying the structures. Thus the uplift would be reflected in the drainage pattern and so further accentuate the surface expression of buried structure. The marked parallelism of the "hinge lines" with the axes of the known structural trends may indicate some relationship between the "springing back" effect of regional uplift on structure. Regional uplift continues at the present time and probably exerts some influence on accumulation of deeper brines as well as the development of surface waters and possibly on the accumulation of petroleum, especially where terrace like structures are involved.

Relationship between surface expression and structural conditions becomes more apparent as drilling operations reveal the various structures, but it is not yet established that surface conditions may be depended upon to correctly interpret subsurface structures. For this reason, surface criteria must remain of secondary importance but useful as clues in connection with more accurate exploratory methods. Numerous examples of surface expression of subsurface conditions have been cited by Newcombeand Lindberg.[1]

THE WEST BRANCH OIL FIELD

Although at the present time it is of lesser importance than other Michigan oil fields in the production of petroleum, the West Branch field is of geological interest and is important in the search for more buried folds of similar type, and the development of the industry outside the central basin. The field is approximately nine miles long and three fourths to one mile wide, with the trend northwest-southeast. The northwest limit of production has not been reached. (August 1936).

The city of West Branch is located upon the productive structure and has many producing wells within its corporate limits. It is the focal point for oil and gas development. Excellent highways and one railroad serve the area. Two pipe line systems take the crude oil from the gathering lines to loading racks on the Michigan Central Railroad. A small refinery is now in operation near the southeast city limit.

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[1]Newcombe, R. B., and Lindberg, Geo. D., Glacial Expression of Structural Features in Michigan; Bull. A.A.P.G. Vol. 19, No. 8, August 1935.

History and Development

The sandstone ledges outcropping in the bed of the Rifle River in Sections 9 and 16 and at the old bridge over the Rifle on the section line of sections 9 and 16 aroused considerable interest and curiosity as to the age of the sandstone. Rominger, who first reported the sandstone placed it in his Waverly group - later known as Marshall. On the State geological map this outcropping was found to be within the younger Michigan formation. This outcropping of an older formation within the areal limits of a younger, gave the first hint that structure as well as river erosion had brought the older rocks to the surface. The outcrop of the Marshall is so far from Mills Township and the slope of the rock into the Michigan Basin such, that normally, the Marshall could be expected far below the surface in Mills Township. Therefore as it is at the surface, it must have been lifted from its projected depth by some structural condition - either a structural fold or a fault.

Acting on this hint, the Pure Oil Company began a test well drilling campaign under the direction of their district geologist, W. A. Thomas. Numerous test wells were drilled, the structural idea confirmed and the structure was fairly defined. A geophysical survey checked and more or less confirmed the findings of the test well exploration.

In 1932 after several years of exploration and leasing activity the Pure Oil Company drilled their first deep well, the W. T. Yeo #1, the record of which follows:

Horton (Ogemaw County)

The Pure Oil Company

William T. Yeo #1 Permit #1246

Drilling Contractor: Hagan and Hagan

Location: NE¼ of NE¼ of NE¼ of Section 2, T. 21 N., R. 2 E. 330 feet from north and 330 feet from east line of quarter section.

Elevation: 832 feet above sea level.

Record by: L.W.Price from driller's log.

	Thickness (Feet)	Depth (Feet)
Pleistocene:		
Drift deposits:		
No record	135	135
Mississippian:		
Coldwater:		
Shale, blue (oil show at 437)	302	437
Sandstone, broken	13	450
Shale, sandy	60	510

	Thickness (Feet)	Depth (Feet)
Coldwater, continued		
Limestone, gritty	40	550
Sandstone, broken; shale	100	650
Sandstone, broken (water at 605)	60	710
Shale, sandy	250	960
Limestone "shells"; shale, white	55	1015
Shale, gritty	79	1094
Shale, red	14	1108
Shale, gritty	38	1146
Sandstone (?), black (Sunbury)	21	1167
Berea-Bedford (Undivided):		
Sandstone	13	1180
Shaly rock (oil and gas at 1171)	8	1188
Sandstone, broken	5	1193
Sandstone, shaly and broken	56	1249
Shale, dark	25	1274
Devonian:		
Antrim:		
Shale, dark	6	1280
Shale, brown	181	1461
Limestone, hard	60	1521
Limestone, dark	29	1550
Shale, black	130	1680
Traverse-Bell:		
Limestone; sandstone	7	1687
Limestone; sandstone, hard	3	1690
Limestone; sandstone, soft (oil, gas & water 1690-1693)	3	1693
Limestone, sandy, hard	39	1732
Limestone, broken	32	1764
Shale, light	20	1784
Shale, white	16	1800
Limestone, hard	5	1805
Limestone, sandy (oil and gas 1813-1815)	28	1833
Limestone; shale	122	1955
Limestone, broken	45	2000
Limestone, white	87	2087
Shale; "shells" (Oil & some water at 2086)	123	2210
Shale, white	130	2340
Limestone "shell"	4	2344
Shale, gray	11	2355
"Shells"	8	2411
Shale	71	2482
Dundee:		
Limestone	52	2534

	Thickness (Feet)	Depth (Feet)
Dundee, continued		
Limestone, brown, hard (water at 2645; increased at 2695; filled up at 2300')	176	2710
Limestone, hard, gritty	45	2755
Detroit River (?):		
Limestone, hard	15	2770
Limestone, hard, dark	9	2779
Limestone, brown, fairly hard	33	2812
Limestone, brown	28	2840
Limestone, hard	41	2881
Salt	148	3029
Salt, limestone, brown	65	3094
Limestone; salt streaks	16	3110
Salt; limestone streaks	25	3135
Limestone, sandy (1 bailer water per hr. at 3215)	85	3220
Salt	55	3275
Limestone, dark sandy	15	3290
Limestone, white, sandy	10	3300
Limestone, brown, sandy	65	3365
Limestone; salt; gypsum	135	3500
Limestone, hard, gray	9	3509
Limestone; some salt (saturated with oil at 3502; sulphur gas at 3583; green oil at 3592)	86	3595
Limestone; gypsum (green oil 3604-9, 5 to 10 bbls. natural 40 gravity)	27	3622
Gypsum; anhydrite	53	3675
Limestone, brown	113	3788
Limestone, gypsum	55	3843
Limestone, brown	63	3906
Limestone, broken	47	3953
Rock, broken sandy	12	3965
Limestone, hard	30	3995
Sylvania:		
Limestone, sandy	30	4025
Limestone, dark broken	25	4050
Limestone, dark broken, sandy	35	4085
Limestone, dark, little sandy	35	4120
Limestone, dark, gritty	28	4148
Limestone, light and dark streaks	60	4208
Limestone, white, hard, sandy	44	4252
Bass Island:		
Limestone, hard black	18	4270
Limestone, hard (30 gals water in 12 hrs. at 4270)	24	4294

	Thickness (Feet)	Depth (Feet)
Bass Island, continued		
Limestone, hard, dark	26	4320
Limestone, broken	78	4398
Limestone, light hard	5	4403
Limestone, light soft	33	4436
Limestone, gray	72	4508
Limestone, broken	8	4516
Limestone, gray	52	4568
Limestone, gray, little sandy	26	4594
Limestone, gray, sandy	32	4626
Limestone, gray, hard	56	4682
Limestone, hard, white	4	4686
Limestone, hard, gray	72	4758
Limestone, brown	61	4819
Limestone, gray	54	4873
Limestone, brown	24	4897
Limestone, gray	192	5089
(Water filled up 500' in 12 hrs. at 5061; later filled up 4550')		
Limestone, hard gray	14	5103
Limestone, hard brown	24	5127
Limestone, hard dark gray	12	5139
Limestone, dark gray	5	5144
Limestone, hard gray	36	5180
Shale, asphaltic	63	5243
Salina (?):		
Limestone, hard brown	4	5247
Shale (?), asphaltic hard	9	5256
Limestone, gray hard	10	5266
Limestone, dark hard	12	5278
Limestone, brown hard	90	5368
Sandstone	29	5397
Sandstone; salt	8	5405
	TOTAL DEPTH	5405

Casing record:
14" 175'
10" 1171'
8¼" 1823'
6-5/8" 2839'
5-3/16" 4004'

Commenced: 1-17-32
Completed: 8- 9-32
Initial production: Dry hole
Plugged and abandoned: 10-6-32

The second deep well drilled by the Pure Oil Company was their Mills Estate #1 in the NE¼ of NW¼ of SE¼ of section 36, T 21 N., R. 3 E., Mills Township (Elev. 799). The Berea grit was at 1163 with 248,000 cu. ft. of gas, the Traverse at 1710 and the Dundee at 2471 feet. Black oil was reported at 2495, water at 2595 and 2300 feet of water in the hole at 2667. The well was plugged and abandoned at

2680 feet.

The first producing well in the area, completed July 20, 1933 was drilled by Alvin Weber on the Wilcox farm, NE¼ of NE¼ of NE¼ of section 34, T. 22 N., R. 2 E., West Branch Township (Elev. 895). The Berea was at 1191, the Traverse at 1714 feet. Oil and gas was struck at 1729 and total depth was 1732 feet. Initial production was rated at 190 barrels per day.

Two productive offset wells in the Traverse formation were completed next, the one to the east having a reported natural initial production of 2534 barrels.

The first well completed as a Dundee producer was the Pure Oil Company's Fisk #1, SW¼ of SE¼ of SW¼ of section 27, T. 22 N., R. 2 E., West Branch Township (Elev. 910). The Dundee was at 2525 feet, with a show of oil at 2606 and oil pays at 2625, 2635 and 2677 feet. Shows of water were at 2708 and 2785 with a hole full of water at 2800 to 2807 feet, total depth. The well was plugged back to 2700 feet. Initial natural production was 21 barrels and 126 barrels after acid. From this locality, drilling expanded several miles northwestward along the structural trend into Sections 13 and 24, T. 22 N., R. 1 E., Ogemaw Township.

The first important extension of the pool to the southeast was C. A. Perry's Wobig Heirs #1, SW¼ of NE¼ of section 6, T. 21 N., R. 3 E., Mills Township (Elev. 837). The Berea was at 1148, the Traverse at 1680 and the Dundee at 2457, total depth 2618 feet. Initial production, after acid treatment, was rated at 100 barrels.

The field has developed rather slowly and by the latter part of July, 1936, there were 138 completed oil wells and one Traverse gas well. Thus far, there have been no dry holes in the Dundee formation, within productive closure. Within the County, 27 wells have been abandoned either as dry holes in the Dundee formation or abandoned at shallower depths upon finding the upper formations structurally low.

Stratigraphy and Structure

In the productive area, the Coldwater formation of Mississippian age is encountered at the base of the drift. This formation is primarily composed of light gray to dark gray shale from 1000 to 1100 feet in thickness. Near the bottom are minor zones of limestone "shells". A pink to red shale from 10 to 15 feet thick is approximately 50 to 70 feet above the base. It is often recorded as "redrock". A "stray" sandstone known as the "Wier" which reaches a thickness of 40 feet is about 250 feet from the eroded top of the Coldwater. This gray sandstone may be reworked Berea. The Wier usually carries water, with frequently a small show of oil or gas.

The Sunbury shale below the Coldwater is the first definite marker in the field. It is a dark brown to black pyritic shale which has an average thickness of 25 feet.

The Berea-Bedford section has a thickness of 80 to 100 feet of grayish fine-grained sandstone and gray shale. The sandstone is known to drillers as the "Berea grit". Many wells have had shows of oil and gas in the Berea. Below this sandstone which is often separated by shale breaks, is the gray shale of the Bedford formation.

The Antrim is conformable below the Bedford. The upper portion of the Antrim shale may be of Mississippian age, but up to the present, pending the settlement of the long controversy of the age of the shale, in general correlation it is classified as Devonian. The Antrim shale is dark brown to black bituminous shale with an average thickness of 450 feet. Limestone shells are often recorded and apparently are lime carbonate concretions. Small shows of gas have been reported in the Antrim shale.

Below the Antrim, the Traverse-Bell section of Devonian age has a rather uniform thickness of 800 feet. The limestone is light buff to gray in color. There is also interbedded shale. Some samples are cherty. In the West Branch structure, the Bell formation is a blue to dark gray shale with an average thickness of 80 feet, but does not have the characteristic black shale at the base.

The Dundee formation of Devonian age, below the Bell shale is a dark gray to brown limestone with a cherty crystalline appearance. Its thickness in the West Branch area is approximately 300 feet.

The West Branch structure is an assymmetrical, elongated anticlinal dome with a northwest to southeast axis with the steeper slope to the northeast. The major fold upon which this anticline is superimposed, plunges southeastward to Saginaw Bay almost at right angles to the regional dip which is southwestward into the Michigan Basin. On the main closure there are minor, local, enechelon closures as is known by many wells. On the northeast flank, there are structural dips slopes of almost 200 feet to the mile. Structural dip to the southeast does not greatly exceed 100 feet to the mile.

Because of the uniformity of the formations, it is apparent that most of the deformation progressed at one time, perhaps slowly. From the steeper north dips, it is assumed that the pressure came from the northeast. Other theories explaining the development of the structures have been advanced, such as settling or faulting in the "Basement Complex". As deep-seated magmas were withdrawn from the area of the basin and then slowly solidified in the granitic areas to the north, as intrusive rocks, the end result was a tilting of the sedimentary formations. The sedimentary rocks can then be described as a

tilted, movable mass on a more stable core. Movement occurred and folding resulted. If the sharp folds of the upper rocks continue in formations below the Salina formation this theory becomes more plausible. It seems that pressure and movement in the "basement" rocks are closely related.

Production

All drilling in the West Branch field has been with standard cable tools or with the portable machine type. Casing procedure is as follows: 10 inch drive pipe is set in the Coldwater shale at the base of the drift; 8¼ inch casing is set in the Coldwater shale below the "Wier" sand to shut off a cavey section and the water usually in the sandstone; 6-5/8 inch casing is often set on top of the Traverse formation if Traverse production is anticipated, otherwise this string is set through the porous water zones of the Traverse to avoid drilling with a hole full of water; 5-3/16 inch casing is then set either on the Dundee formation or a few feet in. A State regulation requires the cementing or mudding of the Traverse formation. The 6-5/8 inch casing and often the 8¼ inch is then usually pulled.

Total cost of completing a Dundee well averages about $10,000.00. Present lifting costs vary from 12 to 30 cents per barrel. Although the greater number of wells are pumped by individula units, many of the larger leases have found central power hookups to be practical.

All of the production in the field has been obtained from the Traverse and Dundee limestones, with the larger production coming from the Dundee.

Accumulation in the Traverse formation is very erratic and production uncertain. Large wells are sometimes struck, but direct offsets are often very light wells or dry holes. Such results are evidence of local porosity and local closure. The coralline texture of the Traverse limestone may in part account for variation in porosity and accumulation.

A light pay zone is found from 8 to 10 feet in the limestone. Several wells have flowed wild but water rapidly encroached. Several wells have found good pay approximately 120 feet in the formation, which is often referred to as the "Lower Traverse". The largest Traverse well was completed by Strange and Fortney-State #B-1, SE¼ of NE¼ of NE¼ of section 1, T. 21 N., R. 2 E., Horton township (Elev. 846). The Traverse was at 1676 feet. From a depth of 1684 to 1686 feet, oil, gas, and water flowed over the derrick crown block, but this show did not seem to be commercial and no deeper Traverse production was expected. However, on September 24, 1935, an oil and gas pay was drilled into at 1796 feet and the well flowed wild for two days. After the well was under control it flowed 500 barrels in one hour and twenty minutes, but was later pinched down to 250 barrels per hour. The well flowed at a

good rate for two weeks before encroachment of water cut the oil. This well has produced 58,420 barrels of Traverse oil up to January 1936 when it became involved in litigation and was shut in.

Other wells have had varying amounts of free Traverse oil and after acid treatment, production has increased. Traverse water encroachment is rapid, and ponds have been required to impound the brine. Most of the Traverse wells have been deepened to the Dundee formation. Several wells in the field have but very little water and only traces of oil or gas which shows the varied porosity of the Traverse limestone.

Three or more oil pays are encountered in the Dundee limestone. The pay is obtained from beds made porous by solution cavities or fossiliferous zones. Total thickness of the combined pays averages about 20 feet. The first oil shows are reported at 10 to 15 feet, the second at about 100 feet, the third at about 140 feet and good pay about 150 feet in the formation. Other minor pay zones are often recorded. The crude oil is black with gravity A. P. I. 36.8°. There is very little gas to flow the Dundee oil, but a well after standing fills from several hundred feet to a hole full of free oil. In several wells, the oil has flowed slowly over the casing head. If pumped or produced naturally, production probably would not exceed 5 to 10 barrels per well daily, but treatment with acid greatly increases production by increasing pore space and the accumulation area within the limestone.

In acidizing, the usual procedure is to tube and treat the well with 1000 gallons of inhibited hydrochloric acid under pressure. The well is then shut in for a day or so. Initial production after acid varies from 50 to 100 barrels per day. The average well rapidly declines to 20 to 25 barrels and then maintains this rate of production. Several wells have been shot with nitroglycerin and then treated with acid. The end result is about the same.

Edge wells in the field have produced varying amounts of brine at depths from 160 to 175 feet in the Dundee. Disposal of brine will become a problem in the West Branch field, but will not be as perplexing as in other Michigan fields as the water drive is not as strong and therefore the brine flow is not so rapid.

Total accumulative production to August 1, 1936 was 1,083,383 barrels. The present daily production is about 2300 barrels or an average of 18 barrels per well. Allowing ten acres to each well location, the present per acre recovery is nearly 800 barrels. This figure is comparative as there are more undrilled than drilled locations. The ultimate per acre recovery of Dundee oil has been estimated to be from 2500 barrels upward.

Possibilities of Deeper Production and Discovery of Undeveloped Structures

As production in the Dundee formation reaches its economic limit in the West Branch Oil Field, it is certain that operators will turn attention to the possibilities of deeper drilling and to the search for other structures.

Only two wells in the West Branch field have been drilled below the Dundee formation. The Pure Oil Company, Yeo #1, NE¼ of NE¼ of NE¼ of section 2, T. 21 N., R. 2 E., Horton township and the McClanahan Oil Company, Guilford #1, NE¼ of NE¼ of NW¼ of section 29, T. 22 N., R. 2 E., West Branch township (Elevation 946 feet).

The Yeo (see log) well was drilled through 288 feet of Dundee(2482 to 2770 feet); the Detroit River was reached at 2770 feet, Sylvania at 3995 feet, Bass Island (Lower Monroe) at 4252, and the Salina (?) at 5243 feet. The well was drilled 162 feet into the Salina (?) formation and plugged and abandoned at 5405 feet, the deepest well in Ogemaw County. A strong sulphur gas was hit in a limestone of the Detroit River formation at 3583 in the Yeo #1 well and at 3716 feet in the Guilford #1. In other areas of the Michigan basin, flows of strong sulphur gas have been found in the same limestone. On several deep wells the drillers were overcome by sulphur gas.

A good show of green oil (40° gravity) was reported in the Detroit River formation in the Yeo #1 from 3604 - 3609 feet. It was estimated to be capable of making several barrels per day natural. Acid treatment may increase the production from this probable lower pay sand. The Guilford #1 did not log an oil pay in the Detroit River formation and after having been drilled to a total depth of 3755 feet was plugged back to 2735 feet and produced as a Dundee well. The presence of the pay zone in the Yeo #1 and its absence in the Guilford #1 may be due to several causes. There may be local porosity and local minor closures similar to the erratic productive conditions in the Traverse formation.

With increased depth structural shift may be found, that is, the structural axes of the deeper formations may not be directly under the axes of structures in the shallower formations. The upper formation structures may not be conformable on the lower; one may be offset from the other. Obviously it will necessitate the drilling of several deep wells to obtain deeper structural control. Structural shifting may possibly be explained by settling in the salt series of the Salina formation, or by a basinward slump combined with pressure. Evidence to prove or disprove either theory is lacking. Several geologists have advanced the hypothesis that closure on deep lying structures will be to the northeast of present shallower productive closure.

The Sylvania section from 3995 to 4252 feet in the Yeo #1 is a sandy limestone. No shows of oil or gas were reported. The Sylvania here has the characteristics of a formation deposited in deep water

by a transgressing sea that reworked and redeposited some of the basal sandstone, believed to be dune or wind blown sand, which is the typical Sylvania sandstone near the outer edge of the Michigan Basin and of the Sylvania outcrop in Monroe County. From this standpoint, reservoir conditions for oil accumulation in the Sylvania do not appear to be ideal in the immediate area.

No shows of oil or gas were found in the Bass Island, but water was found near the top of the formation and at 5061 feet the hole filled with 4550 feet of water. An asphaltic shale which may be indicative of a former acculumation of petroleum, is at the base of the Bass Island limestone.

No shows of oil or gas were found in the 162 feet of Salina at the bottom of the Yeo well. The lower Salina formation has had several good showings of gas in the southern part of the Lower Peninsula. The thickness of the Salina is not known in the West Branch area. Wells nearer the margins of the basins have reported over 1000 feet of Salina and the central basin area may have a considerable increase in thickness up to 1500 feet or more. Production in the deeper rocks which have not been reached by the drill in the Ogemaw area is problematical.

Below the Salina is the Lockport group of the Niagaran in which oil and gas shows have been reported from deep wells in other parts of the state.

The Trenton and St. Peters formations of Ordovician age are the deeper formations, from which production may be possible. These formations are equivalent to the Viola limestone and the "Wilcox" sand of Oklahoma. In the central basin area the Trenton limestone may be of a lithographic texture and may therefore be too fine and lack the porosity for accumulation. The Trenton - Black River is known to reach a thickness of 850 feet in the eastern part of the Lower Peninsula. Toward the base it becomes sandy and impure with a gradational change to the St. Peter formation. The St. Peter sandstone is a white to buff quartzose sandstone and may exceed 200 feet in thickness.

The Trenton formation is now producing small amounts of a high quality oil in Monroe County in the southeastern part of the Lower Peninsula. Numerous other wells have had good shows of oil and gas in the Trenton formation.

It is probable that drilling to depths of 7000 feet and over in the Central basin area will be carried on with heavy rotary drilling equipment. While such deep drilling is uneconomic at the present time it appears inevitable that sooner or later, deep tests will be projected and carried out. But to offset the expensive drilling and operating costs larger and longer lived production must be obtained, than is now produced from shallower formations.

Other Structures

The Sun Oil Company drilled a number of shallow tests in Logan township in an effort to locate possible structure. The evidence from the test wells indicated a northwest to southeast fold, and on this indicated structure the first Dundee test in Ogemaw County to test the oil bearing formations was drilled. This well was the Sun Oil Company Bernard #1, NW¼ of SE¼ of SE¼ of section 16, T. 22 N., R. 4 E., Logan township (Elevation 841 feet). In this well the Marshall (Napoleon) formation was reached at 119 feet, Lower Marshall at 295 feet, Berea 1430 feet, Traverse formation 1965 feet, Dundee 2745 feet, water at 2905 feet and was dry and abandoned at 3025 feet. A gas show was reported at 1430, a show of oil at 1980-1982, and a show of gas at 2332 - 2335 feet,

The second Dundee test to be drilled on this projected structural trend was the Gell, Graves, and Mechling, Incorporated, Kerr #1, SW¼ of SW¼ of SE¼ of section 27, T. 23 N., R. 3 E., Cummings township (Elevation 854 feet). Below the drift at 68 feet, only 24 feet of Marshall sandstone was present, indicative of considerable rise from the Sun well in Logan township. The Berea was at 1380 feet, the Traverse at 1926, and the Dundee at 2705 feet. A show of gas was logged at 2764 feet, a hole full of water at 2870-2875, dry and abandoned at 2880 feet.

The third Dundee test was also in Cummings township, the Muskegon Development Company - Watson #1, NW¼ of SE¼ of NW¼ of section 5, T. 23 N., R. 3 E. (Elevation 919 feet). The first formation below the drift was the Michigan at 235 feet. The Upper Marshall was at 290 feet, the Lower Marshall at 333 feet, Berea at 1760 feet, Traverse at 2315 feet, and Dundee at 3095 feet. A small show of oil was reported in the Traverse from 2330-2332 feet. Water was at 3270 feet and the well was abandoned at that depth. This showed a steep dip to the north and that the structural axis was south of the well.

The third Dundee well in Cummings township was drilled by Richfield-Backus Oil Corporation, Scott and Linton #1, SE¼ of NW¼ of NE¼ of section 18, T. 23 N., R. 3 E. (Elevation 953 feet). This well may have had a thin section of Lower Marshall but is not recognizable from the driller's record. Coldwater shale is recorded from 234 to 1380 feet. The Berea at 1405, Traverse at 1928, and the Dundee at 2698 feet. Water was at 2917 to 2919 feet. Dry and abandoned at that depth.

The Richfield-Backus well shows a structural rise of over 400 feet in a distance of two miles from the Muskegon Development Co. Watson #1 in section 5. (See Plate 4). Further drilling is expected to outline the probable closure which is roughly projected on Plate 3 - The Rose City structure.

Undoubtedly conditions of accumulation and production in any possible oil pool along the Rose City structural trend will be

comparable to conditions in the West Branch field: Erratic Traverse production may be found. Probably several pay horizons with the characteristic black oil are in the Dundee formation. The change in the Dundee oil from the live, green oil of the central Michigan pools to the black oil of the sharper Ogemaw structures, may indicate that the Ogemaw structures are farther from the source beds and consequent accumulation of petroleum, or that oil has migrated from these structures to the central basin leaving the residual black oil. From this we may conclude that production may become progressively lighter in the sharper folds which are nearer the rim of the Michigan basin.

The steep north dip of the Rose City structure indicates a possible reversal within the northeast portion of the county, thereby revealing another possible structural trend. There are no well records by which to locate this trend - its axis may fall in Ogemaw county or in the southern township of Oscoda County. The existence of such trends or folds is predicated on the hypothesis that anticlines similar to the sharp folds in Gladwin, Ogemaw, or the folds in Alcona and Alpena counties are repeated in the intervening counties.

A separate closure on the West Branch structure is shown in southeastern Mills and southwestern Richland townships. The greater portion of the closure appears to be in Clayton township, Arenac County. A small Dundee well was drilled by the Great Western Petroleum Company, Mills Estate #1, NW¼ of SE¼ of SE¼ of section 31, T. 21 N., R. 4 E., Richland township (Elevation 804 feet). Berea was at 1147, Traverse at 1681, and Dundee at 2455 feet. Oil shows were at 2468, 2470, 2587, and a good show at 2590. Initial production after acid treatment was 15 barrels. A well less than a mile due north of this producing well was 200 feet lower showing a structural slope to the northeast.

Northwest of the city of West Branch, the fold appears to swing northward. The northwest limits of the pool have not yet been reached but all available control indicates that a saddle or sag interrupts the structural trend. It is possible that reversal may be present to the northwest, but only future development can prove or disprove the extent of the structure.

Summary

Ogemaw County has one well defined structure on which lies the West Branch oil field. Other structures are indicated by test wells and a few dry holes, and it is not improbable that well placed tests on one or more of the indicated structures may open new pools. Possibilities of oil production in the deeper rocks are interesting but problematical.