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Geology of Arenac County

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THE GEOLOGY OF ARENAC COUNTY

By Gordon H. Pringle¹

Chapter 1

INTRODUCTION

Arenac County, made up of less than 11 townships or about 370 square miles, is on the west side of Saginaw Bay with the south line about 25 miles north of Bay City.

Two paved highways cross the county. U.S. 23 extends north from Bay City to Standish where it divides, M 76 going northwest to the city of West Branch and U.S. 23 following the Lake Huron shore to Alpena. The county and township roads are in fair condition and with the state roads give access to almost any section in the county.

Two railroads serve Arenac County. The Michigan Central Railroad passes through Standish and extends northwest to West Branch; the Detroit and Mackinaw Railroad has its right of way through the eastern part of the county passing through Sagining, Pine River, Omer, Twining, and Turner.

The principal town is Standish which is also the county seat.

The main industries are farming and fishing. The farms are located on the morainal and clay areas. The fishing industry is composed of a few small independent operators located along the Lake Huron shore. There are also some resort areas along the Lake Huron shore, mainly in Whitney and Sims townships, and a rapidly developing resort region along the Saginaw Bay shore of Au Gres township.

Geological interest has been renewed in this county during the past few years because of the possibility of oil and gas production. This interest was greatly increased by the discovery of a small field in Clayton township in November, 1936.

This report is written to bring together the available data on the county and to point out areas where further exploration might be profitable.

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Chapter II

PHYSIOGRAPHY

Geologically Arenac County is near the northeastern edge of the central portion of the Michigan basin, and physiographically in the Glacial Lake Plain Section about Saginaw Bay. The surface of the area differs from the greater portion of the glaciated surface of the State in being composed of sediments, largely of sand and clay, laid down in large bodies of water, because at the time the Saginaw lowland was uncovered by the retreating ice it was covered by a lake, the impounded waters dammed against the ice front.

The Port Huron moraine which marks a temporary readvance of the ice front somewhat modifies the lake plain. This moraine extends from near the southwest corner of the county northeastward into Clayton and Mason townships. Other morainic areas are in the extreme northwest corner of the county, in the northwestern corner of Moffat township, and a very subdued water laid moraine is near Lake Huron in the northeast corner (in northeastern Whitney township, T. 20 N., R. 7 E.).

In the southwest corner of Clayton township the Port Huron moraine is cut by the deep valley of the Rifle River. The highest elevations in the county are along this moraine a short distance north of the river at slightly over 850 feet. From this area the elevations drop gradually in all directions but rise again in the northwestern corner of the county to a little more than 825 feet. South of the river the moraine becomes less prominent and at the Bay County line is barely discernible.

The moraines are composed chiefly of a heavy blue boulder clay with occasional sandy areas. The water laid moraine near Lake Huron seems characterized by fewer boulders and is the site of a small farming area along the sandy lake shore.

The sand and clay areas are in belts trending roughly parallel to the Port Huron moraine. The sand represents deposits in shallow water and the clay in deeper water of the former glacial lakes.

The low sandy plain extending southwestward from the east side of the town of Alger represents an old drainage way of the Au Sable and Rifle Rivers to the Tittabawassee River which was in use at the time the ice stood at the Port Huron moraine on the east side of the Rifle River (Leverett)¹. The eastern outlets of the Au Sable and Rifle Rivers being blocked, drainage was forced southwestward through the Tittabawassee. This area was afterwards covered by a later stage of the glacial lakes.

¹L. R. Schoenmann- Peat and Marl, Surface Geol. of Ogemaw Co., Mich. 1925.

The sand plains about Pinnacle Hill in Section 2, Deep River township, represent, according to Gregory¹, a delta deposit of a stream which occupied the present headwaters of the Rifle River and discharged into glacial Lake Warren. A stratified gravel deposit in the southeast quarter of Section 31, Clayton township, well above the present river level, possibly represents a near shore phase of this delta.

Several sand belts parallel the shore lines of the former glacial lakes. The most prominent shore lines are those of Lake Warren, which may easily be identified in places along the east side of the Port Huron moraine, and the shores of Lakes Algonquin and Nippissing, (Plate 1)

North and west of Standish are other fragmental sand ridges now somewhat obscured by wind action. The ridges are below the Warren beach and above the Algonquin and may possibly represent the shore lines of glacial lakes, Grassmere and Lundy.²

The sandy region between the Algonquin and Nippissing beaches from Saganing north to Omer is characterized by small sand dunes.

The clay areas are usually quite flat to gently rolling. They are composed of a dark blue heavy clay with occasional sand lenses and a few small pebbles.

There are three main rivers in the county. The most important is the Rifle River which is entrenched in a valley about 100 feet deep at the north line of Arenac County and more than 150 feet deep at Pinnacle Hill. The river drops from approximately 700 feet above sea level at the north county line to lake level where it enters Saginaw Bay, a drop of 120 feet or an average of 6 feet per mile. This drop is greater in the northern portion of the county, perhaps as high as $7\frac{1}{2}$ feet per mile.

The course of the Rifle River appears to be influenced to some extent by underlying structural conditions. The river closely follows the Parma-Bayport contact and in the northwest corner of Deep River township turns sharply northward along the edge of the Clayton oil structure.

The Au Gres River is second in importance and enters the county in Section 2 of Turner township, flows southward and enters Saginaw Bay south of the village of Au Gres.

¹W. M. Gregory, Geol. Report on Arenac County, Mich., Geol. Survey Publication 11, Geol. Series 8, 1912 - page 69.

²F. Leverett - F. B. Taylor - U. S. G. S. Mon. L111 - page 404

The east branch of the Au Gres, which enters Arenac County in Section 4, Whitney township, has been diverted by a drainage ditch along the south lines of Sections 9, 10, 11, and 12 and now flows directly into Lake Huron. The drainage ditch is said to have been dug to lessen the flow of flood waters to the village of Au Gres. The result in one sense has not been favorable. The drift in this area is thin and composed largely of clay carrying but little water. Shallow wells drilled into the bedrock below the drift find brackish water in the Michigan formation. The farmers' livestock will not use this water and the water formerly available in the river is lost. Thus the drainage ditch which improved flood conditions for the village has proved to be a hardship to farmers owning livestock in this area.

The Pine River has most of its headwaters in Arenac County with only the south branch rising in Bay County. Three branches join west of Standish to form the main stream of the Pine River.

The surface drift gradually thickens from the east side of the county westward. In Whitney, Sims, Au Gres, and Arenac townships, the drift is thin, rarely exceeding 50 or 60 feet.

In many places the bedrock is at the surface or covered by only a few feet of soil. In the region of the Port Huron moraine the drift thickens to 100 to 200 feet and appears to become but little thinner in the western part of the county.

Bedrock crops out along the Rifle River in the midst of the thick drift because when the Rifle River was diverted eastward after the ice had retreated into Lake Huron, the current of the river was so greatly increased it had the power to cut a deep channel through the moraine into the bedrock.

Chapter 111

AREAL GEOLOGY AND STRATIGRAPHY

In this report a stratigraphic section extending from the Dundee formation of the Devonian system, through the Saginaw formation of the Pennsylvanian system, is discussed.

AREAL GEOLOGY

The outcrops of Arenac County are found in areas of thin drift and in localities where stream action has eroded through the drift in forming their valleys. In discussing the areal geology, the area will be considered as if not covered with glacial drift.

The outcrops visited in the county were of the Saginaw, Parma, Bayport, and Michigan formations. More conclusive evidence may prove that one outcrop is of Napoleon sandstone.

The general pattern of outcrop shows Arenac County to be on a segment of the Michigan Basin having a northwest-southeast strike with the older rocks at the surface in the northeastern part of the county and younger formations cropping out successively to the southwest; thus the Michigan formation outcrops in the northeastern townships and the Saginaw formation in the southwestern. This simple pattern is greatly complicated, however, by structures that bring older formations to the surface, and other structures that produce outliers of younger formations surrounded by the older, as in the outcrops of the Bayport limestone in Whitney and Sims townships. (Plate 2)

The broad outcrop of the Michigan formation is disturbed by folding which brought the Coldwater, Lower and Upper Marshall (Napoleon) formations to the surface in Clayton and Mason townships. (The Clayton High, Chap. IV).

The Sterling structure caused the Michigan, Bayport, and Parma formations to crop out at the surface in Deep River township, and the Marshall and possibly the Coldwater to be at the surface in central Moffat township.

Pennsylvanian System

The Pennsylvanian system in Arenac County is bounded approximately on the northeast by the Rifle River, at least as far to the northwest as Section 3, Deep River township. Beyond this point to the west boundary of the county the rock is obscured by thick drift and the direction of strike unknown. Data are not sufficient to determine the influence of the folding in Moffat Township on the direction of the strike.

The Pennsylvanian in this area consists of two formations, the Parma sandstone¹ at the base and the Saginaw formation, which overlies it.

Saginaw Formation.

The Saginaw is the youngest formation present in Arenac County and has probably the greatest areal extent of any outcropping formation. This formation contains the coal measures and in the years 1875 to 1900 a considerable amount of prospecting for coal was carried on.²

Coal was found in the vicinity of Pinnacle Hill in Sections 2 and 3, Deep River township, and 200,000 tons of cannel coal are reported to have been shipped from the mine. A shaft was sunk in Section 28 of the same township, but coal was never mined because of water conditions in the shaft.

The Saginaw formation varies from 0 feet to 250 feet in thickness. The average thickness near the Rifle River is 90 feet and increases to the southwest. In the southwest quarter of Section 31, Adams township, more than 250 feet of Saginaw is reported.

The Saginaw formation in Arenac County is composed of a series of gray micaceous sandstones, gray, and black carbonaceous shales, gray underclays, and coal. Plant remains and fossils are found in the outcrops along the Rifle River. The small brachiopod *Lingula* is found in the carbonaceous shales and plant remains are distributed throughout most of the formation. Marcasite and clay iron stone concretions, many containing sphalerite, are common.

Parma Sandstone

The Parma is the oldest formation of Pennsylvanian age. The sandstone is not consistently present in the county and often is found replacing the Bayport limestone. Its presence along the entire basal contact of the Pennsylvanian with the Bayport seems questionable.

In most well records in the area where the Parma is present, the Bayport is found to be absent, with the Parma lying unconformably on the Michigan formation. There is no definite proof that this condition is true all along the contact in this county as there are no outcrops or wells to prove the point. The boundary of the Parma is shown on the areal geology map, but its consistent presence is doubtful.

1 W. A. Kelly-Pennsylvanian System in Michigan - Geol. Survey Division Michigan Department of Conservation - Pub. 40, Geol. Series 34.

2 Wm. M. Gregory, Gregory, Geology of Arenac County, Mich., Geol. Sur. Pub. 11 G. S. 18, 1912.

The outcrop in the north branch of the Pine River, Sections 34 and 35, Deep River township, is believed to be Parma sandstone. The sandstone here is a coarse, friable, white sandstone, highly cross bedded and containing small milky quartz pebbles. A well drilled in the SW $\frac{1}{4}$ of Section 27 near this outcrop is believed to have reached a Michigan sandstone below the drift, but it is the writer's belief that the friable sandstone (Parma) was cased off by the drift and considered in the driller's log as drift. The thickness of drift reported in this well, 185 feet, seems to be too great and part of the thickness was no doubt gained by considering the Parma section as drift.

Wells in southeastern Standish township show both Parma and Bayport. The thickness of the Parma when present varies from 30 to 50 feet.

Outcrops

The outcrops of the Saginaw formation are found along the Rifle River. They are confined to an area beginning about 1 mile south of Omer and continue in occasional outcrops in Sections 3 and 4, Deep River township, T. 19N., R.4E.

Outcrops of Saginaw Formation at Omer.

An outcrop begins just west of the Highway Bridge at Omer in the Rifle River. Isolated outcrops continue downstream to the junction of Saverine Creek in Section 22, Arenac township. A few outcrops are found up stream along this creek.

The outcrops at the bridge at Omer are highly cross bedded and dips and strikes are indeterminate. The strike appears to be about S.60°E. and dips S.30°W. The following section was noted: 1. At the base a coarse gray sandstone underlying coarse sandstone with carbonaceous laminations. 2. A sandy carbonaceous shale above which are alternating thin laminations of carbonaceous sandstone and a coarse micaceous sandstone. This formation crops out within an area 800 to 1000 feet from the bridge at Omer. Plant remains are found in the carbonaceous material and a few in the sandstone. Clay ironstone and concretionary layers are found above the sandstone at the railroad bridge south of Omer. The thickness of the various beds is difficult to determine due to the cross bedding and to the small vertical exposure.

Outcrop at Old Brick Plant near Omer.

The old brick plant was located in the northeast quarter of Section 8, T.19N., R.5E. on the north side of the river and the Saginaw shales were obtained from a pit on the south side of the river.

There is an outcrop along the south bank of the river that has the following section:

Zone 1 (base of section).

A dark brown fine grained sandstone overlaid by approximately 1 foot of greenish gray underclay.

In places, this underclay is overlaid by a black carbonaceous sandstone. The top of this zone contains

large, flat, marcasite concretions 1 foot in diameter and 2 or 3 inches thick. The black sandstone averages 1 foot or less in thickness.

Zone 2.

A gray to black, thin bedded carbonaceous shale, gray at the base and becoming black above

The shale contains many small fossils of *Lingula* (*Carbonaria*?) throughout, some of which have been preserved by pyritization. Small round and irregular shaped marcasite concretions are also found in the 3 or 4 feet of shale exposed.

This pit formerly furnished the shale for the brick plant but is now filled with water, making it impossible to obtain a section there. Gregory¹ reports a section from this pit into which the above section fits fairly well.

Outcrop of Rifle River.

Near Section Line between 3 and 4, T 19N. R 4E.

A large outcrop of the Saginaw formation is along the south bank of the Rifle in Sections 3 and 4. This section rises 8 to 15 feet above the level of the river and extends along it for some 200 feet, with a concealed interval between. Two sections were taken, one on each side of a concealed interval.

Section 1 - West of concealed zone.

Zone 1. (base of section).

A white to gray irregularly, thin bedded, medium to coarse grained, micaceous sandstone.

At a distance this zone, because of the thin irregular bedding, appears to be shaly. It contains brownish red clay ironstone concretions and the sandstone is peppered with small iron stains. This zone is 44 inches thick and is set off at the base and top by a nodular zone.

Zone 2.

An extremely thin bedded, black, carbonaceous. laminated paper shale.

A white sandstone forms the laminae, which sometimes thicken to half an inch. A foot or more of white to gray sandstone is at the top. This zone approximates 4 feet in thickness.

Above is a disturbed zone caused by glacial push, composed of a mixture of underclay and light brown sandstone with many small iron stains.

1. Wm. M. Gregory - *ibid* 2, page 137

Section 2 - East of concealed zone.

This section is about 100 feet east of Section 1, with a concealed interval between.

Zone 1

3 feet of coarse gray friable sandstone with gray shaly streaks at the top.

Zone 2.

44 inches of sandstone, same as Zone 1 of previous section.

Zone 3.

2 feet of nodular, medium grained white to gray sandstone.

Zone 4.

1 to 2 feet of paper shales like Zone 2 of Section 1. It appears as if the basal portion of the shale in Section 1 has been replaced here by the nodular sandstone.

Zone 5.

3 to 4 feet of medium grained gray to yellow sandstone, peppered with iron stains. Reworked at the top by glacial action.

Other Outcrops.

Near the bridge crossing of the Rifle River on the west line of Section 2, Deep River township, T.19N., R.4E., isolated sandstone and shale outcrops are found. At the bridge no definite outcrops were seen, although a great deal of float material nearby indicates the proximity of the Saginaw formation to the surface.

Upstream on the north bank, an underclay was found, and on the south side of the river coal, shale and sandstone are found in the dump of an old mine shaft.

East of the bridge a quarter of a mile downstream, Section 1, T.19N., R.4E., a sandstone similar to the one found in Section 3, may be seen on the south bank of the river, and a small outcrop may be on the east line of Section 2, along the north bank of the river.

Mississippian System

The Mississippian system includes the formations from the top of the Bayport limestone, down to and including the upper part of the Antrim shale.

The Bayport, Michigan, Napoleon, Lower Marshall and Coldwater formations are found directly below the drift in places in the county.

Bayport Limestone.

The Bayport is composed of an alternating series of light and dark gray, and buff limestone, dolomitic limestones, dolomites, and sandstones which are usually quite calcareous. Zones of nodular and lenticular chert are common, the lenticular chert being in the basal part of the formation. A white, coarse sandstone forms the greater part of the basal portion of the Bayport, but lenses of a similar sandstone are found throughout the formation. A tan, fine grained, argillaceous sandstone is usually in the section. Occasional carbonaceous bands are found, usually as thin shale partings.

Apparently the formation was deposited under rapidly changing conditions as indicated by the transition to limestone from sandstone.

One horizon in the Bayport is characterized by a fossil assemblage that aids in identification of the limestone and aids also in placing the outcrop definitely within the Bayport section. This fossil assemblage has been used in carrying correlation of the formation through the different sections. There is evidence that the Bayport was deposited in an oscillating sea, but this fossil zone, in a restricted area such as Arenac County, is probably the same age in all outcrops.

Characteristic fossils found in this zone which I have named the Echinochonus zone are Echinochonus, Linoproductus, Rhipidomella, Spirifer, Composita, Triplophyllum, Zaphrentis, Lithostrotion, Allorisma, Sanguinalites, Crenopectin or Aviculopectin, Straparollus, Naticopsis, Sphaeradoma, Fenestella, Fenestrella, Polypora, Hallopora and a Trilobite (Phillipsia?).

The fossils found in other portions of the formation are usually corals, bryozoa, and pelecypods, but brachiopods and gastropods are not found with them.

The Bayport limestone crops out more than any other formation in the county. Outcrops are in the eastern portions of Whitney and Sims townships, and along a ridge extending from point Au Gres northwest past Omer where the ridge disappears under the heavy drift cover.

On the accompanying areal map, the trend is hypothetically continued northwest, but as stated earlier, the possible "high" in Sections 17, 18, 19, and 20 of Moffat township may show a change in the trend in that area. (Plate 2)

Outcrops

Bear Track Inn Section

In the northeast quarter of Section 13, Whitney township, there is a bluff 20 feet or more in height along the lake shore north of Bear Track Inn. Along this bluff are some poorly exposed outcrops. By digging and trenching through the glacial drift southward along the bluff from near the north line of the section, information of the extent of the outcrop was obtained.

Station "0".

Station "0" is located one eighth of a mile south of the north line of Section 13. Here a small valley cuts back into the bluff. An outcrop of green plastic clay containing small selenite crystals, and particles of white gypsum is along the edge of the valley. Drift and broken blocks of a gray calcareous sandstone overlie the outcrop. This green shale is the top of the Michigan, the elevation being 12 feet above Lake Huron or 592 feet above sea level.

Station 1.

S 6°W - 150 feet from Station "0".

From Station "0" a line approximately S 6°W was followed for the entire length of the outcrops. At Station 1 is an old test pit or shaft around which white gypsum is piled.

Station 2.

S 6°W - 620 feet.

Zone 1 - 599-601 feet.¹

A gray very arenaceous limestone.

The limestone is often laminated, the laminae being dense, hard, brown, dolomite varying from very thin to 2 inches in thickness.

Zone 2 - 601-605 feet.¹

4 feet of coarse, soft, blue gray, sandstone, poorly cemented.

Zone 3 - 605-607 feet.¹

A chert zone 2 feet thick.

The chert is lenticular, dark and light in color, and associated with a dense brown dolomitic limestone. The zone is bounded at the base and top by a fine grained brown sandstone. Quartz crystals and geodes are common in the chert zone.

Station 3.

S 6°W - 950 feet.

595½-603½ feet.¹

At Station 3 is a coarse gray sandstone 1½ feet thick at the base and 1 foot of similar sandstone at the top is visible. The interval between is concealed.

603½-605 feet.¹

Same chert zone as at Station 2.

605-606 feet.¹

1 foot of coarse gray friable sandstone.

Station 4.

S 6°W - 1200 feet.

593-595 feet.¹

Here a second and lower chert zone is found, much like the upper chert zone except that the chert seems more consistently lighter in color. It is underlain by 1 foot of coarse gray sandstone.

1. Figures refer to elevations above sea level.

595-602 feet¹
 Concealed interval.
 602-604 feet¹

Upper chert zone with fine grained brown sandstone above.

Station 5.

S 60°W - 1436 feet.
 600 $\frac{1}{2}$

Base of upper chert zone, the remainder of the section is concealed.

The dip along the bluff should very closely approximate the true dip and it is 31 feet per mile. Below is a complete section along the lake bluff near Bear Track Inn. It has a total thickness of 18 feet, the greater portion being sand. It is typical basal section, and is a good example of the sand increase in the basal part of a formation. (Plate 6)

Harmon City Section.

The Harmon City quarry is located on an almost east west ridge extending along the south line of Section 14, and into the southwest corner of Section 13, Whitney township. The old Harmon City quarry is near the south quarter corner of Section 14.

Zone 1.

A small creek near the east line of Section 14 exposed beds corresponding to the lowest beds in the Harmon quarry area. 5 feet of limestone which is below the shale break in the quarry proper is exposed in the creek. The basal 2 feet is a dark gray, massive grainy limestone, in places porous and dolomitic in appearance; above this are 4 feet more of limestone, the upper three feet of which are exposed in the quarry. This limestone is light to dark buff, dense and in places almost lithographic. It contains large chert nodules, which are limy on the outside. The upper 1 foot of the exposure is an almost black, bituminous shale and shaly limestone. Just below the shale break is a narrow zone containing many polypora.

This is the "Echinochonus Zone" and contains the fossil forms listed earlier as characteristic of the zone which is 6 feet in thickness.

Zone 2.

A massive, light gray limestone, slightly shaly at the base, dense and buff colored in the middle and coarse at the top.

It contains both large and small, well rounded chert concretions which often contain fossils.

The fossils of this zone are Allorisma, Sanguinalites, Fenestella, Polypora, Triplophillum, Spirifer or Spiriferina, Productus, Naticopsis, Aviculopectin or Crenopectin. The

¹ Figures refer to elevations above sea level.

zone varies from $3\frac{1}{2}$ to 5 feet in thickness.

From the standpoint of the fauna, perhaps this zone should be placed with the one below, making the Echinochonus zone thicker here than in other sections. However, the basal three feet of the Zone 1 were not fossiliferous; also the zoning here was made on the basis of lithology and not fossils.

Zone 3.

The highest zone was found in the creek section, down dip, as float and dredged material. It is a tan, calcareous, argillaceous, fine grained sandstone. It is probably nearly in place and is stratigraphically higher in the section than in zones 1 and 2.

The combination of this section and the Bear Track Inn section, with allowance for a concealed interval of approximately 12 feet, between the top of the bluff section and the base of the Harmon quarry section, gives a total thickness of the Bayport to 40 feet.

The strike of the beds is approximately east-west with a dip south of 35 feet per mile. A test hole drilled near the quarry gave the Bayport thickness as 35 feet; therefore, theoretically the contact of the Michigan-Bayport should be about 1 mile north of the quarry. Finding an outcrop questionably of Michigan formation in a dredged ditch about 1 mile north partially endorses the theory.

Outcrop on Ridge in Sections 23 and 24, T.20N., R.7E.

Outcrops are found on a topographic ridge a quarter of a mile north of the south-west corner of Section 24. The ridge trends almost east-west and its north slope appears to be a dip slope. Bedrock is exposed at the surface but a vertical section is not exposed.

The rock is the same as found in the Harmon City quarry, the upper massive limestone with the cherty nodules and a portion of the limestone below the dark shale break are present. That the north slope is a dip slope is evidenced by finding the polypora zone, the lowest zone found in this section, only on the south edge of the north slope. The fossils found checked well with those in the Harmon quarry.

Apparently the ridge is on the south slope of a syncline and the Harmon quarry forms part of the north slope.

Whitestone Point Section.

The section at Whitestone Point extends along the lake shore on the east side of Section 25, Whitney township, from near the north line of the section southward for approximately three quarters of a mile.

The outcrop is usually at the shore line or a short distance out in the lake. A coarse gray sandstone is along the northern part of the out-

crop. To the south, a dense buff, dolomitic limestone appears, then a chert zone, and finally a coarse gray sandstone. The chert zone is probably one of those seen in the Bear Track Inn section, but a second chert zone was not found. This fact can be explained by assuming that the axis of the syncline is near or at this place, and therefore much of the vertical section is not exposed, or that these chert zones are not consistent.

The chert zone is also found at the quarter corner of Sections 27 and 28, Whitney township, the axis of the syncline apparently lying near a line connecting this outcrop with the Whitestone Point section. Other outcrops are found in the area but they are similar to those already discussed. (Plate 2)

The western, and a portion of the southwestern boundaries of the outlier in Whitney and Sims townships, were traced by shallow salt water wells in the bed rock. It was found that on a definite Bayport outcrop shallow rock wells furnished fresh water, but at some distance from the Bayport shallow wells produced saline water or water from the Michigan formation. No definite evidence from water wells could be found along the southern boundary and therefore the contact between the Bayport and Michigan is more indefinite to the south.

A section of Bayport outcrop is found at Keystone dam in Section 30 of Burleigh township, Iosco County. This outcrop also lies on the trend of the syncline extending southeastward from Rose City, Ogemaw County, and lies in a small syncline similar to the syncline in which the outcrop in Whitney and Sims townships are located.

Outcrop at Point au Gres.

A series of Bayport outcrops are found along the ridge extending northwest from Point au Gres.

At Point au Gres 6 feet of Bayport limestone are found along the lake shore on the west side of the Point.¹ Here the formation appears to have a N 40°W strike and dip N 50°E. Beds above lake level on the Point are found on the lake floor some distance to the northeast. This apparent easterly dip against the normal southwesterly regional dip suggests a reversal in the southeast plunge of the Clayton structure, although the flexure here may be only local.

Zone 1.

The base of the exposure - dark buff, medium grained sandstone. As this sandstone is at or below lake level its thickness was not determined.

1. This is the limestone named Pointe Aux Gres Limestone by C. C. Douglass in 1840.

Zone 2.

1 foot of gray coarse sandstone, the upper half calcareous.

Allorisma is a very common fossil in the calcareous upper part, but uncommon in the lower part. Other fossils found were bryozoa, of which Fenestella was most abundant, crinoid columns, and a Bellerophon type of gastropod.

Zone 3.

1 foot of gray limestone with a bituminous slightly shaly zone at the base.

Both regular and angular shaped chert and lime nodules are present, but are not found below the shaly zone at the base.

Zone 4.

10 inches of light gray, hard, grainy limestone with rounded and a few irregular shaped lime and chert concretions.

Zone 5.

20 inches of dense, light gray to buff limestone. Fossils found in this zone are Polypora, Fenestella, Triplophyllum, and Echinochonus. Concentric and irregular shaped cherty nodules are in the lower 10 inches.

Zone 6.

19 inches of fine grained, gray to buff limestone, darker and more shaly at the base.

Syringopora and a few crinoid columns are present.

It is my opinion that all of the exposures at Point au Gres above Zone 1 should be included in the Echinochonus Zone.

Vaughn's Quarry.

Section 17, T 19N., R.6W.

Vaughn's Quarry is located near the quarter corner of Sections 16 and 17, on the south side of U. S. 23, and is used at present to furnish limestone for road surfacing in the county.

Several small flexures may be seen in the quarry. They are somewhat irregularly arranged, but usually cut across the general strike of the rocks.

The strike appears to be N 15°E. A dip of N 75°W at 90 to 100 feet per mile was observed. This rapid dip may be only a local condition of the quarry beds, but there is a dip of at least 6 feet in 350 feet or 90 feet per mile from the east side of the quarry to the west.

The following is a section taken here from the base to the top of the quarry:

Zone 1.

A gray, hard, calcareous, coarse sandstone. Where an abundance of calcite is present the sandstone has a greenish glassy appearance. 30 inches of this sandstone is exposed and the basal part becomes a very sandy limestone.

The top of this zone is marked by a thin but consistent streak of a tough black, arenaceous, carbonaceous, shale from 1 to 3 inches thick.

Zone 2.

9 inches of dark buff, dense, hard dolomitic limestone. On weathering, this limestone shows the remains of argillaceous material. It becomes coarser in the upper part and the top is often marked by a thin streak of black shale.

Zone 3.

6 feet of light gray to buff, medium to fine grained, massive limestone. The limestone is quite fossiliferous, and contains geodes and vugs of brown calcite. This is the Echinochonus zone and the following fossils were found: Bryozoa, Productidae, Straparollus, Crenopectin or Avicloptin, Echinochonus and Triplophyllum. The zone is further characterized by geodes of quartz and calcite, associated with vugs and veins of brown calcite. The upper part contains lime and chert nodules and concretions. The top of the zone is marked by 1 to 3 inches of greenish gray to buff shale containing calcite.

Zone 4.

4 feet of blue gray to grayish buff limestone.

The limestone is more grainy, argillaceous, and not so massive as in zone 3. It is most dense at the center and becomes more arenaceous towards the top. It contains calcite and quartz in veins and geodes with small and large limy chert concretions. The most abundant fossils were Lithostrotion, Zaphrentis, and Triplophyllum, with a few crinoid columns. The zone is marked at the top by 3 to 6 inches of dark brown nodular fine grained limestone in sandy brown shale.

Zone 5.

5 feet of tan fine grained, argillaceous sandstone which appears to be somewhat calcareous.

The sandstone contains silicified Lithostrotion. The zone is found only on the west side of the quarry due to the conditions of dip in the quarry rock.

Griffen Quarry.

The abandoned Griffen quarry is located in the NW $\frac{1}{4}$ of Section 1,

Arenac township. The strike here is N 60°W and the dip is S 30°W at 60 feet per mile. This outcrop may be divided into four zones.

Zone 1.

The lowest bed observable on the quarry floor is a coarse light gray to buff calcareous sandstone.

Zone 2.

1 foot of fine grained, gray to buff argillaceous limestone, finely laminated. The rock is hard and splits along the laminae.

Zone 3.

2 feet of fine grained, light brown, argillaceous sandstone. At the top are scattered nodules of calcite and chalcedony. The calcite is white, brown, and bluish; the quartz occurs as chert and chalcedony. Near the top the sandstone is more calcareous and contains small brachiopods resembling *Composita*.

Zone 4.

4 feet of limestone, the basal 1½ feet having thicker and more regular beds than the upper 2½ feet. The zone as a whole contains many small irregularly shaped lime and chert concretions. The limestone is grayish buff in the lower 1½ feet and gray in the upper part.

The upper 2½ feet is thinly and irregularly bedded and from a distance appears brecciated. The complete zone is fossiliferous, *Allorisma*, *Fenestella*, *Polypora*, *Echinochonus*, *Linoproductus*, *Crenopectin* or *Aviculopoctin*, *Triphyllum* and *Lithostrotion* being found. The upper zone also contains druses of calcite and chalcedony.

This is the *Echinochonus* zone of the Griffen quarry.

Kaven's Quarry (at Fire Tower).

The Kaven quarry is located near the east section line road in the SE¼ of Section 34, Mason township, just north of the fire tower. The strike here appears to be N 15°E and the dip NW 55 feet per mile. The lower part of this section resembles the section in Vaughn quarry.

Zone 1.

A gray, weathering to brown, coarse grained friable sandstone, the top only exposed. A fresh portion is very calcareous, and becomes friable on the leaching of the calcite. The top of this zone is marked by about 3 inches of black arenaceous laminated shale or black bituminous shaly sandstone.

Zone 2.

10 inches of dark to blue gray almost lithographic dolomitic limestone, the upper portion becoming nodular.

Zone 3.

6 to 7 feet of limestone.

(a) The zone is marked at the base by 6 to 18 inches of greenish gray to tan, hard arenaceous shale which grades upward into the overlying limestone. The shale often contains a layer of brown calcite, and abundant fossils of *Allorisma*.

(b) Above the shale lies 2 feet of gray to grayish buff, fossiliferous limestone, usually quite arenaceous and with carbonaceous laminations. It contains such fossils as *Echinochonus*, *Spirifer*, *Composita*, *Allorisma*, corals and bryozoa.

(c) Above the shale is 2 feet of gray more coarsely grained arenaceous limestone with carbonaceous laminations. It contains well rounded nodules of chert and lime, some of which are 6 inches in diameter. *Echinochonus* was found at the base of the zone. *Triplophyllum*, *Linoproductus* and *Allorisma* range throughout the zone.

(d) The top of zone 3 is composed of 1 to 2 feet of dark gray to buff, fine grained limestone, containing fewer nodules than the strata below. Many bryozoa such as *Polypora*, *Fenestella* and *Hallopora* are present.

Zone 4.

1 foot of gray arenaceous limestone, which contains many silicified *Lithostrotion* at the center. This zone is not exposed in the quarry, but may be found 300 feet south of the fire tower on the west side of the road. The zone overlies a dark gray, fairly dense limestone which is at the top in the quarry.

Zone 5.

1 foot of arenaceous limestone. The fossil, *Allorisma*, is common. Small quartz and calcite geodes are also present.

This ridge of Bayport limestone extending northwest from Point au Gres is along the regional strike, at least as far as the outcrop at Kaven's quarry. It is quite possible that the strike is changed to a marked degree farther northwest by a fold which is believed to pass through the center of Moffat township.

The thickness of the Bayport in Arenac County varied from 35 to 60 feet. A section in the Norm well in the NE $\frac{1}{4}$ of the SE $\frac{1}{4}$ of Section 3, Lincoln township, is given as 110 feet of which the lower 40 feet is sandstone. No other record of such a thickness for the Bayport can be found, though it is possible it thickened this much to the south.

The formation may often be locally absent and replaced by the Parma sandstone or both Parma and Bayport may be absent.

A visit was made to the Bayport quarry in Section 5, Wisner township, Huron County, for a comparison of the Bayport section there with the Bayport in Arenac County.

Limestone from the Bayport quarry is used as a flux in Saginaw besides such other uses as road surfacing and building stone. The following is a section taken in the quarry from the base upward.

Zone 1.

The base or floor of the quarry is a thin parting of black carbonaceous shale.

Zone 2.

16 inches of brown to dark buff, dense, cherty limestone.

Zone 3.

6 inches of dark limestone spotted with irregular streaks of light gray color.

Zone 4.

48 inches of light bluish gray, arenaceous, limestone.

Locally, the limestone is quite massive, containing vugs of calcite which are usually colored brown. The fossils *Echinochonus*, *Lithostrotion*, *Allorisma*, and a tribolite pygidium (*Phillipsia?*) were found.

Zone 5.

40 inches of dense, massive, light buff limestone which often changes laterally to a gray arenaceous limestone in the basal portion.

This zone contains lime and chert concretions, noticeably concentrated at the base. These concretions are both regular and irregular in shape and range in size from one half inch up to 4 to 5 inches in diameter. There are also a few vugs and geodes of calcite. A *Lithostrotion* and *Linoproductus* were the only fossils found.

Zone 6.

36 to 50 inches of light tan argillaceous limestone. The basal 2 feet of this zone is characterized by two layers of the coral, *Lithostrotion*, lying parallel to the bedding, evidently brought in from an outside source.

The upper part of this zone contains fewer corals, without the parallel orientation of those in the lower part of the zone. The zone as a whole also contains chert nodules and calcite geodes.

A test pit had been dug in the quarry 4 to 5 feet below the black carbonaceous shale which forms the quarry floor. The material excavated included very arenaceous limestone, calcareous sandstone, indications of a lenticular chert zone, and a fine grained, tan argillaceous sandstone. This

material was not seen in its proper order, but gave a good indication of the rock below the quarry floor.

On comparison, this Bayport section in Huron County is very similar in lithology and fossil content to the sections taken in Arenac County.

Few fossils were found in the quarry due to the freshness of the rock face exposed by quarry operations.

The sandy part of the section beneath the quarry floor compared somewhat to the sections along the Lake Huron shore at Bear Track Inn.

The finding of *Echinochonus* and *Linoproductus* besides other fossils reported from this section indicates that the *Echinochonus* zone of Arenac County is present in the Bayport quarry.

Michigan Formation.

The Michigan formation is composed of a series of shales, sandstones, limestones and gypsum. The beds of gypsum thicken and are exposed close enough to the surface to be of commercial importance to the north in the Alabaster quarry in Iosco County. The shales vary from blue, gray, to green in color and the limestones are usually dolomitic, hard and dark colored. Sandstones are common, and are brown or yellowish, and usually are fine grained and argillaceous.

There are not many outcrops of the Michigan formation in Arenac County and those that are found are small with no appreciable vertical exposure.

Outcrops

Outcrop Near Corner of Sections 10, 11, 14 and 15,
Whitney township, T.20N., R.7E.

The material examined from this outcrop (?) is in the drainage ditch that carries the water from the East Branch of the Au Gres River to Lake Huron. The rock is in large slabs and forms a small rapid in the ditch. It is claimed by people living nearby that bedrock was reached here when the ditch was dug. So it appears possible that this rock may at least be nearly in place. The rock found was of two types, a dense, hard, buff colored dolomite and a spotted black and buff sandy dolomite.

Outcrop on M. 65.

This outcrop is located in the northeast quarter of Section 1, Arenac township, about one eighth of a mile south of Big Creek, on M. 65. The outcrop is on the top of a ridge along a shallow road cut and extends 200 feet along the west side of the road.

Zone 1.

The base of the exposure is a bluish gray, medium grained, calcareous, micaceous sandstone.

Zone 2.

6 inches of gray plastic shale or clay.

Zone 3.

6 inches of medium grained greenish gray, very micaceous sandstone.

Zone 4.

2 feet of fine to medium grained, yellow, brown, and green mottled sandstone.

Back of the farm house at this locality a hole 5 feet deep had been dug through gray plastic shale resembling the shale of Zone 2.

Various other small outcrops of the Michigan formation were found in Sections 29, 14 and 20, in Turner township, and another a quarter of a mile northeast of the county line along the Detroit and Mackinac Railroad in Iosco County. These outcrops are usually of fine grained, argillaceous sandstones, and dense, dark dolomites. The outcrop in Iosco County is of gypsum overlaid by a fine grained yellow argillaceous sandstone.

The thickness of the Michigan formation varies from 35 feet to more than 260 feet. The thickest sections in the county apparently are in the structurally low area of Whitney township.

A well in the NW corner of the NW $\frac{1}{4}$ of the NE $\frac{1}{4}$ of Section 24, reports 264 feet of Michigan formation. The average thickness in the county is less than 100 feet.

Marshall Formation.

The Marshall formation is present in all parts of Arenac County except in the immediate vicinity of the Clayton oil field, and possibly in an area in the west central portion of Moffat township. In Clayton township the Marshall surrounds the outcrop of Coldwater shale which encloses the productive area of the Clayton Pool.

The Marshall formation is divided into an upper part, the Napoleon sandstone, and the Lower Marshall.

The Napoleon sandstone averages 100 to 250 feet in thickness. Well records show thicknesses of 150 to 200 feet in Lincoln township, 140 feet in Moffat township, 105 feet in Au Gres township, 165 feet to 270 feet in Standish township, and 143 feet in Turner township.

The Napoleon in this area, as determined from well records and

samples is usually a gray sandstone, with a definite greenish cast, medium grained in the upper part and the lower 20 feet quite coarsely grained. The sandstone outcropping in the Rifle River in Section 7, Clayton township, and in Section 12, Moffat township, may possibly be Napoleon. Much float sandstone with the greenish color is found along the course of the Rifle through these sections. It is possible that at some time of low water an outcrop may be found along the river.

The Lower Marshall varies from 70 to 250 feet in thickness. 70 feet is reported in Section 2, Lincoln township, and 250 feet in Section 3, Lincoln township. Other thicknesses reported are 235 feet in Deep River township, 190 feet in Au Gres, 125 feet in Standish, 97 feet in Moffat, and 210 feet in Mason township.

The Marshall formation is made up of argillaceous, micaceous sandstone, grits, and shales. The formation is occasionally red in the lower portion.

The Marshall formation does not provide a good structural marker, due to its variable thickness. The top of the Sunbury or Berea is the first dependable marker encountered in drilling in Arenac County.

Coldwater.

The Coldwater formation crops out in the productive area in the Clayton oil field and an outcrop may be in Moffat township.

The Coldwater consists of a thick series of blue gray, and gray shales, with some sandstone and limestone lenses. A red rock is reported 50 to 150 feet above the base of the formation, but does not appear consistently at any depth.

The "Weir sand"¹, common in the upper part of the Coldwater in Ogemaw County, is only occasionally found in Arenac County. The Coldwater formation varies from 865 to 1060 feet in thickness and averages 900 feet thick in the Clayton oil field.

Sunbury.

The Sunbury shales lie directly below the Coldwater shale. The Sunbury forms a good marker as the dark brown to black, pyritic shale is in decided contrast to the blue gray, plastic shales above. Contours drawn on the top of the Sunbury would show true structural conditions as the intervals below are quite consistent.

Thicknesses of 9 to 53 feet of Sunbury have been reported by drillers and the average thickness is 25 feet.

Berea-Bedford.

The Berea and Bedford formations underlie all of Arenac County,

1. E. A. Newman - Geol. of Ogemaw County-Progress Report #2. Geol. Sur. Division, Department of Conservation.

the thickness of the two formations being 150 to 200 feet.

The Berea section is much better developed in Arenac County than to the north and west in Ogemaw County. The thickness of the formation varies from 23 to 120 feet, with an average of 90 feet.

The Berea contains gas and in the Clayton field has shown production varying from slight shows to 24,000,000 cubic feet of gas. The gas produced from the Sterling structure north of Sterling was from the Berea.

The Berea is a fine grained, gray sandstone. Water is usually found near the base. The greatest gas production is also found near the bottom of the formation.

Contours drawn on the top of the Berea show no decrease in the intensity of the structure from the Dundee. This may be due to the pre-Berea erosion which acted to accentuate the Berea structure. The largest gas production is found in a syncline in the SE $\frac{1}{4}$ of Section 10, Clayton township, which probably represents an erosional channel which has been favorable for gas accumulation. (Plate 4)

The Bedford is a gray shale and often contains lenses of sandstone and limestone. The thickness varies from 50 to 150 feet, with an average of 75 feet. It is conformable on the underlying Antrim formation.

The Mississippian-Devonian

Antrim formation.

The Antrim shale is a dark brown to black, bituminous, pyritic shale. Occasionally drillers log lime and shell, which are probably portions of large clay ironstone concretions common to the Antrim or its equivalents wherever found. The lower part of the Antrim shale is Devonian. Careful analyses have not as yet been made of the Arenac section to determine how much of the shale is Mississippian or how much is Devonian.

The Antrim in Arenac County varies from 290 to 480 feet in thickness, but the average thickness of 375 feet prevails.

The Devonian System

The Devonian rocks which will be discussed include a section from the Antrim shale down to and including the Dundee formation. The Detroit River formation has been reported in only one well, the Lockhard-Dudley No. 1, Section 23, Mason township.

Traverse-Bell Formations.

The Traverse-Bell section varies from 765 to 900 feet in thickness, but the average of 800 feet is common.

The first Traverse lime below the Antrim shale is generally a brown lime or dolomite 10 to 20 feet in thickness. Below the limestone are usually 200 feet of gray shale, lime, and dolomite; then a section of alternating gray and brown limestone and gray shale, often with chert in the basal portion of the limestone.

The basal part of the Traverse is shaly and the contact with the underlying Bell shale is indefinite, as the Bell in the Arenac area does not have its characteristic black or dark color. Therefore, the Bell is not usually differentiated from the Traverse and the section is reported as Traverse-Bell.

In this area the Bell is a blue to dark gray shale averaging 100 feet in thickness.

A salt brine, often flowing with some pressure, is found at or within 15 feet of the top of the Traverse. The presence of this water zone makes it necessary to drill with a hole full of water to the Dundee or to run the six inch casing partly through the Traverse formation to shut off the brine.

Gas is sometimes found in the Traverse, an estimated 6,000,000 cubic feet of gas being reported from the Buffalo Land No. 2 in Section 10, Clayton Township. Oil shows have been found, but no commercial production has as yet been found in the Traverse lime.¹

Dundee Formation.

The Dundee formation, which furnishes the commercial oil production in the Clayton field, consists of brown to buff limestone. The limestones are usually fairly dense, but in places are earthy or crystalline. A little dolomite is sometimes present as inclusions in the limestone matrix, causing the limestone to have a slightly greater porosity than where the inclusions are absent.

The Lockhard Dudley well, in the SE $\frac{1}{4}$ of the SE $\frac{1}{4}$ of the NE $\frac{1}{4}$ of Section 25, T.20N., R.5E., Mason township, is reported to have been drilled through the entire Dundee section. It is believed that the Detroit River was reached at 3177 feet. If this interpretation is correct, the Dundee has a thickness of 387 feet. Other wells have been drilled into the Dundee from a few feet to 250 feet.

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1. Since the completion of this report a small well in the Traverse limestone has been completed in Section 26, Adams township, for 50 bbls. Initial acid production was found 21 feet in the Traverse.

Chapter IV

STRUCTURE

Arenac County is on a segment of the northeastern edge of the central portion of the Michigan basin and therefore the regional slope or dip is southwestward into the basin, and the general strike of the rock formation is northwest-southeast.

However, this monoclinial regional structure is modified by three northwest-southeast structural folds which cross the county. The northernmost fold is in Clayton township and is the structure on which the Clayton oil field is located. This fold is an extension of the West Branch "high" which continues on into Saginaw Bay. (Plate 3)

To the south another structural fold extends from near Alger in Moffat township southeastward to north of Sterling and Standish and into Saginaw Bay.

A third structure apparently is about two miles south of Standish. It continues northwestward through Gibson township, Bay County and southeastward into Saginaw Bay about one mile south of Saganing. Two small producing wells have been drilled in Sections 11 and 12, Gibson township, Bay County, on this structure. The well in Section 12 produced 40 barrels initial from the Traverse and the well in Section 11 produced 20 barrels initial from the Traverse. These wells are believed to be on the southwest flank of this "high." (Plate 3)

The syncline between the West Branch and Rose City¹ highs (Ogemaw County) extends southeastward and enters the eastern part of Arenac County. Thus the eastern townships, Turner, Whitney, and Sims, are structurally probably the lowest parts of Arenac County, a condition opposed to that expected when only the regional structure is considered.

The folds in Arenac County are characterized by their narrowness, by their steep dips and rapid reversals, conditions which seem to be characteristic of the folds in the northern counties and may indicate that they may have been nearer to the deforming force or stress.

For convenience the structures discussed in this report are named the Clayton, Sterling, and Standish structures.

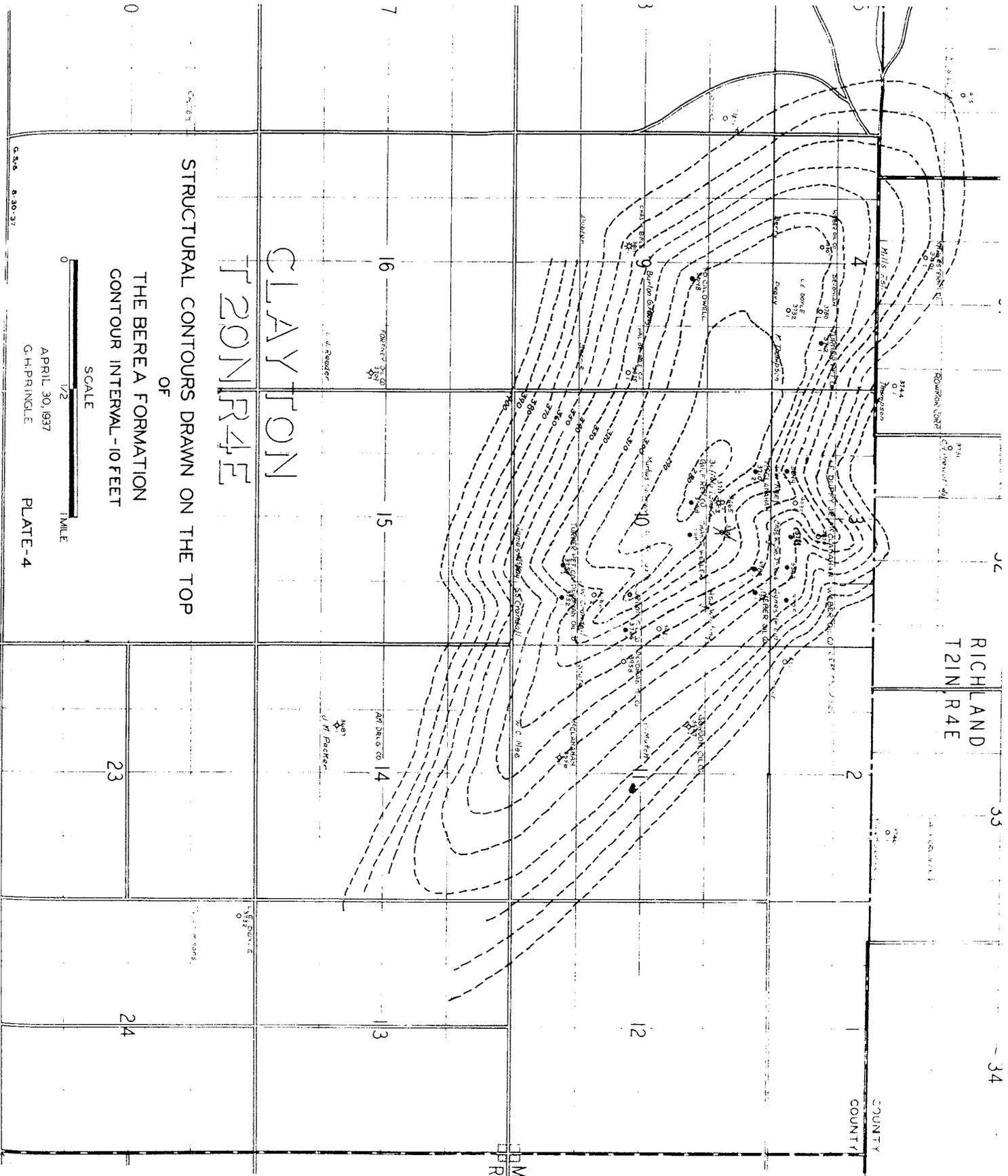
Clayton Structure

The Clayton structure on the southeast extension of the West Branch structure² is an asymmetrical anticline with a northwest-southeast

1. E.A. Newman - Geology of Ogemaw County and West Branch Oil Field, Progress Report No. 2 - 1936, Plate No. 3.
2. E.A. Newman - Geology of Ogemaw County and West Branch Oil Field, Progress Report No. 2 - Page 17.

RICHLAND
T2IN R4E

COUNTY
COUNTY



CLAYTON
T20N R4E

STRUCTURAL CONTOURS DRAWN ON THE TOP
OF
THE BEREA FORMATION
CONTOUR INTERVAL -10 FEET

SCALE
0 1/2 MILE

APRIL 30, 1937
G.H. PRINGLE
PLATE-4

C.S.G. 8-30-37

trend. It plunges southeastward 50 to 60 feet per mile at right angles to the regional dip. This plunge is accentuated near the producing part of the structure.

The northeast flank is the steeper, dipping about 200 feet per mile. The dip of the southwest flank is approximately 100 feet per mile.

The length of the oil pool along the long axis of the anticline is about 2 miles. It is limited on the southeast by the dry Mee well in the NE $\frac{1}{4}$ of SE $\frac{1}{4}$ of SW $\frac{1}{4}$ of Section 11, and on the northwest by the dry Rowmor-Thompson No. 1 in the NW $\frac{1}{4}$ of SE $\frac{1}{4}$ of SW $\frac{1}{4}$ of Section 31, Richland township, Ogemaw County. Both wells were drilled into water. The productive area across the high is still somewhat undetermined, but probably lies within the 1650 foot contour. This gives the field a possible width of 1 mile.

The Clayton structure dies out so rapidly to the southeast that the bedrock again assumes the normal attitude of the regional structure. The outliers of Bayport limestone found at Keystone dam in Section 30, Burleigh township, Iosco County, and the outcrops in Whitney and Sims townships, Arenac County, are in the syncline which is directly northeast of the West Branch structure.

The attitude of the extension of the Clayton structure in Au Gres township is problematical as we have only one well on which to base the position of the contours. However, the outcrop of Bayport limestone on Point Au Gres shows a dip to the northwest which is opposite to the regional dip in this area. This may be only a local flexure, but it may be an indication of the reversal in the southeast plunge of the Clayton structure.

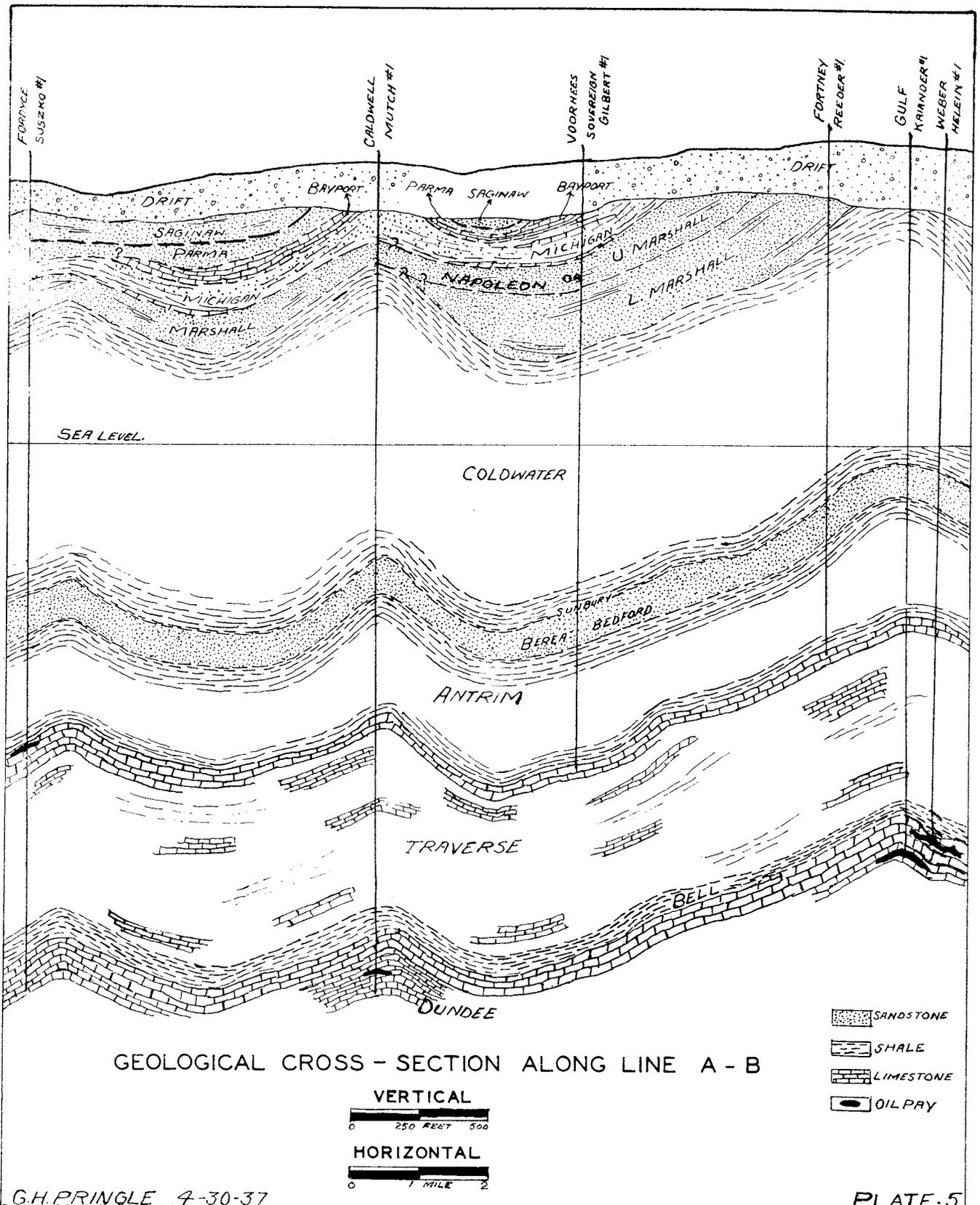
In the Clayton field proper, the intensity of the folding does not appear to lessen with depth down to the top of the Berea. The structure contoured on the top of the Berea appears to be even more accentuated than the Dundee structure.

The minor folds shown by the contours drawn on the Berea may be caused by depositional conditions. The Berea may have been deposited in channels eroded into the Bedford surface.

Sterling Structure

The Sterling structure is on a fold trending northwest-southeast with its long axis north of Sterling.

The outlines of the Sterling structure are at this time (April 1937) rather indefinite. It is possible that a closure exists in the area between Sterling and Standish. A sandstone outcrops on the West Branch of the Pine River due north of Standish. This outcrop is located well down on the south flank of the structure. It is believed at present that this is an outcrop of Parma Sandstone, although it is possible that more evidence may prove it to be a sandstone in the Michigan formation.



GEOLOGICAL CROSS - SECTION ALONG LINE A - B

G.H. PRINGLE 4-30-37
 G.S. - 4 8-30-37

PLATE 5

Two wells have been drilled northeast of Sterling in Sections 16 and 17. The Michigan sandstone was found in them directly below the drift. These wells appear to be up on the flanks of the structure with closure within the 2000 foot contour between them. The evidence seems to show another closure to the northwest along the trend of the Sterling high near the village of Alger. Apparently a thin section of the base of the Marshall underlies the drift and it is therefore possible that the Coldwater formation may crop out below the drift in the near vicinity.

Gregory¹ reports a water well drilled in the NW $\frac{1}{4}$ of Section 17, Moffat township, which was drilled to a depth of 500 feet. The record of the upper 200 feet of the well is not quite clear, but apparently represents 200 feet of drift lying above 300 feet of blue shale with no water. Undoubtedly the 300 foot section of blue shale is Coldwater shale and indicates a Coldwater outcrop or it at least indicates a thin Marshall section below the drift. If the 200 feet is not all drift there can be but a thin section of the Marshall above the Coldwater, judging from the drift conditions in the township.

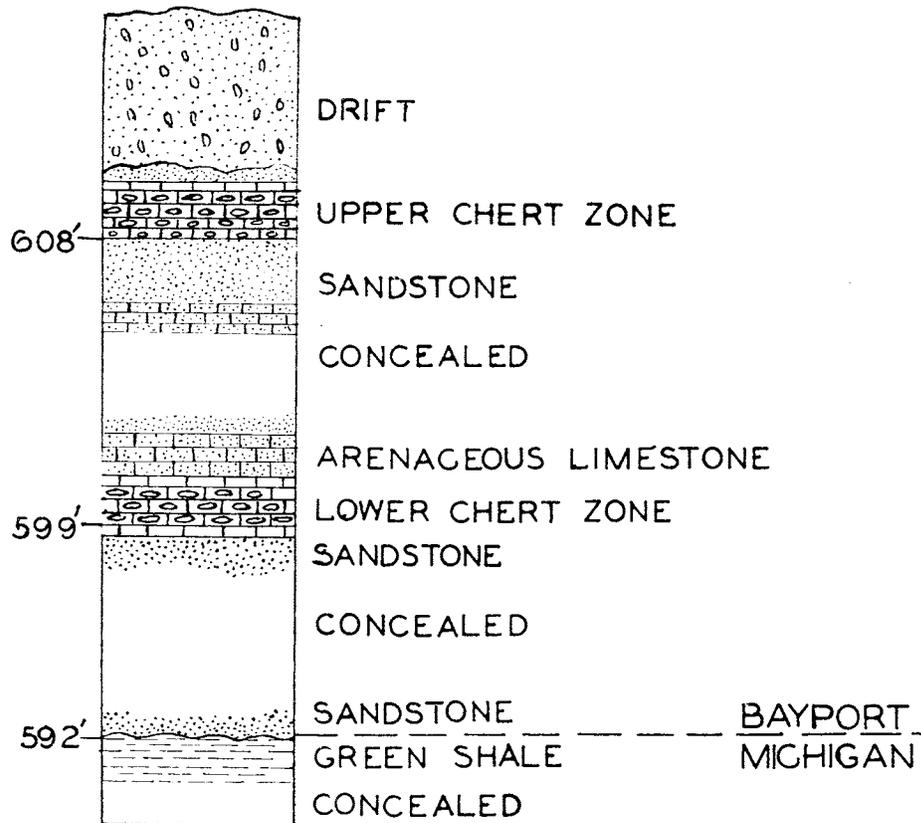
For this reason the areal geology map is quite theoretical in the area about Moffat township as not enough information is available to show any change in the strike of the rocks which might be due to the influence of this indicated structure.

It appears reasonable to think that this area may be possibly structurally 200 feet higher than at Sterling, and also larger, extending into Bourret township, Gladwin County.

Standish Structure

The trend of the fold south of Standish is rather indefinite as determined by our present meager information. Its axis in Standish township is more indefinite, but probably lies south of the well in Section 19. The wells in Gibson township, Bay County, are believed to be on the southwest flank of the structure.

1. W.A. Gregory - *ibid.* - 2 - Page 47, 85



COMPOSITE SECTION ALONG LAKE HURON
 IN SECTION - 13-T20N-R7E
 APRIL 20, 1937

G.H. PRINGLE

PLATE - 6

Chapter V

OIL AND GAS PRODUCTION

Commercial oil and gas were discovered in Arenac County in the fall of 1936 in an extension of the West Branch structure of Ogemaw County into Clayton township, T.20N., R.4E.

Production of oil and gas in the county is now (April 1937) from the Clayton field in Sections 3, 4, 9, and 10 of Clayton township.

Both gas and oil are found in the Clayton field, gas in the Berea sand and oil in the Dundee limestone.

Gas Production

The gas, except in two wells, the McClanahan, Buffalo Land No. 1, and the Bell, Dobler No. 1, has been shut off by the 3 inch casing run through the Berea formation. The amount of gas reported from the various wells ranges from mere shows to 24,000,000 cubic feet per 24 hours. The largest well is the Devonian-Crandall No. 1 in the SE $\frac{1}{4}$ of Section 10.

The greatest gas production is in the southeast quarter of Section 10. A structure map drawn on the top of the Berea indicates a small syncline superimposed on the major Clayton structure. In or near this syncline gas wells with the largest initial productions have been drilled; The Gordon-Crandall No. 2 - 15,276,000 cu. ft., the Devonian-Crandall No. 1 - 24,000,000 cu. ft., and the Turner-McKay - 12,000,000 cu. ft. Other wells have gauged 3,000,000 to 8,000,000 cu. ft. of gas. (Plate 4)

Wells along the northwest-southeast trend of the Clayton structure north of the Buffalo Land No. 2 have had only small shows of gas whereas wells south of this line have produced the largest amounts. Apparently gas is concentrated on the southwestern flank of the Clayton structure, a statement which may be disproved by future drilling.

This localization of gas concentration may be due to the apparent offset to the southwest of the general Berea structure in relation to the general structure of the Dundee. However, the Berea "structure" may be only a depositional condition of the Berea over the Dundee fold as the highest points on both structures are in the same position as the highest Berea and the highest Dundee are both reached in the Buffalo Land Company No. 1, the Gulf Refining - Kaiander No. 1, and the Weller-Crandall No. 1 wells.

The amount of gas recoverable is a problem to be considered. The gas tends to blow down quite rapidly. The Devonian-Crandall No. 1 blew down from 24,000,000 to 8,500,000 cu. ft. in 6 days of open flow and the Turner-McKay blew down from 12,000,000 to 8,000,000 cu. ft. in 12 hours.

This tendency toward rapid depletion and the proximity of water to the greatest gas production, makes a high recovery improbable.

Through the courtesy of Ralph E. Davis, Engineer, of Pittsburgh, a porosity and permeability test of some samples of Berea sand from the Gordon-Crandall No. 2 well in the SE $\frac{1}{4}$ of Section 10, Clayton township, was obtained. The tests were made by the Oil Core Testing Laboratories, Inc., Titusville, Pennsylvania, and show the following results:

Sample	Percent Porosity	Permeability (Millidarcies)
No. 1	25.69	374.19
No. 2	14.97	1.43

The Crandall well had an initial production of 15,276,000 cu. ft. per 24 hours which in two hours blew down to 13,000,000 cu. ft.

In comparison, a sample of "Michigan stray sand" from the Taggart-Johnson No. 8, SW $\frac{1}{4}$ of Austin township, T.14N., R.9W., Mecosta County, had a porosity of 23.75 percent and a permeability of 1128.85 in millidarcies. The initial production in this well was 8,800,000 cu. ft.

There is a possibility of gas production from the Berea sand in the Sterling structure. The Caldwell-Mutch No. 1, in the SE $\frac{1}{4}$ of Section 17, Deep River township, T.19N., R.4E., had 100,000 cu. ft. of gas from the Berea and The Central Drilling Company, Fisk No. 1 in the SE $\frac{1}{4}$ of Section 16 had a show. These wells may be located on opposite flanks of the Sterling high, and may have an area of gas production between them. Gas may possibly be found along this structure northwest of Alger.

Wells drilled in the proximity of the Standish structure have had no shows, but drilling in a favorable location may reveal gas possibilities in the Berea in this structure also.

Oil Production

The discovery well, McClanahan-Siegnous No. 1, in Section 3, Clayton township, was completed November 25, 1936, with an initial production of 1297 barrels and an initial production after acidizing of 1697 barrels.

The Devonian Oil Company and Redman Oil Company, Peavy No. 1, in Section 4, had an initial natural production of 362 barrels which was increased to 1600 barrels by acid treatment.

The other wells have had much smaller initial productions. The Weber-Helein, east offset of the discovery well had an initial acid production

of 625 barrels, the Seigneous No. 3, the west offset, had an initial production of 100 barrels and the Seigneous No. 2, the south offset, had an initial production of 200 barrels. Apparently the two larger wells are located in more porous zones in the Dundee. Five or possibly six pay zones are found in the Dundee.

The largest production has been found in an upper pay zone extending from the top of the Dundee to 40 feet in. The Seigneous No. 1 and Devonian, Redman, Peavy No. 1 are both obtaining production from this upper pay.

The other pay zones are found at 80 feet; 115 to 130 feet; 145 to 160 feet; 175 to 180 feet; and the Turner-Thompson No. 1 found the deepest pay at 217 feet below the top of the Dundee in the limestone. These pays are not found in all wells, indicating again that porosity is local in the formation. Porous zones extend both laterally and vertically.

Again, the Seigneous No. 1 is producing well down the north flank of the Clayton structure, whereas the Peavy No. 1 is well toward the top. This indicates again that the controlling condition of the production may be porosity. The amount of gas in the Dundee is not great. In the majority of the wells the oil rose a few hundred to more than 2000 feet in the casing; however, some wells had natural flow varying from 18 barrels in the Gulf Refining Company-Kaiander No. 1 to 1297 barrels in the McClanahan Company-Seigneous No. 1. The use of acid increased production in these wells to 100 and 1690 barrels respectively.

Edge water has been encountered in four wells in the Clayton field. The Gordon-Mutch No. 1, T.20N., R.4E., Section 11, had water at 200 feet in the Dundee, the McClanahan-Mee No. 1, T.20N., R.4E., Section 11, at 164 feet, the American Drilling Company - Packer, T.20N., R.4E., Section 14, at 236 feet, the Rowmor-Thompson No. 1, T.21N., R.4E., Section 31, Ogemaw County, drilled into water 110 feet below the top of the formation. The water drive is not great and the Dundee water in the Clayton field will probably be easily controlled.

The producing area of this field will be approximately 1200 acres, with the producing area, for the most part, within the 1650 foot contour on the Dundee structure. There may be some production from wells in which the Dundee top is at lower levels, but these wells will probably be found to be similar to the Weber-Helein in the SW $\frac{1}{4}$ of SE $\frac{1}{4}$ of SE $\frac{1}{4}$ of Section 3 (Plate 3) where conditions of accumulation are no doubt controlled by minor flexures.

The ultimate recovery from the Clayton field will probably be 2500 to 3000 barrels per acre for the productive area, although a few leases have now produced and probably in the future will exceed this amount. The characteristics of the oil and production appear very similar to production in the West Branch pool.

The wells in the Clayton field are usually drilled with cable tools; however, a few have been drilled by rotary into the Traverse and then completed with cable tools.

The 10 inch casing is set in the Coldwater below the drift, and the $8\frac{1}{4}$ inch casing is cemented through the Berea to shut off the Berea gas. The $6\frac{5}{8}$ inch casing is usually set through the water-bearing portion of the Traverse to avoid drilling with a hole full of water. The $5\frac{3}{16}$ inch is set on top of or a short distance into the Dundee.

CONCLUSION

Three structures are present in Arenac County: The Clayton structure which is producing at the present time; and the Standish and Sterling structures which have favorable possibilities for oil production in the future.

The extreme eastern portions of the county made up of Whitney, Sims, and portions of Turner and Au Gres townships, appear at present doubtful as to the possibility of oil production; however, future drilling may reveal that this area does have a favorable structure present.