GEOLOGY AND ECONOMICS

OF THE

CRYSTAL-FERRIS OIL AND GAS FIELD

By

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C O N T E N T S

ILLUSTRATIONS

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INTRODUCTION

Location.

The Crystal-Ferris oil field is situated in the central part of the lower peninsula of Michigan in northern Crystal and southern Ferris townships, Montcalm County. The producing area lies about twenty-one miles south of the city of Mount Pleasant and one mile northeast of the resort town of Crystal.

Acknowledgements.

The writer is indebted to members of the Department of Geology of the University of Michigan for aid during the preparation of this thesis; to Drs. A. J. Eardley and T.S. Lovering under whose guidance it was prepared; and to Drs. G. M. Ehlers and R. L. Belknap for helpful suggestions. Messrs. Kenneth Gorton, F. R. Frye, and Gerald Eddy of the Michigan State Geological Survey kindly offered the writer access to state well records.

GEOLOGY

Topography

Relief. - The area is one of low relief, surface elevations ranging from about 770 feet to 900 feet above sea level. There is a gentle regional slope from northwest to southeast. The producing area in Crystal township is almost level, averaging approximately 790 feet above sea level, but low hills rise to the north in Ferris township.

Drainage. - The field lies on the divide between Lake Huron and Lake Michigan, the divide crossing the field in a northwest-southeast direction. Drainage to these two lakes is through the Saginaw and Grand river systems, respectively. The northern part of the field is drained by Ferris Creek, a headwater tributary of the Saginaw River system. The southern part is drained by two small creeks of the Grand River system. Duck Lake, the site of several well locations at the southern edge of the field, extends 1 mile northeast-southwest and ½ mile northwest-southeast in sections 10 and 11, Crystal township.

Stratigraphy

There are no outcrops of bed rock in the area, inasmuch as the Paleozoic section is covered entirely by glacial

SYSTEM	FORMATION	COLUMNAR SECTION	DESCRIPTION OF ROCKS
QUATERNARY	DRIFT		360'± Clay, sand, gravel, boulders
PERMO-CARBONIFEROUS	"RED BEDS"		30'± Sandstone, shale, red
PENNSYLVANIAN	SAGINAW		300' Sandstone, white, black shale, dolomite; pyrite
PENNSYLVANIAN	PARMA		20'± Sandstone, white
	Unconformity		
MISSISSIPPIAN	BAYPORT		40'± Dolomite, brown and gray, sandstone, shale
MISSISSIPPIAN	MICHIGAN		285' Shale, gray, gypsum, anhydrite, dolomite, sandstone. Gas
	Unconformity		
MISSISSIPPIAN	NAPOLEON		100' Sandstone, white
MISSISSIPPIAN	LOWER MARSHALL		100' Sandstone, shale, micaceous red, gray
MISSISSIPPIAN	COLDWATER		1050' Shale, gray, blue, brown and red dolomite
	Unconformity		
MISSISSIPPIAN / DEVONIAN	ANTRIM		425' (total) Shale, black, brown
	Unconformity		
DEVONIAN	TRAVERSE		475' Limestone, dolomite, brown, white, bluish-gray shale, pyrite. Oil
	Unconformity		
DEVONIAN	MONROE		Dolomite, brown, black. Oil

PLATE I.–A GENERALIZED COLUMNAR SECTION OF THE CRYSTAL-FERRIS FIELD.

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drift. As in other oil and gas fields of central Michigan, stratigraphic and subsequent structural studies must be conducted entirely on the basis of evidence afforded by well samples, drillers' logs, and scout reports.

Devonian

Monroe formation. - The term Monroe is used only tentatively for the dolomite below the traverse from which the production has come, but the age of the producing formation has not yet been definitely established. Eddy[1] has reported that one well encountered typical Dundee limestone at the base of the Traverse. Other than this, the known occurrences of the producing formation consist of brown and black dolomite.

The single producing horizon ranges from the base of the Traverse to about 22 feet below. The single pay horizon commonly ranges from 1 to 6 feet in thickness. Edgewater is immediately below, so that wells are usually drilled carefully into the formation just to the "pay" and no deeper. A few wells reporting substantial initial production have proved disappointing because of encroach-

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[1] Eddy, G.E., The Geology of the Crystal Field, Paper read before Michigan Academy of Science, March, 1936.

ment of edgewater and drowning. Others have produced large quantities of brine along with the oil.

In some respects the producing formation is analogous to that at the Vernon pool in Vernon Township, Isabella County about 33 miles north of the Crustal-Ferris field. In both fields the producing formation is chiefly dolomite; oil and water occur near the base of the Traverse; and production is spotty. Fitzgerald and Thomas[2] believe

[2]Fitzgerald, P.E. and Thomas, W.A., The Occurence of Fluorite in the Monroe Formation of the Mt. Pleasant Pool, Papers Mich. Acad. Sci., Vol. XVI, pp. 415-421, 1931.

that the occurrence of fluorite indicates a pronounced unconformity at the base of the Traverse in the Vernon pool and place the producing formation in the Upper Monroe (Detroit River). Newcombe[3] states, and shows by an

[3]Newcomb, R.B., Oil and Gas Fields of Michigan, Geol. Surv. Mich., Pub. 38, Geol. Series 32, p. 166, 1933.

isopach map that oil and water horizon in the Vernon field occur much nearer the base of the Traverse than in other Mount Pleasant fields, where the Dundee limestone is the producing formation. This interval for the productive area of the Vernon pool is about the same as that in the Crystal-Ferris field.

Another consideration which may throw some light on the age of the beds is the position of the "black-water" horizon. Few wells in the Crystal-Ferris field have drilled deep enough to reach the top of this horizon but logs of those which have, report it to be 20 to 50 feet below the base of the Traverse. In a study of Gratiot County oil wells, Gorton[4] found that this interval decreased from the eastern to the western part of this

[4]Gorton, Kenneth, Personal Conversation.

county, i.e., to the part adjacent to the eastern boundary of Crystal and Ferris townships. The "black-water" horizon in other Michigan areas is usually below the top of the Monroe. Newcombe[5] states that in most

[5]Newcombe, R. B., op.cit., p. 97.

wells this water horizon has been found 30 to 50 feet below the Detroit River (Upper Monroe) and Dundee break.

While the foregoing evidence may not warrant a positive conclusion, regarding the age of the producing formation, there is probably an important pre-Traverse unconformity.

Traverse formation. - At the base of the formation is the so-called Bell shale, considered by some a member of the Traverse "group." This subdivision is not recognized by the Committee on geologic names[6] of the

[6] Wilmarth, M. Grace, Tentative correlation of the named units of Michigan (June 1, 1929).

U. S. Geological Survey, however, the Traverse formation being considered by them a single lithologic unit.

This formation is distinguished from the overlying Antrim black and brown shales by the contrast with the limestone beds of the Traverse. The line of separation is not a sharp one, however, since there are beds of shale near the top of the Traverse. In the Crystal-Ferris field, the thickness of the Traverse averages about 475 feet as contrasted with 600 feet in the Mount Pleasant fields to the northeast. A small amount of petroleum is produced from the formation. Crude obtained from the Traverse is notable in that it is free from sulphur.

Mississippian System

Antrim shale. - The contact between the Coldwater formation and Antrim shale can be discerned by means of two criteria; (1) the presence of red dolomite and shale near the base of the Coldwater and (2) the distinct darkening of color below the contact. The color of the Antrim is both black and dark brown. The latter color is probably due to spore cases of Sporangites huronensis.[7]

[7]Ehlers, G.W., Personal Conversation.

Heretofore, the Antrim has been classed as both Devonian and Mississippian, because fossils have been found characteristic of these separate systems in the upper and lower part of the peninsula. G.W. Ehlers[7] favors restriction of the term Antrim to the Mississippian part of the formation. Newcombe,[7a] however, does not divide the formation placing

[7a]Newcombe, R. B., Op.cit., p. 22.

the lower part in the Devonian.

Coldwater formation. - This consists chiefly of about 1050 feet of gray shale that retains remarkably constant lithologic characteristics throughout. In the Gulf-Barger well No. 1, (Appendix), the upper 42 feet was of soft shale, and the underlying 1014 feet of strata of hard shale. There are also several thin beds of brown dolomite, and some pyrite. Near the base of the formation is a horizon of red dolomite and shale.

Absence of Sunbury, Berea, and Bedford formations. - These formations, commonly reported from other areas in central Michigan appear to be absent in the Crystal-Ferris field.

Lower Marshall "Red-Rock." - The red-colored sandstones and shales of this formation form a distinct lothologic unit, but the demarcation from the Upper Marshall is not usually a very clean cut one. In general, at this contact, where the hue of the rock becomes a pronounced red throughout, the formation may be considered lower Marshall. Thickness of the formation is about 150 feet.

Napoleon (Upper Marshall) formation. - At the top of the Marshall formation there is probably a slight unconformity. Thomas[8] and Kirkham[9] have presented the evidence for this break. Below this the Napoleon formation is com-

[8] Thomas, W.A., A Study of the Marshall Formation in Michigan, Michigan Academy of Science Papers, Vol. XIV, pp. 487-498, 1930.

[9] Kirkham, Virgil R.D., Unconformity at the top of the Marshall Formation in Michigan, (Abstract) Geol. Soc. America Bull., Vol. 43, pp. 137-138, 1931.

monly a sandstone, white, gray, and brown in color. Near the base of the formation in the Crystal-Ferris Field, brown and pink colors predominate. Similar occurrences in the Mount Pleasant area have been explained by Newcombe[10] as the result of reworking of Lower Marshall

[10] Newcombe, R. B., Oil and Gas Fields of Michigan, Geol. Surv. Mich., Pub. 38, Geol. Series, 32, p. 160, 1930.

"Red-Rock" and its mixing with the other source material of the Napoleon formation. The formation is about 100 feet thick.

Michigan formation. - The Michigan formation is usually set off sharply from the overlying Bayport beds. It is commonly composed of gray shale and gypsum with some anhydrite, and brown dolomite. Near the base of the formation is the so-called Michigan "Stray" sand, which as in other fields of Michigan is the chief gas producing horizon. This sand is very similar lithologically to the underlying Marshall sandstone. Thickness of the whole formation is about 285 feet.

Bayport limestone. - The Bayport formation probably underlies disconformably the Pennsylvanian strata. It consists of limestone, dolomite, black and gray shale, and white sandstone. Its thickness is variable but averages about 40 feet.

Pennsylvanian System

Parma sandstone. - Where separable from the Saginaw, the Parma is usually composed of white sandstone. Its thickness in the Crystal-Ferris Field varies greatly but commonly is about 20 feet.

Saginaw formation. - The Saginaw is distinctly separable from the overlying rocks in the Crystal-Ferris Field but cannot always be differentiated from the underlying Parma formation. It consists of interbedded white sandstone, black, gray, and blue shale, and dolomite. The thickness of the Saginaw averages about 300 feet.

Permo-Carboniferous

"Red-Beds." - The presence of the "Red-Beds" in the field has been inferred from drillers' logs which report red sand and shale about 30 feet in thickness at the base of the drift. The most recent geologic map of Michigan,[11] apparently using this interpretation, places

[11] Martin, H., Shown before Michigan Academy of Science, March, 1936.

the boundary between the "Red-Beds" and underlying Pennsylvanian strata along the western and northern edge of the field. The interpretation, however, should be regarded as tentative. It is uncertain whether the reported "Red-Beds" are Permo-Carboniferous or the lower part of Pleistocene drift.[12]

[12] In Mich. Geol. Surv., Well Records, reported sediments of red color have been correlated with both the lower drift and the Permo-Carboniferous.

Pleistocene

Drift. - The surficial deposits of the area are glacial till and outwash gravels, formed by the Saginaw lobe of the Laboradorian ice sheet.[13] Well samples are not

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[13]Leverett, Frank, Map of the Surface Formations of the Southern Peninsula of Michigan, U.S. Geol. Survey and Mich. Geol. Survey Pub., 1924

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usually taken of glacial drift but some of the drillers' logs report clay, shale, sand, gravel, and boulders. The thickness of the drift varies but averages about 350 feet for the field.

Structure

Regional.- The lower peninsula of Michigan is a structural basin, consisting of Pre-Cambrian rocks overlain in normal succession by the Paleozoic strata. The latter dip from all sides toward the center of the peninsula.

The Crystal-Ferris field lies about 28 miles south of the deepest part of the Michigan Basin. Wells drilled north of the field show that there is a regional dip to the north of about 25 feet per mile.

A northwest-southeast anticlinal high connecting the Crystal-Ferris field and the Millbrook-Hinton-Belvi-

PLATE 3.- CROSS-SECTION ALONG AA' PLATE 2.

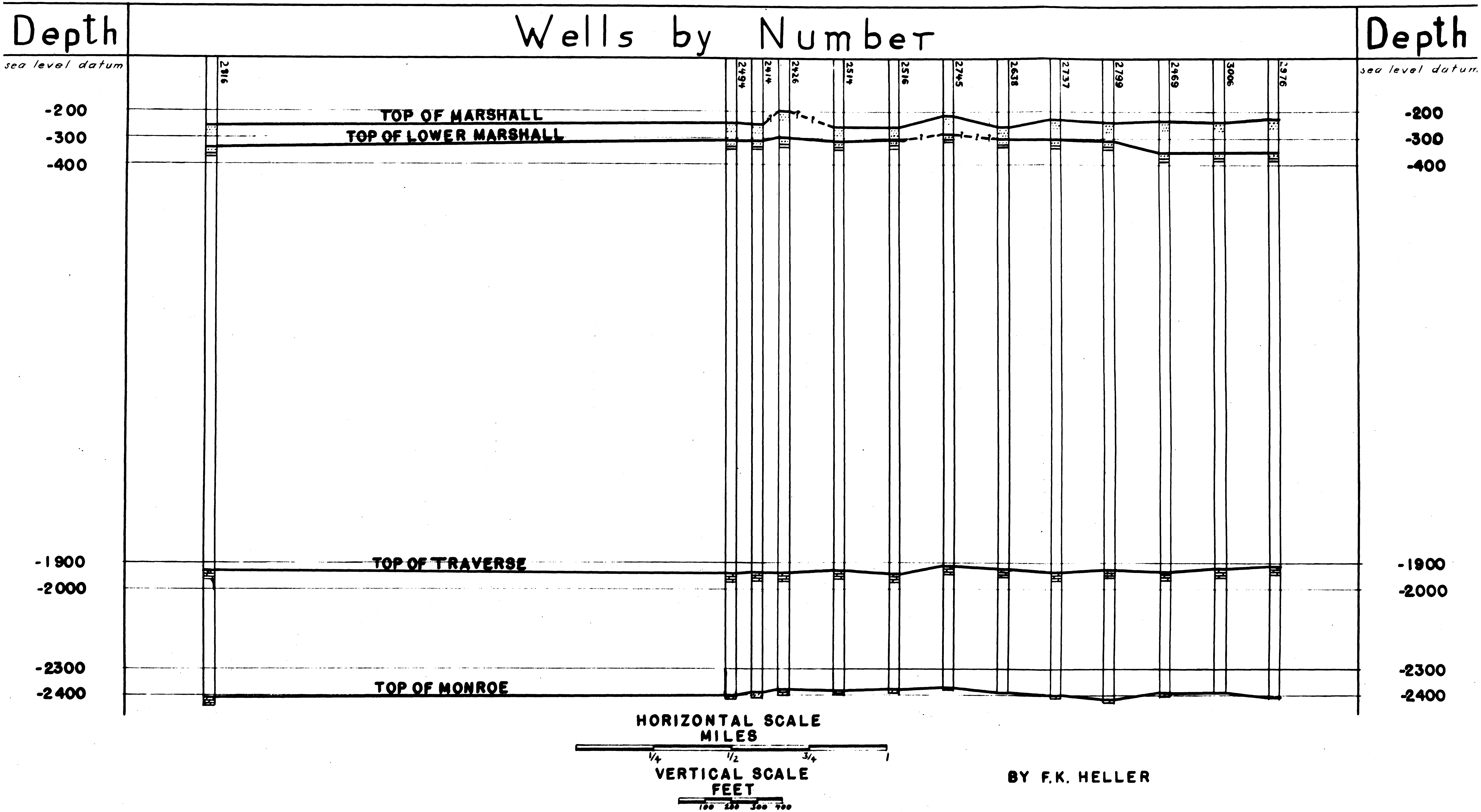

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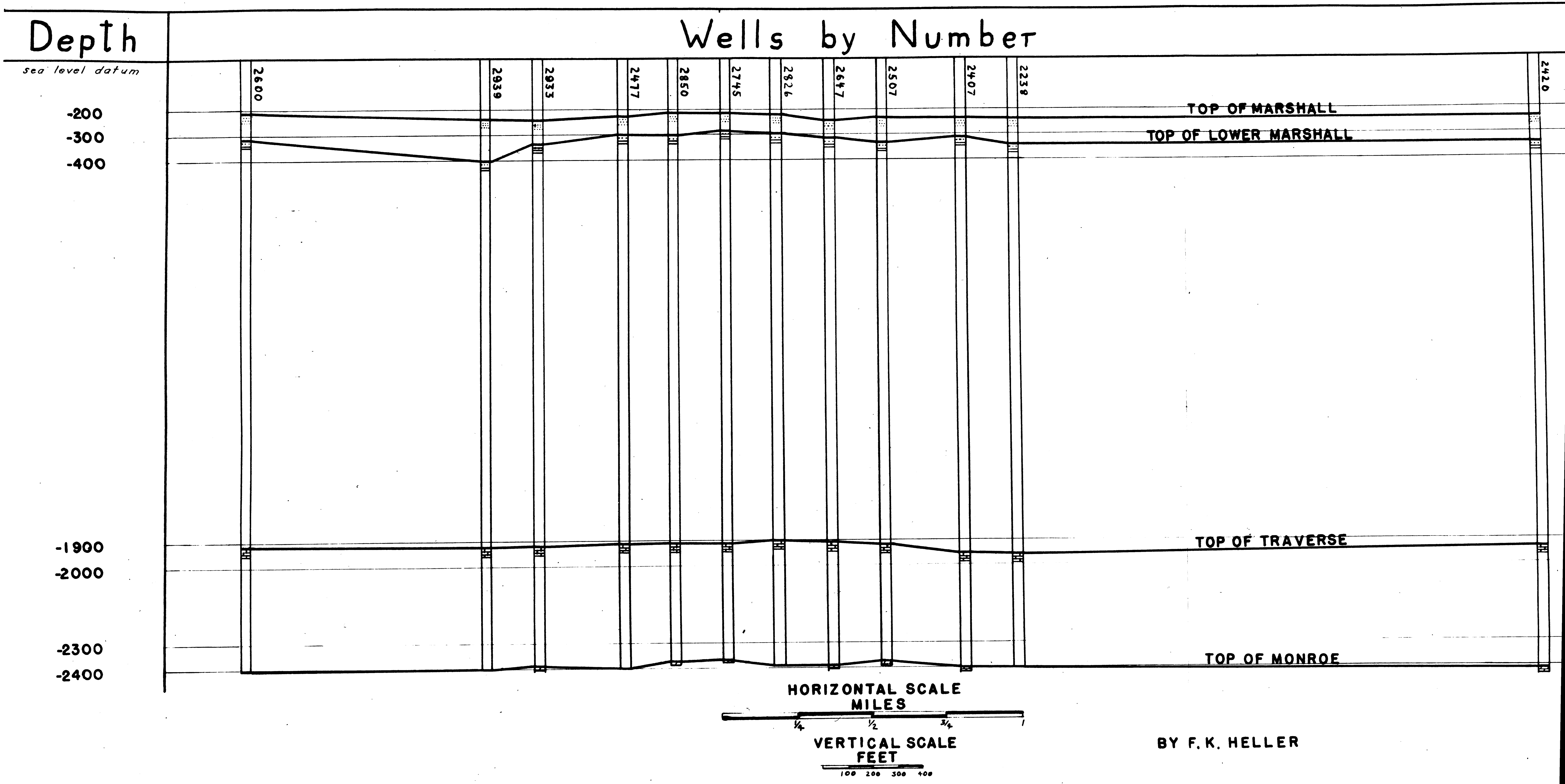
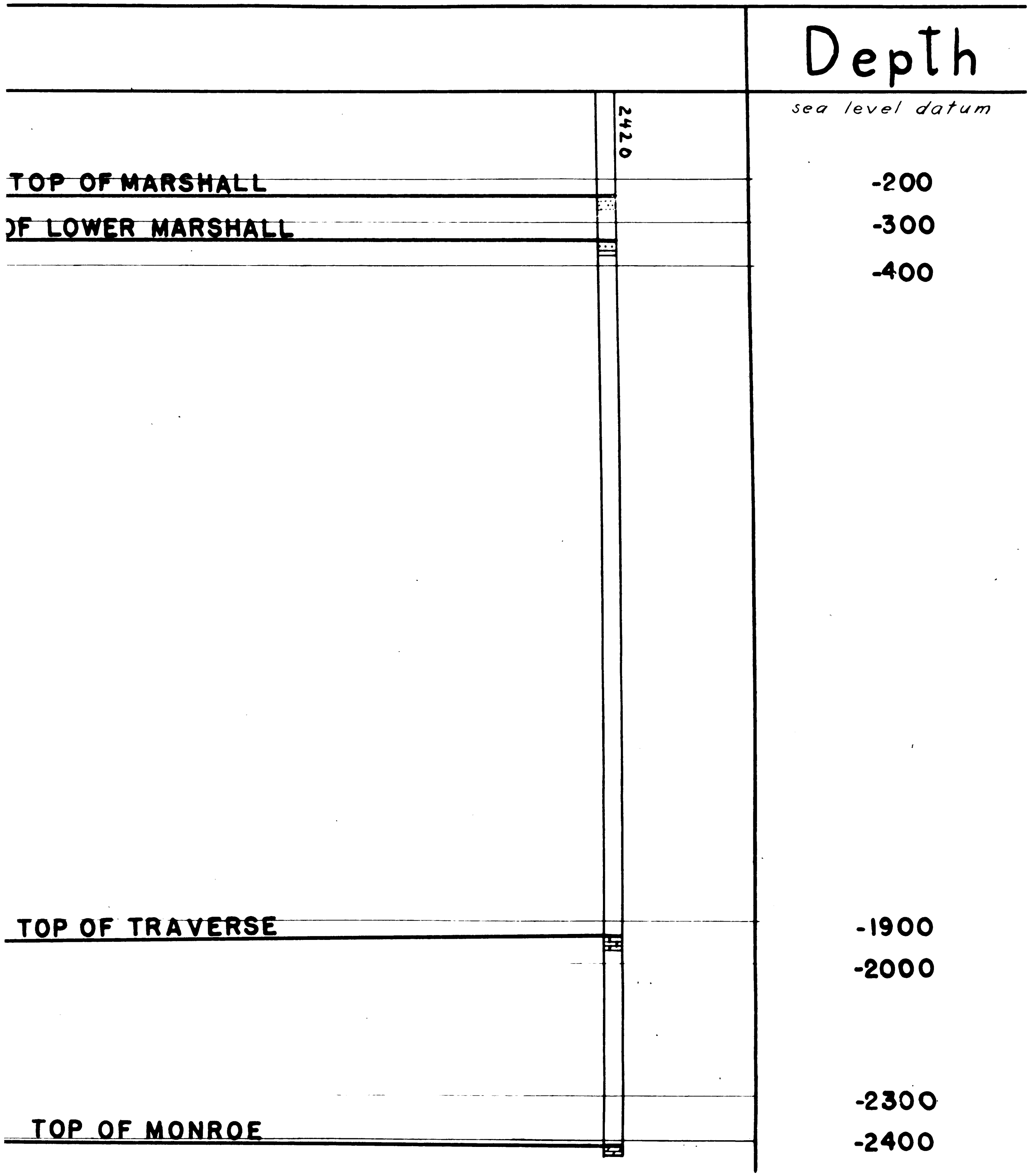
PLATE 4.--CROSS-SECTION ALONG BB', PLATE 2.



BB', PLATE 2.



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Monroe. Two of these, at or near wells No. 2745 (Pure-Preston No. 4) and No. 2426 are reflected directly above on higher horizons. The upfold at well No. 2745 which as shown by Plate II is at or near the top of the closure on the anticline, is reflected on structures of all formations shown, namely, the Traverse, Marshall "Red-Rock," and Upper-Marshall formations. The high at well No. 2426 is reflected on the Marshall "Red-Rock" and Upper Marshall formations. The third high which has highest known elevations at wells No. 2469 and No. 3006 is not reflected above on the structure of the formations shown.

Plate IV is a cross-section along trace BB', Plate II. The high of the highest known part of Monroe structure, well No. 2745, through which cross-sections AA' and BB' intersect, is reflected directly above by a broad fold upon the Marshall "Red-Rock" and Upper Marshall formations.

A study of the relationship of structure to production shows that the two are directly connected. The highest initial production in the field, estimated at 8,500 barrels per day, has come from the well that drilled into the highest known point on structure. This well is the Pure-Preston No. 4, S.W., S.E., N.E., section 3, Crystal township (Plate II).

An average of the initial production obtained from all wells at each contour interval, shows that the average initial production progressively decreased toward the lower wells on the structure. Also it has been found that there is a relationship between the smaller highs and lows and production, the former being more and the latter less productive than the immediately surrounding areas.

In section 26, Ferris township, there is some production from what appears to be a northward plunging nose (Plate II).

Extent of Field. - At the close of December 1935 there were 930 producing acres (Table 1, p. 23). This area is confined to sections 1, 2, 3, 4, 10 an 11 Crystal township and sections 26, 34, 35, and 36, Ferris township.

There are, at present, some potential producing areas as yet undrilled. A large part of the area under Duck Lake should give some production. The western part of section 3 and eastern part of section 4, Crystal township, is also an area that would probably yield some oil.

In addition, there is a possibility of there being extensions from the chief structure, as yet not outlined, by drilling.

Unconformities. - The unconformities present in the Crystal Ferris field are those between the Monroe and Traverse, Traverse and Antrim, Antrim and Coldwater, Napoleon and Michigan, and Bayport and Parma (or Saginaw).

The Monroe and Traverse unconformity has been discussed and the evidence reviewed (pp. 4, 5).

Evidence for the Traverse-Antrim unconformity has been given by Kirkham[14] who came to the conclusion that

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[14]Kirkham, V.R.D., Unconformity at the top of the Traverse Formation in Michigan; (Abstract). Geol. Soc. American Bull. Vol. 43, pp. 136-137 (1931).

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where the Antrim formation was thicker the Traverse was thinner and vice-versa. In all cases, however, the total thickness of the two formations was about the same.

A Berea and Coldwater Break is found in western Michigan.[15] This appears to be replaced in the Crystal-Ferris field by an Antrim and Coldwater Break.

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[15]Newcombe, R.B., op. cit., p. 99.

The break between the Upper Marshall and Michigan formations has been reviewed by Thomas[16] and Kirkham.[17]

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[16]Thomas, W.A., op. cit., p. 8.

[17]Kirkham, Virgil R.D., op. cit., p. 8.

Thomas also found evidence for an unconformity within the Upper Marshall.

The Bayport and Parma (or Saginaw) unconformity is the break found in many parts of the country between the Mississippian and Pennsylvanian Systems.

Origin of Structures. - The origin of the Crystal-Ferris structure is probably closely related to the formation of the Michigan Basin. The latter probably originated in Pre-Cambrian time[18] and during most of its

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[18]Pirtle, G.W., Michigan Structural Basin and its Relationship to the Surrounding Areas, pp. 145-153, A.A. P.G. Bull., Feb. 1932.

Newcombe, R.B., op. cit., pp. 101-112.

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structural evolution has been elongated northwest-southeast. It has many of the characteristics of a geosynclinal area. Postive masses surrounding the basin include the Canadian shield on the northeast, the two northward extending prongs of the Cincinnati Arch from southeast to southwest, and the Wisconsin Arch on the west. Negative areas surrounding the area were probably connected at various period during its history with the seas of the Michigan Basin. These areas include the Appalachian geosyncline on the southeast, the Logansport sag and Indiana and Illinois coal basin on the southwest, and the Lake Superior geosyncline to the northwest. An extended discussion of the origin of the Michigan Basin cannot be given here, but the theories of the origin of the folds within the basin will be reviewed briefly.

Theory of Differential Compaction. - Prior to the intensive drilling for oil in the Michigan Basin, it was thought that the dominant folds of the lower peninsula were elongated with and plunging toward the center of the basin. It was considered that these folds were formed during the subsidence of the basin due to differential compaction.

Characteristics of this type of fold include (1) thinning of compacted strata over the crest and thickening off of the flank of anticlines, and (2) a progressive decrease of dip above the irregularities of bed rock over which compaction occurs. The first characteristic is found in folds of the Michigan Basin: In the Crystal-Ferris field it was found that, in general, the Traverse formation thickened off structure. The second characteristic would seem to indicate that if the compaction occurred over an irregular Pre-Cambrian rock surface, folding would have to be the result of deflection that would be effective through several thousand feet of sediments. If folding occurred in this manner, their dips would be gentle.

Theory of Horizontal Compression. - Regional diastroplasm, resulting in the transmission of horizontal forces has been suggested[19] as a factor causing folds within

[19]Pirtle, G.W., op. cit., p. 153.

the Michigan Basin. Simple horizontal compression does not seem in itself to be a tenable explanation. Folds thus formed are (1) elongated at right angles to the direction of compressive stresses and (2) have high dips. There is some indication of an elongation of folds in the Michigan Basin in a northwest-southeast direction. However, folds of high dip are extremely uncommon in the area.

Movements in Pre-Cambrian Rocks. - In Pre-Cambrian time it is probable that the Michigan Basin was elongated northwest-southeast, parallel to a Wisconsin mountain range to the west.[20] It seems likely that predominate

[20]Pirtle, G.W., ibid., p. 153.

folds and faults were oriented parallel to this direction of elongation. These folds and faults were an initial line of weakness. After the burial of these folds and faults, subsequent movements along the old lines of weakness may have resulted in the deflection of overlying sediments.

Solution theory. - Newcombe[21] has suggested that the

[21]Newcombe, R.B., op. cit., pp. 116, 118, 119.

dissolving of beds of salt, gypsum and anhydrite, may have resulted in faulting and folding of overlying beds. However, definite evidence for or against this theory has not been found in the Michigan Basin.

In each of the foregoing theories, only one factor was stressed as a possible cause of folding in the Michigan Basin. The writer is of the opinion that the most tenable explanation may not be found in any one theory, but will be developed from a combination of theories.

ECONOMICS

Production

Discovery. - The Crystal Ferris field was discovered March 29, 1935 by the Leonard-Durbin No. 1, located NW, NW, NE, section 11, Crystal township. The well was a wildcat, being the first drilled for oil in this township. Before the discovery the only oil production from Montcalm county had been about 12 miles northwest in Home township. Here three wells had been producing from the Traverse formation. During the previous summer two wells had been drilled for oil in northern Ferris township in sections 11 and 16, six miles north of the discovery. Both had been dry holes.

Subsequent Operations. - Initial production of the Leonard-Durbin amounted to about 3600 barrels per day. Immediately there was a rush for leases, and drilling rigs were erected at a rapid pace. A number of wells were drilling in the area before the second well was completed. The latter was the Eastern Gulf-Barger no. 1 brought in May 24, 1935. The well flowed 55 barrels in the first 35 minutes, but this was followed by encroachment of water. This was the first definite indication of the thinness of the "pay" horizon and proximity of the water beneath. Since that date care has been exercised in order not to drill too far into the "pay."

The first trend of development was to the northwest extending the field into Ferris township. The finding of oil by the Strange and Fortney-Rockelman Lott No. 1, NW, SW, SE, Section 10, on their location southeast of Duck Lake, has resulted in an extension to the south. This includes one producing well and several locations in Duck Lake. A number of wells have reported several thousand barrels initial production. Pure-Preston No. 4, NW, SE, NE, Section 3, Crystal Township has reported the highest, viz., 8,500 barrels estimated.

Proration. - Proration did not become effective until the middle of 1935.[22] The percentage of allowable production

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[22] Wiedeman, A.J., Umpire, Michigan Oil Producers Committee, Written Communication.

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varied each month depending upon market conditions. The percentage was based upon potential production as determined by open flow for a limited number of hours. However, the wells were pinched in for only a few months.

Brine Disposal. - The large amount of brine which comes out with the oil provides a problem in the matter of its disposal. Pits have been excavated for this purpose but are, of course, not fully satisfactory. Plans are now being perfected for returning waste to sub-strata which could readily absorb it.[23] The Parma and Monroe are two horizons which may be used for this purpose. In the case of the former, brine waste could be let down

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[23]Weideman, A.J., Umpire, Michigan Oil Producers Committee, Written Communication.

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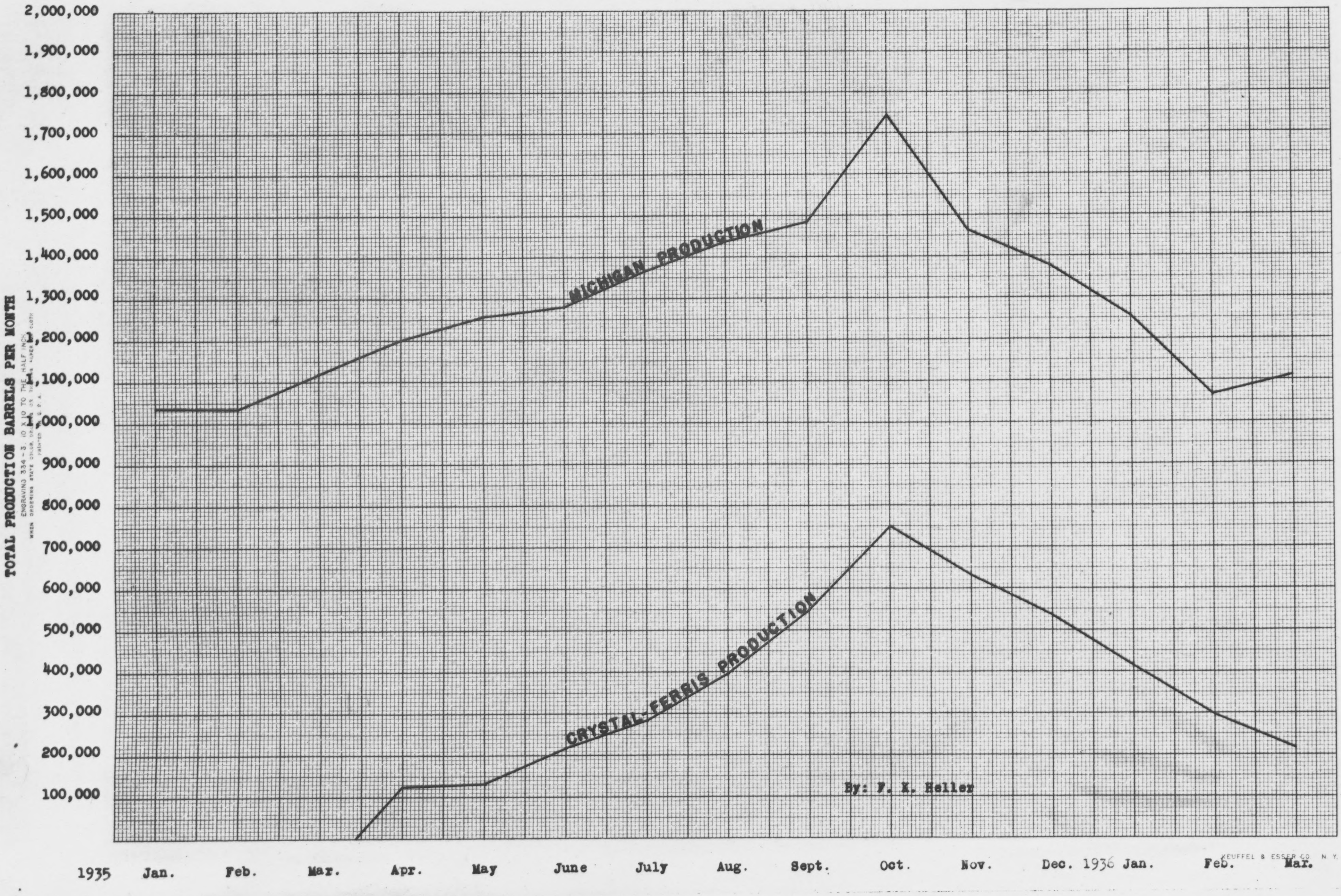
between casing, while to the latter it could be let down through wells at the border of the field where edgewater is present.

Decline Curves and Table. - Figure 1 shows a production curve for the field together with one for the state as a whole from which the marked influence of the field on the trend of Michigan's production may be noted.

Table I showing detail and figures of production for the field was obtained through the courtesty of Mr. F. R. Frye, petroleum engineer of the Michigan Geological Survey. From the table it may be noted that at the close of March, 1935, 4,535,861 barrels of oil had been produced from the Crystal-Ferris field. Monthly production advanced steadily from the time of the discovery until October, 1935. During the latter month, a flush production of 747,936 barrels per month was reached. Since then there has been a steady decline in monthly yields. In March, 1936, 218,155 barrels were produced,

Figure I - Chart Showing Monthly Oil Production Curve of Michigan and the Crystal-Ferris Field.



approximately 29% of the October, 1935 production.

TABLE I.

Date	Monthly Production (Barrels)	Cumulative Production (Barrels)	No. of Wells	Daily Ave. Production (Barrels)	Prod. Per Well (Barrels)	Prod. Ac.	Yield Per Prod. Acre (Barrels)
1935							
Mar. Aprl.	123,343	123,343	1	3,628	123,343	10	12,334
May	130,601	253,944	4	4,213	32,850	40	6,348
June	208,936	462,880	6	6,964	34,821	60	7,715
Jul.	282,573	745,453	17	9,115	16,622	170	4,385
Aug.	397,368	1,142,821	28	12,818	14,191	280	4,081
Sept.	547,716	1,690,537	47	18,257	11,653	470	3,509
Oct.	747,936	2,438,473	65	24,127	11,686	650	3,751
Nov.	632,692	3,071,165	79	21,089	8,008	790	3,887
Dec.	534,099	3,605,264	93	17,226	5,743	930	3,876
1936							
Jan.	414,242	4,019,506	108	13,363	3,835		
Feb.	298,200	4,317,706	112	10,283	2,663		
Mar.	*218,155	4,535,861		2,663			

*Obtained from Mich. State Tax Commission.

Transportation.[24]

Crude is shipped from the field by tank trucks, pipe lines, and railroad tank cars. At the time of the discovery trucking was the only available means of moving the crude to refinery centers. A number of tank trucks were then

[24] A review, chiefly from Pipe Line News and Articles by P.W. Elliott, Michigan Correspondent, Oil and Gas Journal, April 4, 1935 to May 7, 1936.

used for this purpose in the emergency brought on by the first production of the Leonard-Durbin no. 1. This method of movement was a temporary one, however, and has since been replaced almost altogether by pipe lines, supplemented to some extent by railroad tank cars.

Pure Transportation Co., a subsidiary of Pure Oil Co., and largest crude transporting company in Michigan, is the owner of two pipe lines from the field. One of these is a 4-inch line extending 9 miles north to loading racks on the Pere Marquette Railroad near the village of Vestabury. The same company owns a 4-inch line running due south 7 miles to Carson City on the Grand Trunk Railroad. This line which was the first to be laid to this railroad, made possible a one-line railway haul to the Old Dutch Refinery Company at Muskegon.

Simrall Pipe Line Co., which is the second largest crude transporting company in Michigan, owns and has interest in the most extensive system of pipe lines serving the field. The largest of these is owned with the Standard Oil Co. of Ohio, each company having a 50 percent interest in the line. This is a 140 mile, 8-inch, welded line extending from the field to Toledo, Ohio. The dhief outlet for this line is the refining plant of Standard Oil Company of Ohio. The present capacity of this line is about 100,000 barrels per day although this probably can be increased if necessary. These companies have on the field two 35,000 barrel storage tanks and a station with two pumping engines.

In addition Simrall owns a 9-mile, 4-inch line, extending north to loading racks at Riverdale on the Pere Marquette Railroad, this line offering about the same facilities as Pure Transportation Co.'s line to the same railroad. Another line in which Simrall has sole ownership is a 6-inch line connecting the field with the Roosevelt Refinery at Mount Pleasant.

A 6-inch line of the Wolverine Pipe Line Co., follows the Montcalm-Gratiot County line, along the eastern edge of Crystal township, to Carson City. Part of the oil transported on this line is refined by Crystal Refining Co. of Carson City, and part is shipped to Muskegon. Still another line has been laid 8 miles south to Butternut on the Grand Trunk Railroad west of Carson City.

Mid-West Refinery Co. is the owner of a 16-mile, 4-inch line supplying its plant at Alma directly from the field. The same company has a gas line from the field, gas being used as fuel at the refinery.

A 4-inch line, having a capacity of 6000 to 8000 barrels per day, has been constructed by the McClanahan Pipe Line Co. from the field to the McClanahan Refinery at St. Louis, about 20 miles distant.

Refining and Marketing.

Most of the refining of Crystal-Ferris crude is done at Toledo, Ohio and at a number of cities and towns in Michigan. The latter includes Naph-Sol and Old Dutch Refining Companies, of Muskegon, McClanahan Refineries, Inc., St. Louis, Roosevelt Refining Co. of Mount Pleasant, Mid-West Refining Co. of Alma and others including many small independent refineries.

Character of the Oil. - Crystal-Ferris crude compares favorably with other Michigan crudes but not with mid-continent oils, which have a higher octane rating. It has typically a greenish cast. Following are the results reported from a series of tests upon this crude:[25] Gravity

[25]Conine, R.C., Outlook for Michigan Refineries is a Question of Cracking, Oil and Gas Journal, June 20, 1935.

42.4 degrees A.P.I.; flash below room temperature; pour, below -35; B.S. & W. 0.4 per cent; viscosity at 70 degrees F., 40 seconds; sulphur 0.52 per cent; water 0.4 per cent.

Straight Run versus Cracking. - Most Michigan Refineries have "straight-run" equipment, exceptions being Naph-Sol and Old Dutch Companies of Muskegon which have cracking equipment. It is doubtful if many of the smaller independent refineries could profitably support installation of cracking units. As has been pointed out[26] the refineries which have skimming units must depend in a large measure on production of heavy lubricating stock for retail markets. The "straight-run" Michigan gasoline with its low octane rating cannot compete on an equal basis with that from mid-continent oils having a much higher anti-knock value. Dubbs engineers are quoted as stating that maximum octane values can be obtained from Michigan oil if cracking is done on a two coil basis, one for the "straight-run" and product, and one for the remainder of the crude.[26]

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[26]Ibid.

Shortage of Crude. - Another problem, namely that of crude shortage, is being faced by the smaller independent refineries of the state. This is due in part to (1) declining production and (2) new crude markets outside of the state. Larger refineries having their own private source of supply do not have this factor to contend with.

Crude Oil Prices.- At the time when the Leonard Durbin No. 1 was brought in, the crude was bought at about $1.02 per barrel. This has since been increased, the latest price quoted for Crystal-Ferris crudes by Pure Oil Company and Simrall Corporation being $1.32 per barrel.[27] This is

[27] Oil and Gas Journal, p. 90, May 7, 1936.

somewhat higher than prices paid, for crude in most other areas, probably the result of demand by refiners. Michigan retail gasoline, as pointed out, is handicapped in the open market by its low octane rating.

Future of the Field.

The Crystal-Ferris field has passed the period of flush production and is now in the period of declining yields. It has certain producing conditions which indicate that it will not be a long-lived field. Perhaps the primary factor which will determine this is the thinness of the "pay" horizon. There is no lower horizon which may be considered a potential future source of oil. The large amount of brine produced with the oil is in itself an indication that the present magnitude cannot be maintained. The cumulative production, however, compared to that of other Michigan oil fields is already sufficient to give it a position of one of the state's major fields.

APPENDIX

Crystal (Montcalm)

Gulf Refining Company

Geo. Barger #1 Permit #2395

Location: SW, SW, SE, section2, T.10N., R.5W.
330 feet from S line and 330 feet from W line of quarter section.

Elevation: 787 feet above sea level.

Record by F. K. Heller from driller's log* and samples.

Commenced: 4/15/35. Completed: 5/24/35. Initial Production: 55 bbls. in 35 min. then stopped and went to water.

	Thickness (Feet)	Depth (Feet)
Pleistocene		
Drift:		
*Clay	20	20
*Sand	20	40
*Clay	10	50
*Sand	15	65
*Gravel; Clay	20	85
*Gravel; Sand	115	200
*Clay	10	210
*Gravel; Sand	140	350
Pennsylvanian:		
Saginaw and Parma Formations (undivided):		
*Shale, dark	109	459
*Sandstone	51	510
*Sandstone	10	520
*Shale, gray	24	544
Sandstone, white, black shale, Pyrite		544
No sample	9	553
Shale, grayish-blue	32	585
Sandstone, white, brown dolomite and Limestone, black and blue shale	40	625
Mississippian:		
Bayport Formation:		
Dolomite, brown white sandstone, Pyrite	14	639
Sandstone, white, calcarious	8	647
Sandstone, white, limestone	18	665
Dolomite, brown, white, sandstone	13	678
Dolomite, brown, gray	9	687
Dolomite, brown	2	689

	Thickness (Feet)	Depth (Feet)
Bayport Formation (cont'd):		
Sandstone, brown limestone	8	697
Sandstone, white, pyrite	4	703
Sandstone, white, brown limestone	6	709
Limestone	6	715
Sandstone, limestone	6	721
Limestone, brown	7	728
Limestone, brown, white sandstone	7	735
Limestone, brown	15	750
Michigan Formation:		
Shale, gray, gypsum, dolomite	260	1010
Shale, gray, gypsum, sandstone		
Pyrite	10	1020
Napoleon (Upper Marshall)Formation:		
Sandstone, white, gray shale,		
Dolomite, gypsum, pyrite	10	1030
Sandstone, white	26	1056
Sandstone, white	60	1116
Sandstone, brown, white	9	1125
Sandstone, white, brown, micaceous	10	1135
Lower Marshall (Red-Rock) Formation:		
*Red rock	21	1156
Sandstone, white, micaceous	9	1165
*Red rock	10	1175
Sandstone, red, micaceous	21	1196
Sandstone,brown, black shale	9	1205
Dolomite, gray, gray shale	15	1215
Sandstone, red, micaceous, gray shale	10	1225
Coldwater Formation:		
Shale, gray, soft	42	1267
Shale, gray, brown dolomite, pyrite	993	2260
Shale, gray red dolomite	21	2281
Antrim Formation:		
Shale, black, brown	404	2685
Shale, black	15	2699
Devonian:		
Traverse Formation:		
Shale, bluish-gray brown limestone	14	2713
*Shale, brown	7	2720
Shale, gray, brown limestone, dolomite	53	2773
Limestone, brown, gray shale	51	2824
Limestone, brown	7	2831
Limestone, brown, gray shale	5	2836
Limestone, brown	23	2859

	Thickness (Feet)	Depth (Feet)
Traverse Formation (cont'd):		
*Limestone	10	2869
Limestone, brown, gray	98	2967
*Limestone	10	2980
Limestone, brown, gray	25	3005
Limestone, bluish-gray shale	18	3023
Shale, gray, limestone	13	3036
Limestone, gray shale	39	3075
*Limestone	10	3085
Limestone, gray shale	41	3126
Shale, gray	42	3168
Shale, gray, limestone	7	3178
Monroe (?) Formation:		
Dolomite, brown, gray	21	3199
*Limestone	2	3201

*Pay-3185
*Gas increase and salt water 3183-86

Total Depth 3201

Crystal Township (Montcalm County)

Fred W. Turner

McConkey #1 Permit #2409

Location: NE, SE, SW, section 10, T. 10N, R.5W.
990 feet from the south line and 725 feet from the east line of quarter section.

Elevation: 792 feet above sea level.

Recorded by F.K. Heller from driller's log and samples.

Casing Record: 10" 389', 8-1/4" 762', 6-5/8" 1250', 5-3/16" 3145'.

Commenced: 4/30/35 Completed: 6/11/35 Initial Production Dry Hole
P. & A. 6/29/35

	Thickness (feet)	Depth (feet)
No record	0	700
Mississippian:		
Bayport Formation:		
Dolomite, limestone, gray, white	10	710
Sandstone, white, gray and white limestone	10	731
Sandstone, white, gray and brown		
Dolomite, pyrite	10	741
No sample	9	750
Sandstone, white, brown		
Dolomite, pyrite		750
No sample	12	762
Michigan Formation:		
*Shale, green	13	775
*Shale, grey	35	810
*Shale, dark	48	858
Gypsum, gray shale	7	865
Shale, gray, gypsum, dolomite	10	875
*Shale, dark	15	890
Gypsum, gray shale, dolomite	10	900
No sample	7	907
Gypsum, gray shale, dolomite	7	914
Gypsum, gray shale, dolomite	9	923
No sample	17	940

Crystal, Montcalm
Fred W. Turner
McConkey

#2409

	Thickness (feet)	Depth (feet)
Dolomite, gypsum, gray shale	10	950
Gypsum, white, dolomite, gray shale	8	958
Dolomite, gypsum	8	966
Dolomite, gray, dolomite, gypsum	9	975
Shale, gray, dolomite, gypsum	18	993
No sample	7	1000
Shale, gray, dolomite		1000
No sample	15	1015
Dolomite, gypsum, gray Shale, pyrite		1015
*"Shells"	19	1034
Napoleon (Upper Marshall) Formation:		
*Sandstone (water 1055')	28	1062
Sandstone, white	6	1068
Sandstone, white	7	1075
Sandstone, white	8	1083
Sandstone, white	8	1091
No sample	29	1120
Sandstone, white, brown	5	1125
Sandstone, white, brown	1	1126
Lower Marshall Formation:		
Sandstone, red micaceous	2	1128
*"Red-Rock"	17	1145
Sandstone, red, micaceous	5	1150
Sandstone, red, micaceous	7	1157
Sandstone, red, micaceous	6	1163
Sandstone, white, red, micaceous, Gray shale	8	1171
Shale, gray, micaceous sandstone	6	1177
Shale, gray, pyrite	10	1187
Sandstone, red, gray shale	21	1208
*Shale, blue	47	1255

Crystal, Montcalm
Fred W. Turner
McConkey

#2409

	Thickness (feet)	Depth (feet)
*Shale, dark	495	1750
*"Grit"	8	2287
Antrim Formation:		
*Shale, black	313	2600
Shale, black, pyrite		2600
No sample	60	2660
Devonian:		
Traverse Formation:		
Shale, gray, blue, pyrite		2660
No sample	20	2680
Shale, gray, blue, pyrite		2680
No sample	30	2710
Shale, gray, dolomite		2710
No sample	5	2715
Shale, gray, dolomite, pyrite		2715
No sample	35	2750
Limestone, gray, brown, gray shale		2750
No sample	30	2780
Limestone, gray, gray shale, pyrite		2780
No sample	20	2800
Limestone, white, gray, brown, pyrite		2800
No sample	41	2841
Limestone, white, gray, brown	8	2849
No sample	304	3153
Shale, bluish-gray	10	3163
Shale, bluish-gray	7	3170
Shale, bluish-gray	9	3179
No sample	5	3184
Shale, gray	9	3193
No sample	7	3200
Monroe (?) Formation:		
Dolomite, brown	4	3204
Dolomite, brown	12	3216
Dolomite, brown	4	3220

Ferris (Montcalm)

Daily Crude Oil Company

E. J. Fulford #1 Permit #2976

Location: SW, NW, SW, section 36, T.11N., R.5W., 990 feet from the north line of quarter section and 330 feet from west line of quarter section.

Elevation: 809 feet above sea level.

Record by F. K. Heller from incomplete set of samples, and state drilling record (driller's log destroyed by fire).

Commenced: 12/28/35. Completed: 2/25/36. Initial Production: 30 bbls. After Acid, 400 bbls.

	Thickness (Feet)	Depth (Feet)
No record	0	915
Mississippian:		
Michigan Formation:		
Shale, gray, brown dolomite, Gypsum, pyrite	5	920
No sample	5	925
Shale, gray, brown dolomite, Gypsum, pyrite	10	935
No sample	84	1019
Shale, gray, gypsum, gray (Micaceous) sandstone	8	1027
Gypsum, white, gray shale, Gray (Micaceous) sandstone	8	1035
No sample	7	1042
Napoleon (Upper Marshall) Formation:		
Sandstone, white, fine	8	1050
No sample	35	1085
Sandstone, white, fine	5	1090
No sample	80	1170
Lower Marshall Formation:		
Sandstone, red, fine	10	1180
Sandstone, red, fine	5	1185
Shale, red	7	1192
Shale, gray, sandstone, gypsum, Dolomite	11	1203
Shale, red, gray	8	1211
No sample	4	1215
Shale, gray	5	1220
Sandstone, white, Micaceous, gray shale, pyrite	8	1228

	Thickness (Feet)	Depth (Feet)
Coldwater Formation:		
Dolomite, gray, brown, Micaceous, fossiliferous	7	1235
Dolomite, gray, brown, Sandy	15	1250
No sample	6	1256
Sandstone, white, fine, Gray shale, gypsum	7	1263
No sample	2	1265
Dolomite, gray, micaceous Gray, shale, pyrite	5	1270
Shale, gray, soft	5	1275
No sample	6	1281
Shale, gray, soft	9	1290
No sample	10	1300
Shale, gray, soft	5	1305
No sample	895	2200
Shale, gray, brown dolomite	13	2213
Shale, gray, brown dolomite	10	2223
Shale, gray, brown dolomite	6	2229
Shale, gray, brown dolomite	5	2234
Shale, gray, brown dolomite	14	2248
Shale, gray, brown dolomite	5	2253
Dolomite, red, gray shale	9	2262
Shale, gray, brown and red dolomite	9	2271
Antrim Formation:		
Shale, black	9	2280
No sample	110	2390
Shale, black, pyrite	10	2400
Shale, black, pyrite	14	2414
Shale, black, pyrite	14	2428
Shale, black	12	2440
Shale, black	10	2450
Shale, black	10	2460
Shale, black	15	2475
Shale, black, gray	10	2485
Shale, black, gray	14	2499
No sample	101	2600
Shale, gray, brown, pyrite	12	2612
Shale, gray, brown, pyrite	12	2624
Shale, gray, brown	16	2640
No sample	8	2648
Shale, gray, brown dolomite, pyrite	12	2660
Shale, black, brown, gray, Brown dolomite, pyrite	57	2717
Shale, gray, brown dolomite, pyrite	8	2725

	Thickness (Feet)	Depth (Feet)
Devonian:		
Traverse Formation:		
Limestone, brown, white, pyrite	9	2734
Limestone, brown, gray, Gray shale, pyrite	9	2743
Limestone, brown, gray, Black shale, pyrite	7	2750
Limestone, brown, gray, White, gray shale, pyrite	9	2759
Shale, gray, brown dolomite	11	2770
Limestone, brown, white, Gray shale, pyrite	38	2808
No sample	9	2817
Limestone, white, brown, Gray shale	18	2835
Limestone, brown, white, Gray shale	15	2850
No sample	5	2855
Limestone, brown, white, Black shale	8	2863
No sample	12	2875
Limestone, white, brown		2875
Limestone, brown, white, bluish-Gray shale	21	2896
Limestone, white, brown, Gray and black shale	10	2906
No sample (top "Dundee" of state drilling record)	310	3216
Monroe Formation:		
No sample	5½	3221½
Total depth		3221½

Crystal Township (Montcalm County)

Gordon Oil Company

W.E. Strait #4 Permit No.2781

Drilling Contractor - Gordon Oil Company

Location: NE 1/4 of SE 1/4 of section 3, T 10N, R. 5W

660 feet from the S line and 330 feet from E line 1/4 sec.

Elevation: 796 feet above sea level

Record by Frederick K. Heller from driller's log and scout reports

Casing record 14", 10" 399, 8-1/4" 765, 6-5/8" 1260, 5-3/16" 3174.

Commenced: 9/25/35 Completed: 11/27/35 Initial Production: 25 bbls after acid 1416 bbls

	Thickness (feet)	Depth (feet)
Pleistocene:		
Drift:	386	386
Pennsylvanian:		
Saginaw and Parma Formations undivided:		
Sand	89	475
Shale	85	560
Sandstone, white	115	675
Mississippian:		
Bayport Formation:		
Limestone, shell	60	735
Michigan Formation:		
Mud, blue	11	746
Gyp. shell	5	751
S hale	34	785
Limestone, shells	8	793
Shale	27	820
Gyp. and shell	30	850
Limestone, shell (show gas 916-975)	75	925
Shale, shells	30	955
Shale	20	975
Limestone	3	978

Crystal, Montcalm
W.E. Strait

#2781

	Thickness (feet)	Depth (feet)
Shale	27	1005
Sandstone	15	1020
Shells, shale	20	1040
Napoleon (Upper Marshall) Formation:		
Sandstone, water 1045	70	1110
Lower Marshall Formation:		
Red Rock SLM	80	1190
Coldwater Formation:		
Shale, blue	25	1215
Limestone shell	10	1225
Shale, bule	35	1260
Shale	795	2055
Shale, black	195	2250
Shale, red	8	2258
Shale, black	8	2266
"Berea," grit	10	2276
Devonian		
Antrim Formation:	20	2296
Shale, black	397	2693
Shale, brown - SLM	23	2715
Shale, gray		
Traverse Formation:		
Limestone - Traverse SLM	22	2737
Shale	9	2746
Limestone - Traverse	18	2764
Oil & Gas (576 bbls. 24 hrs.) produced 2000 bbls from Traverse	11	2775
Limestone - Traverse, water 2776	275	3050
No record	30	3080
Limestone	30	3010
Shale	73	3183
Monroe (?) Formation:		
Limestone "Dundee" SLM		3183
Limestone	7	3190
Limestone, coarse, shelly	4	3194
Oil & Gas		3194
Total Depth		3194

Crystal Township (Montcalm County)

Evans #1

Permit #2492

Location: NE, NE, NE, section 22, T. 10N., R5W.

Elevation: 787 feet above sea level.

Record by F. K. Heller from incomplete set of samples.

Completed 9/6/35
Initial Production - Dry Hole

	Thickness (feet)	Depth (feet)
No. samples	3159	3159
Traverse Formation		
Shale, bluish gray, limestone	2	3161
Shale, bluish gray, limestone	3	3164
Shale, bluish gray, limestone	3	3167
Shale, blue, hard	8	3175
No sample	4	3179
Shale, bluish gray, limestone	6	3185
No sample	2	3187
Shale, blue	2	3189
Shale, blue, pyrite	4	3193
Limestone, blue shale	3	3196
Limestone, blue shale	2½	3198½
No samples (?)	12	3210½
Monroe (?) Formation		
Dolomite, brown	83½	3293
Dolomite, black, brown	13	3306
Total Depth		3306

Geol. M.T.
Heller 1

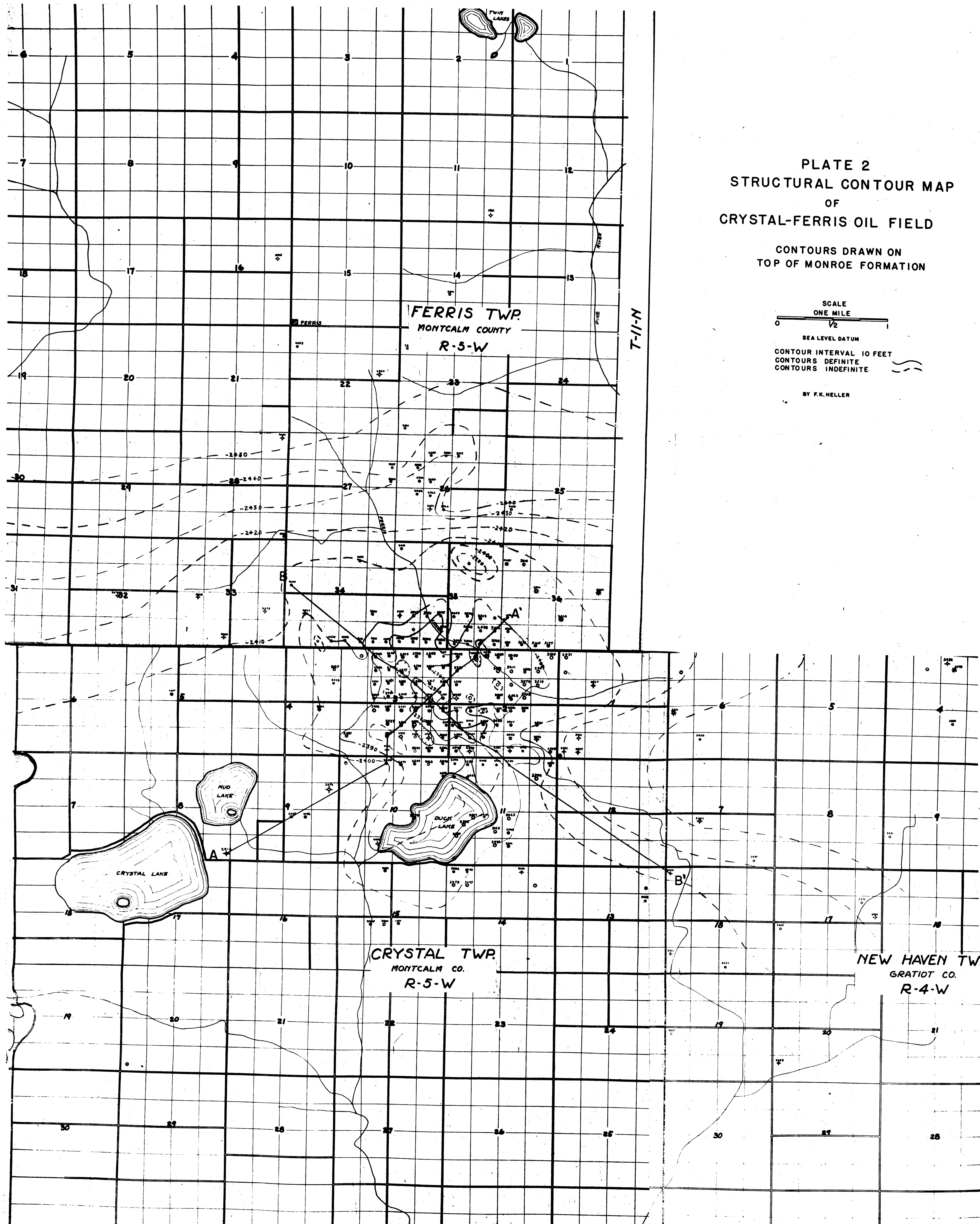

PLATE 2
STRUCTURAL CONTOUR MAP OF CRYSTAL-FERRIS OIL FIELD

CONTOURS DRAWN ON TOP OF MONROE FORMATION

SCALE
ONE MILE
0 1/2 1

SEA LEVEL DATUM

CONTOUR INTERVAL 10 FEET
CONTOURS DEFINITE
CONTOURS INDEFINITE

BY F.K. HELLER