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URBANA

REPORT OF INVESTIGATIONS — NO. 67

POROSITY, TOTAL LIQUID SATURATION, AND PERMEABILITY OF ILLINOIS OIL SANDS

BY

R. J. Piersol, L. E. Workman and M. C. Watson

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This Report is a Contribution of the Divisions of Oil and Gas, Subsurface Geology, and Physics.

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POROSITY, TOTAL LIQUID SATURATION, AND PERMEABILITY OF ILLINOIS OIL SANDS

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INTRODUCTION

Summary

In this investigation, covering an elapsed period of eight years, studies were made of the porosity, saturation, and permeability of 45 cores, representing ten Illinois oil sands. In general the Illinois oil sands are quite open sands, averaging about 17 per cent porosity; the total liquid (oil and water) saturation is high, in many instances showing complete saturation of pore space; and the permeability is exceedingly high, in many cores with values ranging up to 2000 millidarcys or more with an average for all 45 cores of 273 millidarcys. This may be compared with an average of about 5 millidarcys for the Bradford oil sand. The degree of uniformity of permeability with depth in certain of the cores studied indicates that the particular sand is suitable either for water flooding or air repressuring.

The investigation of the relative vertical and horizontal permeability included six cores representing five "sands". The Hoing sand and Kimmswick lime show the same permeabilities but in the Robinson, Biehl, and Cypress sands the horizontal permeability is greater than the vertical by ratios of 2:1 or less.

An inspection of the results of permeability and porosity studies of a typical core indicates that, for a homogeneous sand, there is a rough linear relationship between the porosity and the logarithm of the permeability.

Results show that there is a large loss of liquid (from 20 to 25 per cent) due to evaporation attendant on the usual methods of wrapping samples intended for saturation tests. This large error may be avoided by weighing saturation samples immediately after their removal from the core barrel.

Values of porosity and permeability are reported by four other laboratories (U. S. Bureau of Mines, Tide Water Laboratory, Core Testing Laboratories, Inc., and a "commercial laboratory") each of which tested samples from a different core. Their results for these cores show excellent agreement with results obtained by the Survey laboratory for samples from the same cores taken adjacent to those tested by the other laboratories. In no instance is the difference in values obtained by the Survey laboratory and the other laboratory for the same core greater than the difference in values between two neighboring samples.

Throughout this work, a sample from Dyroff well No. 27, which had been tested for porosity and permeability by the U. S. Bureau of Mines and returned to the Survey along with the U. S. Bureau of Mines results for it, was used as a standard of comparison for measuring the porosity and permeability results obtained by the Survey laboratory.

The results for wells whose cores represent the Cypress sand and McClosky lime in a deep part of the Illinois basin indicate relatively lower average porosity and higher average permeability values than found for these sands in cores from more shallow wells. This investigation will be extended to include the study of cores from the deep Illinois basin as such cores become available for analysis.

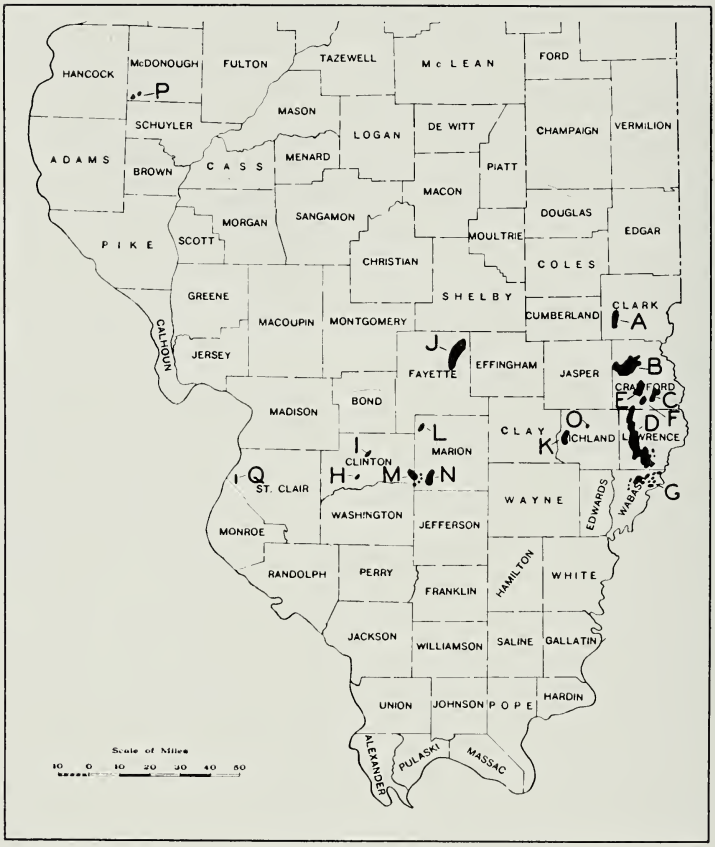

Fig. 1.—Map showing location of oil pools, sands from which have been cored and studied in the Survey laboratory as listed below:

A—North Johnson pool
Howe well No. 30

B—Crawford-Main pool
Clark well No. 19
Clark well No. 20
Furman well No. 10
Henry well No. 14
Snyder well No. 6
Stifle well No. 23
Wattleworth well No. 18
Athey well No. 1

C—Flat Rock pool
Cochran well No. 1

D—Lawrence County pool
Crump well No. 27
Kirkwood well No. 13
Christensen well No. 1
Christensen well No. 2
Rogers well No. 14

E—New Hebron pool
Mohler well No. 15

F—Parker pool
Weger well No. 14

G—Allendale pool
Lithurland well No 9
Madden well No. 9
Madden well No. 10

H—Bartelso pool
Trame well No. 2

I—Carlyle pool
Deters well No. 39

J—Louden pool
Koberlein well No. 1
Morrison well No. 1
Morrison well No. 2
Sefton well No. 1
Sinclair well No. 2

K—Noble pool
Arbuthnot well No. 9
Schilling well No. 1

L—Patoka pool
Merryman well No. 1
Merryman well No. 17

M—Centralia pool
Storer well No. 2
Storer well No. 4

N—Salem pool
Tate well No. 1
West Nation School well No. 1

O—Olney pool
Sager well No. 3

P—Colmar-Plymouth
Binney well No. 24
Jarvis well No. 14
McFadden well No. 31

Q—Dupo pool
Dyroff well No. 27

Purpose of Investigation

Many of the older oil pools in Illinois are passing through the stage of their natural decline in production when it becomes necessary either to discontinue operation or to introduce artificial methods of recovery. Since at present it is not economically feasible to mine oil in Illinois, the two methods of improved recovery to be considered are air-repressuring and water-flooding. In order that either of these methods be profitable, it is essential that the oil sand still retain a sufficiently large quantity of oil per acre that is removable with reasonable ease. The oil reserve per acre depends upon the thickness of oil sand, its porosity, and its oil saturation. The proportion of the remaining oil which is subject to recovery by repressuring or water-flooding depends largely upon two factors, namely, the permeability of the oil sand as a whole, and the differences in permeability of horizontal layers of the oil sand. Thus the first purpose of this investigation was to furnish information to the operators of the "stripper wells" in Illinois which would assist them in utilizing improved methods for the recovery of the remaining oil from the old fields.

Since this project was begun new oil pools have been discovered in the deeper parts of the Illinois basin. In general the oil sands found in the deeper parts of the basin are a continuation of the same sands from which the stripper wells are now producing. Thus the second purpose is to provide oil operators with information on the porosity and permeability of the producing sands in the deep Illinois basin, based on studies of the same sands at shallow depths and on studies of cores from the increasing number of deep wells.

Scope of Investigation

The experimental phase of the investigation includes the determination of porosity, saturation (for available saturation samples), and permeability of 45 cores from ten Illinois oil sands (fig. 1). Also the relative vertical and horizontal permeability was determined for six cores from five different oil sands. The degree of evaporation of liquid from saturation samples was determined for various types of sealing. A geologic description was made for each core.

The investigation also included the standardization of porosity and permeabiliy results by means of a sample calibrated by the U. S. Bureau of Mines. Checks were made on porosity and permeability values for different samples from the same cores as obtained by the U. S. Bureau of Mines Laboratory, Tide Water Laboratory, Core Testing Laboratories, Inc., and a "commercial laboratory" and by the Survey laboratory.

The values for porosity, saturation, and permeability for cores from the various sands are compared. The relation of permeability to porosity is studied.

This investigation includes studies of silica oil sands and limestone oil sands. The physical texture of the former resembles that of ordinary sandstone. The limestones investigated in this report are the McClosky, Niagaran, and Kimmswick. The McClosky consists of oolitic limestone, the Niagaran is a porous limestone, frequently sandy, and the Kimmswick is a crystalline limestone. Figure 2 is a photomicrograph of a sample of the McClosky from Arbuthnot well No. 9. The left view represents a broken surface; the right view, a smooth surface, acid rinsed. The actual size is shown by the scale beneath.

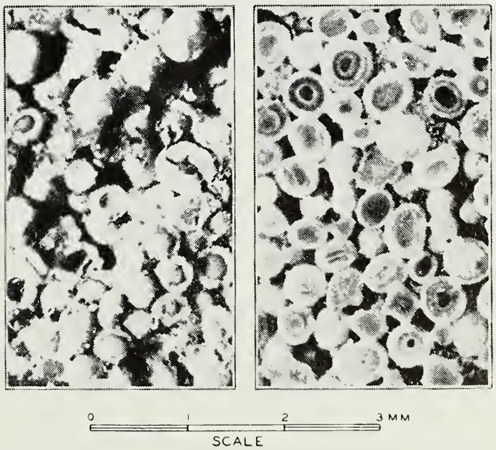

Fig. 2.—Photomicrograph of McClosky lime from Arbuthnot well No. 9.

Early Coring in Illinois

In 1926, Moulton[1] described the coring of a well at Allendale, Wabash County, recommending coring of oil sands as a means of choosing the preferable method of improved oil recovery. In 1928, Lamar[2] reported results on the texture, the porosity, and the saturation of a core taken in the Siggins pool, Cumberland County. Also a few wells were cored in the southeastern Illinois oil field, most of them on the repressured properties of Tide Water Oil Company north of Robinson.

In 1931, the State Geological Survey obtained a cable-tool core-barrel for cooperative use with Illinois oil operators. The advantages of information thus obtained were described by Bell and Piersol.[3]

Acknowledgments

The wells were cored through the cooperation of Mr. C. C. Carroll, Manager of the Ohio Oil Company; Capt. B. O. Mahaffy, President of W. C. McBride, Inc.; Mr. Warren Hastings, Trustee of Warren Hastings et al.; Mr. Alex. N. Warner, President of Warner-Caldwell Oil Company; Mr. W. S. Corwin, Manager of Tide Water Associated Oil Company; Mr. Alex U. McCandless, President of Mahutska Oil Company; Mr. George S. Buchanan, President of Adams Oil and Gas Company; Mr. Frank Barnes, Superintendent of Craig and Lowrie Oil Company; Mr. Shubert Fox of the Kesl-Fox Company; Messrs. C. U. Downey and W. F. Connor; Messrs. R. R. Rowland and V. Littlejohn; Mr. L. A. Mylius, Consulting Geologist for Canary and Sherman, Phayer et al, and Mabee Drilling Company; Mr. Sam Jarvis of Jarvis Bros.; Mr. W. C. Kneale, Production Superintendent for the Texas Oil Company; Mr. J. V. Barr; and Mr. Wallace Hagen of the Wicklund Development Company.

Mr. M. H. Flood, Engineer of the Ohio Oil Company; Mr. M. J. Kenefake of the Tide Water Oil Company; and Mr. R. E. Hilpert, Engineer of W. C. McBride, Inc., on various occasions assisted in coring wells.

[1]Moulton, Gail F., Notes on a core bit for cable tools: Illinois State Geol. Survey, Illinois Petroleum No. 2, May 29, 1926.

[2]Lamar, J. E., A study of the core of the Yanaway well No. 23 in the Siggins pool: Illinois State Geol. Survey, Illinois Petroleum No. 15, May 12, 1928.

[3]Bell, A. H., and Piersol, R. J., The need for sand coring in the southeastern oil field: Illinois State Geol. Survey, Illinois Petroleum No. 21, December 19, 1931.

Dr. John W. Finch, Director; Mr. R. A. Cattell, Chief Engineer of the Petroleum and Natural Gas Division; and Mr. T. W. Johnson, Natural Gas Engineer of Petroleum Experimental Station at Bartlesville, Oklahoma; all of the U. S. Bureau of Mines, made standardization of porosity and permeability results possible through the calibration of core samples.

Dr. A. H. Bell, Geologist and Head, Oil and Gas Division, State Geological Survey, supervised the selection of samples to be tested. Mr. L. E. Workman, Geologist and Head, Sursurface Division, State Geological Survey, made the geological examination of the cores and prepared the portion of this report describing the logs of the cores. Assistance in coring was given by the following members of the State Geological Survey: Dr. G. V. Cohee, Assistant Geologist, Mr. Perry McClure, Assistant Geologist, Mr. E. T. Benson, Assistant Geologist, Dr. C. W. Carter, Assistant Geologist, and Mr. J. L. Carlton, Research Assistant, all of the Oil and Gas Division; and Mr. E. M. Baysinger, Assistant in the Subsurface Division.

All the experimental data on porosity, saturation, and permeability herein reported were obtained by Dr. M. C. Watson, Assistant Physicist, Physics Division, State Geological Survey.

The study of the relation of vertical to horizontal permeability was made by Mr. W. H. Allen, a graduate student in the Department of Geology, University of Illinois under the supervision of Professor F. W. DeWolf, Head of the Department of Geology, University of Illinois. The detailed results are described in his thesis, "The permeability of certain Illinois oil sands in the direction of the bedding planes and in the transverse direction", which was accepted in partial fulfillment of the requirements for the degree of Master of Science in Geology in the Graduate School of the University of Illinois, 1937. In this study, Mr. Allen was assisted by Mr. M. J. Deuth, also a graduate student in the Geology Department, University of Illinois.

Dr. M. M. Leighton, Chief of the State Geological Survey, made this investigation possible through his continued interest in the relation of core study to improved methods of production and more recently to production in the Illinois Basin.

METHODS AND PROCEDURE

Methods of Testing Used in This Investigation

The physical tests on an oil sand core include determinations of its porosity, saturation, and permeability. By definition, porosity of an oil sand is that fraction of the total volume of the sand which is available for saturation with oil or other fluids. In this investigation and in this report, the term saturation is used to denote the total liquid saturation (oil or oil and water) and by definition is that fraction of the pore volume of the oil sand occupied by liquid. Also by definition, the permeability of an oil sand is the quantitative magnitude of its inherent property which permits flow of fluid through the sand.

POROSITY TESTS

In brief, a porosity test is the experimental determination of the ratio of the volume of fluid necessary to completely saturate the pore space of a sample of oil-extracted sand to the volume of the sample.

There are two general types of porosity determinations: (a) effective porosity and (b) total porosity tests. The former type differs from the latter in that it does not measure the volume of the closed pore space. In the very open sands prevalent in the Illinois oil field the two types of tests give very nearly the same results.

The modified Barnes method[4] for determination of effective porosity was used throughout this investigation. The method is as follows:

Approximately 30-gram samples are used. In order to remove the oil from the sample, it is treated in a Soxhlet extractor for 48 hours using carbon tetrachloride as the solvent. The oil-extracted sample is dried in an oven at 105°C. for 2 hours and weighed. It is then placed in a glass vacuum flask which is evacuated by a water aspirator, at a pressure of about 1.7 cm. of mercury, for 1⅓ hours. Sufficient acetylene tetrachloride is introduced into the flask through a separatory funnel to completely submerge the sample and the evacuation is continued for an additional 30 minutes. The vacuum is then released and the sample remains submerged over night. The next morning the saturated sample is drained for 10 seconds, the hanging drop is removed with a glass rod, and the sample is rapidly transferred to a stoppered bottle and weighed, the bottle being used to prevent evaporation losses while weighing. Knowing the weight of the bottle, the weight of the saturated sample can be calculated. This weight, less that of the oil-extracted sample, is the weight of the acetylene tetrachloride which saturates the pore space. The volume of the liquid saturating the pore space is calculated from the density of the liqiud at the temperature at the time of the latter weighing. Next the volume of the sample is determined by the pycnometer method. The weight of the pycnometer with the same liquid and saturated sample is determined. Knowing the weights of the saturated sample and the pycnometer filled with liquid, the volume of the sample may be calculated. The volume is numerically equal to the weight of the pycnometer filled with liquid plus the weight of the saturated sample less the weight of the pycnometer with sample and liquid, divided by the density of liquid at the temperature at time of testing. Finally the per cent porosity is calculated as the ratio of the volume of the pore space to that of the sample.

Porosity determinations on the first few cores, and on all cores for which saturation samples were not available, were made on the samples which had been prepared for permeability tests. The procedure in each case is exactly the same, the only difference being in the size of the porosity sample.

WATER CONTAMINATION OF CORE DURING CORING

The core is submerged in water throughout the coring period (usually from 45 minutes to 2 hours). The permeability of the sand permits flushing of the oil by water, and the degree of contamination is proportional to the permeability of the sand. The unusually high permeabilities of Illinois oil sands therefore result in excessive contamination of samples during coring.

[4]Fancher, G. H., Lewis, J. A., and Barnes, K. B., Min. Ind. Exp. Sta., Penn. State College, Bull. 12, pp. 117–118, 1933.

Since this investigation was begun, various articles[5] have appeared in the literature concerning the occurrence of connate water in oil sands which pump only oil. Based on his experimental results, Schilthuis[5] arrived at the conclusion that the percentage of the connate water present in a sand decreases with increased permeability of a sand. Evidently the percentage of connate water present in a core sample can be determined directly only for a sample uncontaminated by drilling water. Thus the determination of the percentage of connate water in highly permeable sand is unusually difficult due both to the probable low connate water content and to contamination by drilling water with resultant oil loss. Campbell[5] states that in the majority of cases the oil found in the core will be the residual oil content of the reservoir after complete water drive and gas expansion.

Because of such contamination, all saturation determinations were based on the total liquid saturation.

EVAPORATION OF LIQUIDS IN CORES

By weighing the saturation samples immediately after their removal from the core barrel, there was no opportunity for liquid loss due to evaporation. However, if the saturation results herein reported are to be compared with saturation results on samples wrapped in the field, then it is necessary to use a correction for the latter results, the magnitude of this factor depending upon the per cent evaporation loss. In this connection Campbell[5] has noted the desirability of making saturation tests in the field.

Various methods of sealing of samples have been recommended and are used by various core-testing laboratories.

The first method of sealing consists of wrapping the saturation sample with a double layer of wax paper and placing it in a wide-mouth pint glass jar with a self-sealing cap. The second method of sealing consists of wrapping the saturation sample in wax paper and submerging in melted paraffin. After cooling, the package is again wrapped in wax paper and dipped in paraffin.

Each of the two methods of sealing was tried on four samples from Wattleworth well No. 18. The average loss during seven days from samples sealed in jars was 24.4 per cent and that from samples wrapped in wax paper and dipped in paraffin was 20.2 per cent (table 1).

TABLE 1.—EFFECT OF METHOD OF SEALING ON PERCENTAGE EVAPORATION LOSS OF LIQUID FROM CORES FOR A 7-DAY PERIOD.

Depth (feet)	Percentage Evaporation Loss	
	Sealed in jars	Paraffin wrapped and dipped
985	27.0	20.4
986	26.1	19.0
987	24.2	19.9
988	20.1	21.5
Average	24.4	20.2

SATURATION TESTS

In brief, the saturation method used in this investgation consists of measuring the weight of liquid contained in the sample, calculating the weight of oil necessary to completely saturate the pore space in the sample, and then calculating the per cent saturation as the ratio of the former to the latter weight.

The sample to be tested, about 100 grams in weight, is weighed to an accuracy of 10 mg. immediately upon removal from the core barrel at the well. Upon return to the laboratory, the oil is extracted from the sample as described in the method for testing porosity. The oil-extracted sample is

[5](1) Barnes, K. B., Porosity and saturation methods: Proceedings of the Chicago, Ill., meeting of the Am. Petroleum Inst., Nov. 12, 1936.
(2) Campbell, J. H., The application of core analysis to well completion: a paper presented at the Sixth Annual Petroleum Conference of the Illinois-Indiana Petroleum Association, June 4, 1938.
(3) Clough, H. K., The evaluation of oil bearing cores: The Oil Weekly, June 15, 1936.
(4) Dunlap, E. N., Influence of connate water on permeability of sands to oil: Petroleum Technology, Feb., 1938.
(5) Hill, E. S., Methods of determining the oil saturation of oil sand samples: Min. Ind. Exp. Sta., Penn. State College Bull. 19, 1935.
(6) Horner, W. L., Determination of oil content of sands for water flooding: Petroleum Engineer, April, 1935.
(7) Horner, W. L., Contamination of cores: The Oil Weekly, July 1, 1935.
(8) Krause, L., and Powell, G. N., Jr., Core analysis valuable in water flooding work: The Oil Weekly, Feb. 1, 1937.
(9) Lewis, J. A., and Horner, W. L., Interstitial water saturation in the pore space of oil reservoirs: Geophysics Magazine, Oct., 1936.
(10) Pyle, H. C., and Jones, P. H., Quantitative determination of the connate water content of oil sands: Proceedings of the Chicago, Ill., meeting of the Am. Petroleum Inst., Nov. 12, 1936.
(11) Schilthuis, R. J., Connate water in oil and gas sands: Petroleum Technology, Feb., 1938.
(12) Taylor, F. B., Completely equipped laboratory: The Oil Weekly, Dec. 21, 1936.

weighed and the per cent weight of liquid is calculated in terms of the weight of the oil-extracted sample.

The total sample is too large for the pycnometer. Therefore about one-third of the sample, so taken as to be representative of the whole sample, is used in the pycnometer test for total volume determination and pore volume determination. The latter two tests are made exactly as described for the smaller sample. The weight of total liquid in this sample is calculated by the aliquot method, i. e., the weight of the smaller oil-extracted sample is to the weight of the larger oil-extracted sample as the weight of the liquid in the small sample is to the weight of liquid in the larger sample.

The specific gravity of the liquid in the oil sand is assumed to be the same as that of a sample of oil collected from either the cored well or an adjacent well. Then the weight of the oil necessary to completely saturate the pore space is calculated as the product of the pore volume and the specific gravity of the oil. The per cent saturation of the sample is calculated as the ratio of the weight loss, due to extraction, to this theoretical weight for complete saturation.

Because of the difficulty of determining the oil-water ratio and the amounts of connate water and coring water present in the samples, the specific gravity of the liquid is arbitrarily taken as that of the oil in the well. Since the specific gravities of oil and water are about 0.85 and 1.00 respectively, the total liquid saturation of pore volume of a sample, calculated upon the assumption that only water is present, would differ from that calculated upon the assumption that only oil is present by one part in seven. If the liquid were assumed to be half oil and half water, the difference would be reduced to one part in fourteen.

In addition to the calculation of the per cent total liquid saturation of pore volume of the samples, the saturation of each core is expressed in terms of the total liquid saturation of the core in barrels per acre-foot. To obtain this value, the average porosity of the core is multiplied by its average saturation which gives the average of the ratio of total liquid volume to total volume for the core. This result is then multiplied by the volume of one acre-foot in barrels, giving total liquid saturation in barrels per acre-foot. One acre-foot is 43,560 cubic feet or 7,756 petroleum barrels.

PERMEABILITY TESTS

In brief, a permeability test consists of the measurement of the conductivity of a sample to fluid flow per cm. cubed per unit pressure drop.

The law governing the rate of flow of fluid through a porous body was discovered by Darcy[6] and is known as Darcy's law. This law may be stated algebraically as follows:

$$K = F \frac{VL}{AP}$$

Where K is the permeability (darcys); F is the rate of flow (cc. per sec.); V is the absolute viscosity of the liquid (centipoises); L is the length of sample in direction of flow (cm.); A is the cross-sectional area of sample (sq. cm.); and P is the differential pressure (atmospheres).

The method used to determine permeability in this investigation is similar to that described by Barnes.[7]

Due to the high friability, parting planes, and thin shale laminae in most Illinois oil sands, the core samples are small, so all permeability samples were cut to rectangular test pieces, 1 x 1 cm. in a vertical direction and 2 cm. in a horizontal direction (parallel to the bedding plane).

In all permeability tests herein reported air was used as the fluid. Due to the compressibility of air, the effective pressure P in the above mentioned Darcy formula is the pressure difference through the sample multiplied by the mean pressure (arithmetic average of absolute inlet and outlet pressures) and divided by the atmospheric pressure (outlet pressure).

Above a critical rate, the flow of a fluid through a porous medium changes from viscous flow to turbulent flow. Darcy's law is valid only for viscous flow. Therefore data for use in calculation of permeability were taken only in the range of viscous flow.

Details of Procedure

Prior to starting the experimental work herein reported, a sample from the Dyroff well No. 27 was sent to the U. S. Bureau

[6]Darcy, H., "Les fontaines publiques de la ville de Dijon," 1856.

[7]Fancher, G. H., Lewis, J. A., and Barnes, K. B., Min. Ind. Exp. Sta. Penn. State College Bull. 12, pp. 123-139, 1933.

of Mines for the purpose of control of porosity and permeability values. The U. S. Bureau of Mines cut a sample from it, made porosity and permeability tests, furnished the Survey laboratory the experimental results, and returned the core sample for checking by the Survey laboratory.

CHECK WITH U. S. BUREAU OF MINES

The U. S. Bureau of Mines used the following procedure in obtaining the porosity of the above sample: "The porosity of the sands was determined by the use of compressed air in arriving at the volume of the sand grains in the specimens. The volume of sand grains plus the volume of the pores (bulk volume) was determined with a Russel volumeter using acetylene tetrachloride as described in Bureau of Mines Report of Investigations 2876, entitled 'Use of Acetylene Tetrachloride Method of Porosity Determination in Petroleum Engineering Studies,' by Chase E. Sutton, published in 1928. The difference between the bulk volume and the volume of the sand grains gives the volume of voids in the sample, and this volume divided by the bulk volume multiplied by 100 gives the porosity in per cent."

The value reported by the U. S. Bureau of Mines for this sample is 16.6 per cent porosity.

Using this sample, calibrated by the U. S. Bureau of Mines checks were made using the original Barnes porosity method and the modified Barnes method. The original method differs from the modified method, previously described herein, solely in that by the former method evacuation does not start until after the sample is submerged in acetylene tetrachloride.

In this check, the volume of the sample was obtained by the pycnometer method. Using the original Barnes method, the average of three check determinations shows 16.7 per cent porosity. Using the modified Barnes method, the average of three check determinations shows 16.5 per cent porosity. Instead of evacuating with a vacuum pump to a pressure of 4 mm. of mercury, a water aspirator which evacuates to the vapor pressure of water (about 1.7 cm. of mercury) was used in a further series of porosity tests by the modified Barnes method. The average result, using the water aspirator, shows 16.4 per cent porosity. This porosity result, with a value differing by 0.2 per cent from that established by the U. S. Bureau of Mines, was considered to be of the necessary degree of accuracy and therefore a water aspirator was used for evacuation throughout this investigation.

The U. S. Bureau of Mines also established the permeability for this same test piece from the Dyroff well No. 27. They used the same method of permeability testing as described herein. They reported a value of 24.5 millidarcys.

Using this same test piece, the Survey results for three consecutive tests show values of 26.2, 25.9, and 24.4 millidarcys, or an average of 25.5 millidarcys. Thus it is seen that the variation between the U. S. Bureau of Mines and the Survey results for permeability is less than the extreme variation between duplicate Survey tests.

PREPARATION OF SAMPLES, ETC.

The investigation of all cores herein reported includes both porosity and permeability tests. In all instances in which the Survey core barrel was used, a Survey representative was present to make saturation tests. However, this investigation also includes studies of several cores taken by the operator, with no Survey representative present to make saturation tests.

The procedure used in coring a well by the Survey was as follows:

In the coring of an oil sand the core barrel is attached to the drill stem by the use of a "sub" as shown in figure 2, "The Need for Sand Coring in the Southeastern Illinois Oil Field," by A. H. Bell and R. J. Piersol, Illinois State Geological Survey, Illinois Petroleum No. 21 (1931). The bit is attached to the outer core barrel, being raised and lowered like an ordinary bit, but the inner tube remains stationary except that it is driven downward as drilling progresses. The average length of the coring run is about three feet, the core drilling rate being from one to two feet per hour. At the end of each run the core barrel is pulled from the well, the core removed from the barrel, the drillings removed from the well by a bailer, about 30 gallons of water poured into the well, and the coring is resumed.

As core is removed from the barrel it is fed into a trough. Usually about two-thirds of the sand is recovered in the form of biscuits, from a fraction of an inch to about three inches thick. The fine material is discarded and the biscuits are flushed with water. Samples are immediately selected for saturation tests. For the first few cores, saturation samples were taken at about one-foot intervals. Later on a composite saturation sample was taken for each run, this sample consisting of fragments of biscuits taken at about one-foot intervals.

Each saturation sample is weighed immediately and placed in a paper sack so marked as to identify the sample.

Biscuits for permeability tests are then selected at an average interval of about one foot. Each permeability sample is also placed in a separate paper sack so marked as to identify the sample.

The remainder of the core is placed in a wooden core box, with depths marked on the box. A geological study is made of this core in the Survey laboratory.

After the saturation samples are taken to the laboratory, the oil is extracted and their porosity and saturation values are determined as described.

In a few samples of low permeability, it is found that the volume of pore space occupied by the original liquid in the saturation sample is greater than the pore space calculated from the weight of acetylene tetrachloride absorbed. In these instances, the per cent porosity is determined by the volume of pore space occupied by the original liquid and is so recorded in this report.

The samples selected for permeability are cut with a carborundum saw to 1 x 1 x 2 cm. rectangular test pieces. These test pieces are oil-extracted in the same manner as the saturation samples.

After oil extraction, the samples are tested for permeability as described. At least two tests are made at different pressures, to insure that the test is made in the range of viscous flow.

In the investigation of the relation of vertical and horizontal permeability, 1 cm. cubes are cut from the remaining portions of samples previously tested for permeability. Care is taken to mark clearly two opposite vertical faces. Then the oil from these cubes is extracted and they are tested in identically the same manner as the rectangular samples.

LOGS OF CORES, AND EXPERIMENTAL RESULTS

Porosity, Saturation, and Permeability

This chapter includes the logs of 45 cores from 40 wells (four of the wells included cores from two or three different sands) representing 17 pools in 10 oil sands, and the tabulated results of tests on porosity, saturation, and permeability. For cores for which saturation samples were available, the total liquid saturation in terms of barrels per acre-foot is shown in a footnote to the tables. Tabulated results on relative vertical and horizontal permeability for six cores from six pools in five different sands are also given.

The order of presentation of both logs of cores and experimental results is according to sands, pools, and wells. The sands are presented according to their geologic horizon, from the top downward; the various pools in each sand are listed in alphabetical order, and the wells in each pool are listed alphabetically by lease name.

Upper Partlow Sand

north johnson pool

The Upper Partlow sand was cored only on Howe well No. 30 in the North Johnson pool.

Tide Water Associated Oil Co.—F. Howe well No. 30, S. E. cor. sec. 3, T. 9 N., R. 14 W., Clark County
Surface elevation 618 feet

	Thickness Ft.	Thickness In.	Depth Ft.	Depth In.
Beginning of core			500	0
Pennsylvanian system				
Sandstone, gray, fine, occasional thin streaks and patches of oil	0	8	500	8
Sandstone, gray, fine, pyritic near base	1	4	502	0
Shale, dark gray	1	0	503	0
Sandstone, gray, fine, containing some streaks of oil, partings of shale, dark gray; sample 1	0	6	503	6
Sandstone, gray, coarse, pyritic, containing oil; samples 2–5	4	6	508	0
Shale, sandy, light gray, pyritic	0	1	508	1
Shale, dark gray, micaceous	0	5	508	6
Sandstone, gray, coarse, pyritic and carbonaceous; sample 6	1	0	509	6
Sandstone, light gray, fine, containing streaks of oil; samples 7–9	3	8	513	2
Sandstone, light gray, fine, containing streaks of oil, numerous partings of shale, dark gray; samples 10–19	9	11	523	1
Shale, dark gray	2	0	525	1
Sandstone, light gray with thick bands of dark gray, medium to coarse, containing oil; samples 20–28	10	11	536	0
Sandstone, dark gray with occasional streaks of light gray, medium grained, containing oil; samples 29–34	6	0	542	0
Sandstone, light gray, coarse, containing oil, very coarse and slightly pyritic at 548 to 549 feet; samples 35–55	21	0	563	0
Shale, dark gray	14	2	577	2

Table 2 below shows porosity and saturation results for composite samples taken from each run, and permeability results for samples taken at about one-foot intervals in the upper Partlow sand from Howe well No. 30 in the North Johnson pool.

The data are plotted in figure 3, page 52.

Table 2.—Porosity, Saturation and Permeability of Upper Partlow sand, North Johnson pool, Howe well No. 30 (Fig. 3).

Sample No.	Depth (ft.–in.)	Porosity (per cent)	Saturation (per cent)[1]	Permeability (millidarcys)
1	503–6	21.2	92.0	10.9
2	504–6			6.75
3	505–6			3.90
4	506–6	15.5	87.4	
5	508.0			
6	509–6			33.8
7	511–0	19.2	89.8	34.6
8	512–6			22.8
9	513–2			23.6
10	514–2			29.7
11	515–2	19.5	94.6	112.
12	516–2			175.
13	517–2			28.3
14	518–2			74.3
15	519–2	21.0	91.9	197.
16	520–2			55.4
17	521–2			234.
18	522–1	18.8	94.7	20.5
19	523–1			16.1
20	525–1	23.4	99.8	304.
21	526–1			441.
22	527–6			311.
23	529–3	22.4	97.7	255.
24	531–0			265.
25	532–3			452.
26	533–6	20.7	100.	374.
27	534–9			404.
28	536–0			749.
29	537–0			369.
30	538–0			408.
31	539–0	20.1	97.3	256.
32	540–0			244.
33	541–0			186.
34	542–0			106.
35	543–0	21.9	98.6	147.
36	544–0			34.5
37	545–0			84.8
38	546–0			574.
39	547–0	23.4	98.2	183.
40	548–0			386.
41	549–0			784.
42	550–0	21.8	98.5	116.
43	551–0			505.
44	552–0			600.
45	553–0			552
46	554–0			1320
47	555–0			924.
48	556–0	23.2	95.0	870.
49	557–0			1490.
50	558–0			2430.
51	559–0			1390
52	560–0			586.
53	561–0	20.5	98.5	875.
54	562–0			600.
55				5.84

[1]Total liquid saturation of the core in terms of bbls. per acre-foot is 1473.

Robinson sand

The Robinson sand was cored in the Crawford—Main, Flat Rock, Lawrence County, New Hebron, and Parker pools.

See figures 4-9, pages 53-56.

CRAWFORD—MAIN POOL

Clark well No. 19, Clark well No. 20, Furman well No. 10, Henry well No. 14, Snyder well No. 6, Stifle well No. 23, and Wattleworth well No. 18 were cored in the Crawford—Main pool. Furman well No. 10 and Snyder well No. 6 were cored by the operator, the Warner Caldwell Oil Company, a Survey representative being present at the time of coring to take saturation samples. (Figs. 4-5, pp. 53, 54.)

Table 3 below shows porosity and permeability results for samples taken at six-inch intervals, and saturation results for samples of the Robinson sand taken at about one-foot intervals from Clark well No. 19. (Fig. 4, p. 53.)

Mahutska Oil Co.—R. M. Clark well No. 19, Cen. N. line SE. 1/4 SW. 1/4 sec. 17, T. 7 N., R. 13 W., Crawford County

Surface elevation 513 feet

	Thickness Ft.	Thickness In.	Depth Ft.	Depth In.
Beginning of core			905	4
Pennsylvanian system				
Sandstone, light gray, fine to medium, soft, containing oil; samples 1–8	4	6	909	10
Sandstone, light gray, fine to medium, containing oil, interlaminations and partings of shale, dark gray; samples 9–23	11	2	921	0
Shale, dark gray, with zones containing numerous thin laminae of sandstone, light gray, fine	39	0	960	0
Sandstone, light gray, fine to medium, containing oil, interlaminated shale, dark gray; sample 24	4	0	964	0
Sandstone, light gray, medium, containing oil, partings of shale, dark gray, decreasing downward; samples 25–51	14	0	978	0
Shale, dark gray, occasional laminae of sandstone, light gray, fine	6	0	984	0
Sandstone, light gray, medium to coarse, containing oil, numerous partings of shale, dark gray; sample 52	1	0	985	0
Sandstone, light gray, coarse, soft, containing oil, micaceous and carbonaceous in bottom 2 feet; samples 53–70	9	0	994	0

TABLE 3.—POROSITY, SATURATION, AND PERMEABILITY OF ROBINSON SAND, CRAWFORD —MAIN POOL, CLARK WELL NO. 19 (FIG. 4).

Sample No.	Depth (ft.–in.)	Porosity (per cent)	Saturation (per cent)[1]	Permeability (millidarcys)
1	905–4	23.4	100.	502.
2	905–11	21.9		534.
3	906–6	22.4	97.8	668.
4	907–1	20.3		324.
5	907–8	19.7	88.5	266.
6	908–3	18.7		252.
7	908–10	18.6	92.8	211.
8	909–5	18.3		210.
9	910–0	21.0	100.	112.
10	910–8	17.5		126.
11	911–4	19.9	100.	116.
12	912–0	17.4		219.
13	913–0	19.8	100.	160.
14	913–8	18.2		311.
15	914–4	18.2	100.	204.
16	915–0	19.9		311.
17	915–8	21.1	100.	444.
18	916–2	23.4	100.	471.
19	916–8	19.4		190.
20	917–4	19.0	100.	163.
21	918–4	13.0	78.6	14.3
22	919–10	14.2	91.3	56.4
23	920–4	13.9		49.0
24	964–0	13.9	80.3	10.2
25	964–6	13.9		5.21
26	965–0	16.4	84.8	22.3
27	965–6	16.0		5.94
28	966–0	15.9	92.6	4.24
29	966–6	16.8		10.0
30	967–0	17.2	87.5	15.2
31	967–6	17.0		10.1
32	968–0	16.5	99.3	6.02
33	968–6	16.4		6.96
34	969–0	17.3	96.1	12.7
35	969–6	16.4		15.7
36	970–0	17.7	98.6	31.6
37	970–6	16.7		6.43
38	971–0	18.2	93.3	26.7
39	971–6	16.7		18.3
40	972–0	17.0	98.2	31.4
41	972–6	61.6		7.88
42	973–0	19.3	95.4	64.6
43	973–6	18.3		41.6
44	974–0	20.5	100.	73.8
45	974–6	18.8		63.2
46	975–0	19.7	100.	23.9
47	975–6	18.3		83.8
48	976–0	21.2	100.	124.
49	976–6	18.4		61.8
50	977–0	22.5	100.	50.6
51	977–6	26.1		108.
52	985–0	8.65	100.	1.28
53	985–6	7.30		3.39
54	986–0	6.70	100.	0.21
55	986–6	6.60		308.
56	987–0	19.9	100.	0.00
57	987–6	21.3		225.
58	988–0	24.0	100.	130.
59	988–6	24.4		1190.
60	989–0	26.1	100.	1000.

Table 3.—(Concluded)

Sample No.	Depth (ft.–in.)	Porosity (per cent)	Saturation (per cent)[1]	Permeability (millidarcys)
61	989–6	3.38		0.00
62	990–0	23.6	100.	60.4
63	990–6	21.8		89.4
64	991–0	27.1	93.2	766.
65	991–6	22.0		202.
66	992–0	25.2	100.	630.
67	992–6	13.5		236.
68	993–0	24.9	100.	311.
69	993–6	21.8		722.
70	994–0	19.5	100.	289.

[1]Total liquid saturation of the core in terms of bbls per acre-foot is 1376.

Mahutska Oil Co.—R. M. Clark well No. 20, NW. 1/4 SE. 1/4 SW. 1/4 sec. 17, T. 7 N., R. 13 W., Crawford County

Surface elevation 512.3 feet

	Thickness Ft.	Thickness In.	Depth Ft.	Depth In.
Beginning of core			865	0
Pennsylvanian system				
Sandstone, light gray, fine, containing oil, partings of shale, dark gray; sample 1	3	0	868	0
Shale, dark gray, lenses and laminae of sandstone, light gray, fine, containing oil	0	6	868	6
Shale, dark gray, laminae of sandstone, light gray, fine	18	6	887	0
Sandstone, light gray, fine, hard, slightly pyritic, containing oil, occasional zones with partings of shale, dark gray; samples 2–16	15	6	902	6
Shale, dark gray, interlaminated with sandstone, light gray, containing oil	6	0	908	6
Sandstone, light gray, fine, hard, containing oil, 4-inch quartzitic layer at 915′, abundant partings of shale, dark gray; samples 17–20	20	0	928	6
Shale, dark gray, interlaminated with sandstone, light gray	3	10	932	4
Sandstone, light gray, fine, containing oil, abundant partings of shale, dark gray, in upper 22 feet, less abundant below; samples 21–30	35	8	968	0
Shale, dark gray, containing sandy zones	12	0	980	0
Sandstone, argillaceous, light gray, medium to coarse, pyritic, carbonized plant remains	4	0	984	0
Shale, dark gray, laminae of sandstone, light gray, fine	1	0	985	0
Shale, dark gray to black, very soft	1	0	986	0
Shale, dark gray	5	6	991	6

Table 4 below shows porosity and saturation results for composite samples taken from each run, and permeability results for samples of the Robinson sand taken at one-foot intervals in the upper part of the sand and at greater intervals in the lower part of the sand from Clark well No. 20 in the Crawford—Main pool.

The data are plotted in figure 4, page 53.

Table 4.—Porosity, Saturation, and Permeability of Robinson sand, Crawford—Main pool, Clark well No. 20 (Fig. 4).

Sample No.	Depth (ft.–in.)	Porosity (per cent)	Saturation (per cent)[1]	Permeability (millidarcys)
1	866–4	15.3	52.9	18.5
2	877–0			17.7
3	888–0	20.5	84.2	667.
4	889–0			433.
5	890–0			171.
6	891–0	20.0	80.3	150.
7	892–0			264.
8	893–0			246.
9	894–0			53.8
10	895–0	20.9	79.5	45.4
11	896–0			297.
12	897–0			603.
13	898–0			232.
14	899–0	20.2	91.2	438.
15	900–0			353.
16	901–0			103.
	908–6 912–6	17.3	76.4	
17	914–0	17.0	79.9	72.1
18	918–6			57.4
19	923–0	18.8	73.8	167.
20	927–0	20.9	71.3	382.
	932.4	17.4	94.4	
21	935–4			284.
22	939–0	18.8	95.0	51.8
23	943–0			43.6
24	946–4	17.9	85.2	79.4
25	950–0	17.0	85.9	47.8
26	953–0			4.54
27	956–0	17.8	86.8	10.7
28	959–0			6.24
29	962–0	16.0	91.0	0.39

[1]Total liquid saturation of the core in terms of bbls. per acre-foot is 1211.

Warner-Caldwell Oil Co.—J. C. Furman well No. 10, NW. 1/4 SW. 1/4 NW. 1/4 sec. 6, T. 6 N., R. 12 W., Crawford County

Surface elevation 521 feet

	Thickness Ft.	Thickness In.	Depth Ft.	Depth In.
Beginning of core			895	0
Pennsylvanian system				
Sandstone, fine-grained, compact, interlaminated with shale, dark gray	4	0	899	0
Sandstone, light gray, fine, compact, containing oil, interlaminated with shale, dark gray	10	9	909	9
Well drilled without coring	63	3	973	0
Sandstone, medium-grained, containing some oil; samples 1–5	4	0	977	0
Shale, light gray, with thin sandy streaks	6	0	983	0

Table 5 below shows duplicate porosity, saturation, and permeability results for samples of the Robinson sand taken at about one-foot intervals from Furman well No. 10 in the Crawford—Main pool.

See figure 4, page 53.

Tide Water Associated Oil Co.—H. Henry well No. 14, NE. 1/4 SE. 1/4 sec. 10, T. 7 N., R. 13, W., Crawford County

Surface elevation 530 feet

	Thickness Ft.	Thickness In.	Depth Ft.	Depth In.
Beginning of core			955	0
Pennsylvanian system				
Sandstone, light gray, medium to coarse, containing oil, occasional partings of carbonaceous material and some mica; samples 1–16	16	6	971	6
Same, with no oil; samples 17–19	3	0	974	6
Same, with oil; sample 20	0	6	975	0
Shale, sandy, green and gray	1	0	976	0
Sandstone, light gray, fairly hard, containing traces of oil; samples 21–23	3	0	979	0
Shale, green and gray, sandy in upper part	0	6	979	6
Sandstone, light gray, fairly hard; samples 24–25	3	0	982	6
Shale, dark gray	0	6	983	0
Sandstone, light gray, fairly hard; sample 26	1	0	984	0
Shale, dark gray, sandy in upper 6 inches	3	0	987	0

Tables 6A and 6B show porosity, saturation, and permeability results for samples of the Robinson sand taken at one-foot intervals from Henry well No. 14 in the Crawford—Main pool.

The data are plotted in figure 4, page 53.

Table 5.—Porosity, Saturation, and Permeability of Robinson sand, Crawford—Main pool, Furman well No. 10 (Fig. 4).

Sample No.	Depth (ft.–in.)	Porosity (per cent)	Saturation (per cent)[1]	Permeability (millidarcys)
1a	973–0	15.9	66.6	37.6
1b		14.9	73.2	53.2
2a	974–0	18.4	79.4	146.
2b		17.6	82.6	145.
3a	975–0	16.9	67.3	27.1
3b		16.5	69.2	23.9
4a	976–0	18.2	74.8	13.3
4b		18.1	73.9	15.1
5a	977–0	15.0	50.3	49.8
5b		15.9	46.9	

[1]Total liquid saturation of the core in terms of bbls. per acre-foot is 886.

Table 6A.—Porosity, Saturation, and Permeability of Robinson sand, Crawford—Main pool, Henry well No. 14 (Figs. 4 and 36).

Sample No.	Depth (ft.–in.)	Porosity (per cent)	Saturation (per cent)[1]	Permeability (millidarcys)
1	956–0	19.3	84.0	22.9
2	957–0	16.1	96.9	3.76
3	958–0	17.7	84.0	58.4
4	959–0	19.0	100.	12.3
5	960–0	18.8	78.0	83.3
6	961–0	17.9	78.8	46.8
7	962–0	19.7	91.7	114.
8	963–0	19.8	76.5	153.
9	964–0	19.1	79.8	97.8
10	965–0	18.3	89.3	84.3
11	966–0	20.0	76.4	227.
12	967–0	20.0	77.8	238.
13	968–0	18.9	100.	100.
14	969–0	17.2	100.	44.1
15	970–0	18.5	74.9	358.
16	971–0	18.3	85.0	185.
17	972–0	19.8	80.8	156.
18	973–0	18.9	92.3	119.
19	974–0	18.9	78.8	118.
20	975–0	16.2	100.	122.
21	977–0	16.1	100.	1.81
22	978–0	15.5	100.	0.58
23	979–0	15.1	100.	0.40
24	981–0	12.9	98.8	
25	982–0	15.9	85.8	2.70
26	983–6	13.8	100.	1.11

[1]Total liquid saturation of the core in terms of bbls. per acre-foot is 1237.

Table 6B.—Permeability and Porosity of Robinson sand, Crawford—Main pool, Henry well No. 14

Tested by Tide Water Laboratories, Inc.

Laboratory No.	Depth (feet)	Permeability (millidarcys)	Porosity (per cent)
037- 1	956.0	1.3	15.6
2	57.0	4.4	15.8
3	58.0	59.6	16.9
4	59.0	6.5	15.0
5	60.0	20.0	16.8
6	61.0	8.1	15.3
7	62.0	59.7	18.5
8	63.0	187.6	19.3
9	64.0	103.9	13.5
10	65.0	235.9	19.0
11	66 0	134.3	18.0
12	67.0	67.6	18.3
13	68.0	197.4	18.2
14	69.0	281.3	19.9
15	70.0	185.0	18.3
16	71.0	350.9	18.0
17	72.0	159.6	18.4
18	73.0	134.0	18.3
19	74.0	214.3	17.7
20	75.0	4.5	15.3
21	77.0	212.5	19.3
22	78.0	1.4	15.2
23	79.0	0.3	11.9
24	981.0	1.1	14.7

Warner-Caldwell Oil Co.—I. M. Snyder well No. 6 SW. 1/4 SW. 1/4 N.E. 1/4 sec. 6, T. 6 N., R. 12 W., Crawford County

Surface elevation 527 feet

	Thickness Ft.	Thickness In.	Depth Ft.	Depth In.
Beginning of core			976	0
Pennsylvanian system				
Shale, gray	1	6	977	6
Sandstone, light gray to white medium to coarse, occasional micaceous partings, "containing much gas;" samples 1–10	6	6	984	0
Sandstone, as above, but containing oil which was apparently more abundant below 991 feet; samples 11–27	11	0	995	0

Tables 7A and 7B show porosity, saturation, and permeability results for samples of the Robinson sand taken at six-inch intervals from Snyder well No. 6 in the Crawford—Main pool.

See figure 5, page 54.

Table 7A.—Porosity, Saturation, and Permeability of Robinson sand, Crawford—Main pool, Snyder well No. 6 (Fig. 5).

Sample No.	Depth (ft.–in.)	Porosity (per cent)	Saturation (per cent)[1]	Permeability (millidarcys)
1a	978–4	17.9	78.9	39.0
1b		18.4	77.0	38.3
2a	978–10	22.1	75.7	153.
2b		21.9	76.5	128.
3a	979–4	20.3	75.4	79.5
3b		21.0	72.4	87.9
4a	979–10	19.4	65.3	37.6
4b		18.3	70.4	28.5
5a	980–4	19.2	85.4	32.3
5b		19.5	84.0	39.9
6	981–4	16.4	85.3	10.7
7a	981–10	16.7	85.4	12.7
7b		16.0	90.3	13.8
8a	982–4	17.6	86.3	28.6
8b		18.3	82.4	28.3
9a	982–10	15.9	85.0	8.7
9b		15.2	89.9	8.5
10a	983–6	16.3	85.4	14.6
10b		16.3	84.9	14.0
11a	984–2	15.5	87.9	14.4
11b		15.7	86.2	13.1
12a	984–10	15.7	98.3	9.8
12b		16.5	91.7	13.1
13a	985–6	19.1	85.2	71.9
13b		19.1	85.0	71.9
14a	986–0	19.7	88.3	79.8
14b		20.0	86.1	78.6
15a	986–6	19.4	85.3	57.9
15b		19.8	88.3	56.7
16	987–0	15.7	88.9	24.1
17	988–6	15.6		28.7
18a	989–0	19.6	85.4	67.8
18b		19.2	87.3	70.3
19a	989–6	18.8		120.
19b		17.0		102.
20a	991–0	18.6	87.8	90.6
20b		19.1	85.3	86.5
21a	991–8	16.3		29.5
21b		16.9		33.4
22a	992–6	19.3	100	93.4
22b		19.1	100	94.5
23a	993–0	19.6		58.2
23b		19.4		59.3
24a	993–6	19.6	92.2	64.9
24b		19.0	96.0	54.5
25a	994–0	19.0		55.6
25b		18.8		60.2
26a	994–6	20.7	94.3	166.
26b		20.0	99.6	143.
27a	995–0	20.4		128.
27b		20.2		121.

[1]Total liquid saturation of the core in terms of bbls. per acre-foot is 1226.

TABLE 7B.—POROSITY AND PERMEABILITY OF ROBINSON SAND, CRAWFORD—MAIN POOL, SNYDER WELL NO. 6.

Tested by the Core Testing Laboratories, Inc.

Sample No.	Depth (feet)	Porosity (per cent)	Sample No.	Depth (feet)	Porosity (per cent)
1......	978.5	19.10	1....	978.6	65.0
2......	982.8	19.72	2....	979.9	51.4
3......	984.6	16.50	3....	981.0	44.8
4......	985.6	20.53	4....	982.8	41.8
5......	986.6	18.46	5....	984.0	5.6
6......	987.6	15.89	6....	984.4	.55
7......	988.6	17.60	7....	985.0	16.6
8......	989.6	22.09	8....	986 0	44.9
9......	990.8	15.58	9....	987.1	10.8
10......	991.8	20.70	10....	988.2	59.9
11......	992.9	19.40	11....	989.1	96.5
12......	993.9	22.00	11....	989.7	117.7
13......	994.9	21.10	13....	990.5	63.9
			14....	991.3	92.1
			15....	992.7	34.2
			16....	994.2	215.4
			17....	995.2	128.6

Tide Water Associated Oil Co.—E. Stifle well No. 23
Cen. SE. 1/4 NW. 1/4 sec. 10, T. 7 N., R. 13 W., Crawford County

Surface elevation 525 feet

	Thickness Ft.	Thickness In.	Depth Ft.	Depth In.
Beginning of core...........			957	0
Pennsylvanian system				
Sandstone, somewhat shaly, greenish-gray, fine, micaceous..................	2	6	959	6
Shale, dark gray............	3	6	963	0
Shale, interlaminated with sandstone, occasional thick lenses of sandstone containing oil....................	11	0	974	0
Sandstone, medium- to coarse, occasional micaceous and carbonaceous partings and zones, contains oil, pyrite abundant in lower 1 foot; 6-inch shale layer below 975′ 6″, 2-inch shale below 976′ 2″, and 1-inch shale below 977′6″; sandstone samples 1–45....................	27	6	1001	6
Shale, dark gray............	1	0	1002	6

Table 8 below shows porosity and permeability results for samples of the Robinson sand taken at six-inch intervals and saturation results for samples taken at one-foot intervals from Stifle well No. 23 in the Crawford—Main pool.

See figure 5, page 54.

TABLE 8.—POROSITY, SATURATION, AND PERMEABILITY OF ROBINSON SAND, CRAWFORD—MAIN POOL, STIFLE WELL NO. 23 (FIG. 5).

Sample No.	Depth (ft.–in.)	Porosity (per cent)	Saturation (per cent)[1]	Permeability (millidarcys)
1.....	974–6	24.6	100	62.3
2.....	975–0	19.3	100	151.
3.....	976–6	24.1	100	1090.
4.....	977–0	25.4	100	1136.
5.....	977–10	24.6	100	696.
6.....	978–8	23.4	100	484.
7.....	979–2	21.0		306.
8.....	979–10	24.2	100	294.
9.....	980–6	20.6	100	221.
10.....	981–2	23.2	100	191.
11.....	981–10	20.6		223.
12.....	982–6	24.3	100	194.
13.....	983–0	17.5		94.3
14.....	983–6	19.1	100	25.6
15.....	984–0	16.5		21.1
16.....	984–6	19.8	100	75.9
17.....	985–0	20.5		182.
18.....	985–6	24.4	100	584.
19.....	986–0	18.8		85.6
20.....	986–6	20.4	100	69.4
21.....	987–0	20.9		172.
22.....	987–6	22.4	100	187.
23.....	988–2	17.7		57.7
24.....	988–10	18.3	100	42.0
25.....	989–6	19.9		119.
26.....	990–2	21.2	100	206.
27.....	990–10	21.5		455.
28.....	991–6	22.9	100	354.
29.....	992–2	19.8		195.
30.....	992–10	22.6	100	242.
31.....	993–4	20.5		253.
32.....	993–10	23.9	100	206.
33.....	994–4	22.0		396.
34.....	994–10	23.5	100	337.
35.....	995–4	20.6		214.
36.....	995–10	23.4	100	122.
37.....	996–4	19.3		150.
38.....	996–10	24.9	100	17.7
39.....	997–6	20.8		190.
40.....	998–2	25.4	100	87.8
41.....	998–10	17.4		49.3
42.....	999–2	19.0	100	56.5
43.....	999–10	17.3		21.2
44.....	1000–2	13.3	100	0.59
45.....	1001–0	7.85		0.00

[1]Total liquid saturation of the core in terms of bbls. per acre-foot is 1621.

Tide Water Associated Oil Co.—J. J. Wattleworth well No. 18 cen. SW. 1/4 SW. 1/4 sec. 10, T. 7 N., R. 13 W., Crawford County

Surface elevation 531 feet

	Thickness Ft.	Thickness In.	Depth Ft.	Depth In.
Top of "gas sand" carrying some gas in this area			900	0
Pennsylvanian system				
Well drilled in "gas sand" without core	11	0	911	0
Sandstone, light gray, medium-grained, occasional partings of shale, dark gray	0	6	911	6
Sandstone, light gray, medium-grained, interlaminated with shale, dark gray	4	0	915	6
Shale, dark gray, occasional thin laminae of sandstone, light gray	3	6	918	0
Well drilled without coring	27	0	945	0
Sandstone, light gray, fine to medium, interlaminated with shale, dark gray	17	9	962	9
Sandstone, argillaceous, greenish-gray very fine	11	3	974	0
Shale, dark gray, occasional thin laminae of sandstone, light gray	4	6	978	6
Sandstone, light gray, medium-grained; sample 1	1	0	979	6
Shale, dark gray, laminated	0	6	980	0
Sandstone, gray, coarse, containing oil and some gas; micaceous and carbonaceous partings at 992′6″; samples 2–16	14	0	994	0
Sandstone, gray, coarse, containing less oil than above, bituminous and pyritic near base, micaceous and carbonaceous partings at 1000′; samples 17–36	20	0	1014	0
Sandstone, gray, very coarse, bituminous and pyritic, some oil	1	0	1015	0
Shale, dark gray, laminated	0	6	1015	6
Limestone, dark gray to black, pyritic, showing cone-in-cone structure	0	6	1016	0

Table 9 below shows porosity, saturation, and permeability results for samples of the Robinson sand taken at one-foot intervals from Wattleworth well No. 18 in the Crawford—Main pool.

The data are shown graphically in figure 5, page 54.

Table 9.—Porosity, Saturation, and Permeability of Robinson sand, Crawford—Main pool, Wattleworth well No. 18 (Fig. 5).

Sample No.	Depth (ft.–in.)	Porosity (per cent)	Saturation (per cent)[1]	Permeability (millidarcys)
1	979–0	23.7	100.	85.1
2	980–0	20.6	86.3	188.
3	981–0	18.5	89.2	68.7
4	982–0	20.3	81.3	278.
5	983–0	19.8	82.7	163.
6	984–0	17.8	89.4	42.0
7	985–0	19.4	83.5	174.
8	986–0	17.1	90.2	39.8
9	987–0	20.1	83.1	238.
10	988–0	19.4	77.0	160.
11	989–0	19.5	100.	73.7
12	990–0	20.8	90.1	276.
13	991–0	18.8	100.	26.9
14	992–0	23.0	100.	178.
15	993–0	20.4	83.2	195.
16	994–0	21.1	93.8	446.
17	995–0	19.3	83.4	141.
18	996–0	20.1	83.8	180.
19	997–0	18.8	86.2	91.2
20	998–0	20.3	79.9	271.
21	999–0	19.0	100.	69.4
22	1000–0	17.5	100.	67.9
23	1001–0	18.4	99.6	89.6
24	1002–0	19.1	93.8	105.
25	1003–0	18.7	74.8	202.
26	1004–0	15.2	100.	9.29
27	1005–0	9.90	93.5	0.92
28	1006–0	16.4	93.9	33.8
29	1007–0	18.3	100.	77.9
30	1008–0	15.8	100.	15.3
31	1009–0	17.8	100.	80.1
32	1010–0	19.2	100.	26.6
33	1011–0	9.94	94.7	5.15
34	1012–0	16.7	100.	81.0
35	1013–0	14.4	100.	41.4
36	1014–0	12.3	100.	4.31

[1]Total liquid saturation of the core in terms of bbls. per acre-foot is 1306.

FLAT ROCK POOL

Cochran well No. 1 was the only well in the Flat Rock pool which was cored in the Robinson sand.

Downey and Connor—W. N. Cochran well No. 1, SE. 1/4 SE. 1/4 NW. 1/4, sec. 12, T. 5 N., R. 12 W., Crawford County

Surface elevation 523 feet

	Thickness Ft.	Thickness In.	Depth Ft.	Depth In.
Beginning of core			891	0
Pennsylvanian system				
Siltstone, brownish-gray, numerous paper-thin partings of carbonaceous shale; samples 1 and 2	2	6	893	6
Sandstone, very fine, oil-bearing, numerous partings of carbonaceous micaceous shale; samples 3–7	4	6	898	0
Shale, dark gray, numerous paper-thin partings of gray sandstone	2	0	900	0
Sandstone, cherty, brownish-gray, slight oil show	1	0	901	0
Sandstone, gray, fine, micaceous, compact, containing cherty bands and partings of carbonaceous shale; sample 8	1	0	902	0
Coal	1	0	903	0
Shale, silty, light gray, containing fossil plants	5	0	908	0
Shale, dark gray, weak, carbonaceous	1	0	909	0
Shale, silty, no core	18	0	927	0
Sandstone, brown to brownish-gray, fine, somewhat compact, samples 10 and 11 at 930 and 931 feet	5	0	932	0
Coal	1	6	933	6
Shale, silty, dark gray, carbonaceous	1	6	935	0
Shale, no core	24	0	949	0
Robinson sand				
Sandstone, white, medium-grained, micaceous, oil bearing; samples 12–16	4	0	953	0
Same, but more oil bearing; samples 17–23	8	0	961	0

Table 10 below shows porosity and saturation results for complete samples taken from each run, and permeability results for samples of the Robinson sand taken at one-foot intervals from Cochran well No. 1 in the Flat Rock pool. As shown by discontinuities in sample depths listed in this table, there are breaks in the sand.

The results are shown graphically in figure 6, page 54.

TABLE 10.—POROSITY, SATURATION, AND PERMEABILITY OF ROBINSON SAND, FLAT ROCK POOL, COCHRAN WELL NO. 1 (FIG. 6).

Sample No.	Depth (ft.–in.)	Porosity (per cent)	Saturation (per cent)[1]	Permeability (millidarcys)
1	892–0	18.9	84.1	0.46
2	893–0			0.298
3	894–0			
4	895–0	15.8	74.9	
5	896–0			
6	897–0			
7	898–0			
8	902–0	15.3	59.2	12.9
9	927–0			52.0
10	930–0	22.1	57.9	56.4
11	931–0			47.6
12	949–0			282.
13	950–0			168.
14	951–0	22.6	59.0	300.
15	952–0			162.
16	953–0			157.
17	954–0	24.3	61.2	175.
18	955–0			326.
19	956–0	19.9	30.4	149.
20	957–0			30.6
21	958–0	21.3	77.7	150.
22	960–0	18.8	63.5	57.5
23	961–0	21.0	64.5	342.

[1]Total liquid saturation of the core in terms of bbls. per acre-foot is 980.

LAWRENCE COUNTY POOL

In the Lawrence County pool the Robinson sand was cored only in Crump well No. 27.

W. C. McBride, Inc.—Crump well No. 27, NE. 1/4 SW. 1/4 SW. 1/4 sec. 19, T. 4 N., R. 12 W., Lawrence County

Surface elevation 428.7 feet

	Thickness Ft.	Thickness In.	Depth Ft.	Depth In.
Beginning of core			878	0
Pennsylvanian system				
Siltstone, medium to dark gray, compact, grading downward to sandstone	1	8	879	8
Sandstone, brown, very fine, containing oil; sample 1	0	8	880	4
Sandstone, light gray, very fine	0	4	880	8
Sandstone, light gray, very fine, irregularly interbedded with shale, silty, dark gray; samples 2–3	1	5	882	1
Sandstone, argillaceous, light gray, very fine, very pyritic, containing a little oil	0	5	882	6
Sandstone, argillaceous, light gray, very fine, irregularly interbedded with shale, dark gray	0	4	882	10
Sandstone, brown, very fine, pyritic, containing oil; sample 4	0	10	883	8
Shale, silty, dark gray, micaceous, pyritic	0	1	883	9
Sandstone, brown, very fine to fine, slightly friable, containing oil; samples 5–6	1	3	885	0
Shale, silty, dark gray, concontaining laminae of sandstone, light gray, very fine	0	1	885	1
Sandstone, brown, fine to medium, containing oil	0	6	885	7
Shale, sandy, dark gray, interlaminated with sandstone, light gray	0	1	885	8
Sandstone, brown, fine to medium, containing oil	0	1	885	9
Sandstone, calcareous, fine to medium, very pyritic, containing some oil	0	1	885	10
Nodule of pyrite surrounded by weak clay	0	1	885	11
Sandstone, gray to light brown, very fine, interbedded with shale, silty, dark gray, sample 7	0	4	886	3
Sandstone, brown, very fine, containing oil	0	4	886	7
Sandstone, brown, medium-grained, porous, friable, saturated with oil; samples 8–14	6	5	893	0

Table 11 below shows porosity, saturation, and permeability results for samples of the Robinson sand taken at one-foot intervals from Crump well No. 27 in the Lawrence County pool.

The data are plotted in figure 7, page 55.

Table 11.—Porosity, Saturation, and Permeability of Robinson sand, Lawrence County pool, Crump well No. 27 (Fig. 7).

Sample No.	Depth (ft.–in.)	Porosity (per cent)	Saturation (per cent)[1]	Permeability (millidarcys)
1	880	11.9	74.8	2.78
2	881	6.3	90.5	0.00
3	882	10.3	92.2	0.00
4	883	13.0	70.7	27.8
5	884	18.6	57.4	118.
6	885	19.1	89.9	361.
7	886	12.2	70.5	148.
8	887	17.5	43.4	1002.
9	888	19.0	79.3	1270.
10	889	20.8	59.1	2760.
11	890	20.7	82.0	1490.
12	891	10.7		6.10
13	892	21.4		4250.
14	893	20.0	82.4	3290.

[1]Total liquid saturation of the core in terms of bbls. per acre-foot is 912.

NEW HEBRON POOL

In the New Hebron pool the Robinson sand was cored only in Mohler well No. 15.

Mahutska Oil Co.—Mohler well No. 15, 900 feet from N. line, 1320 feet from W. line of the SW. 1/4 sec. 22, T. 6 N., R. 12 W., Crawford County

Surface elevation 530 feet

	Thickness Ft.	Thickness In.	Depth Ft.	Depth In.
Beginning of core			921	0
Pennsylvanian system				
Sandstone, light gray, fine, containing oil, carbonaceous plant fossils; sample 1	0	6	921	6
Shale, dark gray	4	11	926	5
Shale, dark gray, thin partings of sandstone, light gray	1	7	928	0
Shale, dark gray, interbedded with sandstone, light gray, fine, containing slight amount of oil	1	6	929	6
Shale, dark gray, containing 1/16″ to 1/4″ partings of sandstone, light gray, fine, making up about 1/10 of core	10	6	940	0
Same, about 1/6 of core consisting of sandstone partings containing oil	2	6	942	6
Shale, dark gray, interlaminated with equal proportions of 1/8″ to 1/2″ layers of sandstone, gray, fine, containing oil	2	6	945	0
Shale, dark gray, interlaminated with varied proportions of 1/4″ to 3/4″ layers of sandstone, light gray, fine, containing oil	4	0	949	0
Sandstone, light gray, with few partings of shale, dark gray, carbonaceous; samples 2 and 3	1	0	950	0
Sandstone, light gray, fine, containing oil, numerous thin partings of shale, dark gray to black, carbonaceous plant fossils; samples 4–25	17	6	967	6
Sandstone, light gray, fine, friable, containing oil, few partings of shale, dark gray to black, carbonaceous plant fossils; samples 26–35	9	6	977	0
Sandstone, light gray, fine, containing oil, carbonaceous plant fossils; sample 36	1	0	978	0
Sandstone, calcareous, light gray, hard, very fossiliferous with plant fragments; samples 37 and 38	2	6	980	6
Shale, calcareous, dark gray	2	0	982	0

Table 12 below shows porosity and saturation results for composite samples of the Robinson sand taken from each run, and permeability results for samples taken at one-foot intervals from Mohler well No. 15 in the New Hebron pool.

The data are presented graphically in figure 8, page 55.

TABLE 12.—POROSITY, SATURATION, AND PERMEABILITY OF ROBINSON SAND, NEW HEBRON POOL, MOHLER WELL NO. 15 (Fig. 8).

Sample No.	Depth (ft.–in.)	Porosity (per cent)	Saturation (per cent)[1]	Permeability (millidarcys)
1	921–0	15.4	84.4	16.8
2	949–0	14.6	72.3	4.10
3	950–0			5.24
4	950–8			2.28
5	951–4	14.7	80.0	13.7
6	952–0			10.3
7	952–8			
8	953–6			3.33
9	954–3			1.73
10	955–0	15.8	87.0	1.66
11	955–9			17.0
12	956–7			5.21
13	957–5			1.38
14	958–3			
15	958–11			6.92
16	959–7	17.2	75.3	27.9
17	960–3			14.5
18	961–0			20.2
19	961–10			2.48
20	962–9			
21	963–8	17.9	81.3	14.2
22	964–7			24.1
23	965–6			33.3
24	966–6	16.4	86.3	0.52
25	967–6			2.23
26	968–0			27.2
27	969–0			85.0
28	970–0	20.0	81.8	20.8
29	971–0			124.
30	972–0			98.2
31	973–0			179.
32	974–0			127.
33	975–0	20.6	90.3	162.
34	976–0			180.
35	977–0			98.7
36	978–0	19.6	98.0	137.
37	979–0			143.
38	980–0			4.26

[1]Total liquid saturation of the core in terms of bbls. per acre-foot is 1117.

PARKER POOL

The Robinson sand was cored only in Weger well No. 14 in the Parker pool.

Craig and Lowrie Oil Co.—R. Weger well No. 14, NW. 1/4 NE. 1/4 sec. 15, T. 5 N., R. 12 W. Crawford County

Surface elevation 587 feet

	Thickness Ft.	Thickness In.	Depth Ft.	Depth In.
Beginning of core			987	0
Pennsylvanian system				
Sandstone, light gray, fine, hard, micaceous, pyritic zones, thin streaks of oil; samples 1–5	4	6	991	6
Sandstone, argillaceous, dark gray, fine, micaceous	2	6	994	0
Sandstone, light gray, fine, hard, micaceous pyritic zones, thin streaks of oil; sample 6	1	0	995	0
Sandstone, argillaceous, dark gray, fine, micaceous	4	0	999	0
Sandstone, light gray, partings of shale, dark gray	0	10	999	10
Sandstone, light gray, fine, hard, containing some oil; sample 7	1	8	1001	6
Shale, dark gray, laminae of sandstone, light gray	0	4	1001	10
Sandstone, dark gray, hard, micaceous	0	6	1002	4
Sandstone, light gray, fine, hard, containing oil; sample 8	0	8	1003	0
Shale, dark gray	0	4	1003	4
Sandstone, light gray, fine, hard, containing oil, partings of shale, dark gray; sample 9 taken at 1005′6″	2	10	1006	2
Sandstone, argillaceous, dark gray, fine, hard, micaceous	1	6	1007	8
Sandstone, light gray, fine, containing oil, interlaminated with shale, dark gray	2	4	1010	0
Sandstone, light gray, fine, hard, containing oil; sample 10	0	8	1010	8
Sandstone, argillaceous, dark gray, fine, hard, micaceous.	1	4	1012	0
Sandstone, light gray, fine, hard, containing oil; sample 11	0	9	1012	9
Sandstone, light gray, fine, interlaminated with shale, dark gray, two 2-inch beds of sandstone containing oil	1	3	1014	0
Sandstone, light gray, fine, hard, containing oil; sample 12	0	8	1014	8
Sandstone, argillaceous, dark gray, fine, micaceous	1	6	1016	2
Sandstone, gray, fine, hard, containing oil; samples 13 and 14	1	10	1018	0
Sandstone, very argillaceous, dark gray, micaceous	1	0	1019	0
Sandstone, light gray, fine, hard, pyritic, containing oil; samples 15 and 16	2	8	1021	8
Shale, dark gray, interlaminated with sandstone; sample 17	0	8	1022	4
Sandstone, light gray, fine, hard, pyritic, containing oil, some partings shale, dark gray; sample 18	0	8	1023	0
Sandstone, light gray, fine, soft, containing oil; samples 19–25	7	0	1030	0

Table 13 below shows porosity and saturation results for composite samples of the Robinson sand taken from each run, and permeability results for samples taken at one-foot intervals at the top and bottom, and at greater intervals at the center of the sand from the core of Weger well No. 14 in the Parker pool.

Results of the tests are shown graphically in figure 9, page 56.

Table 13.—Porosity, Saturation, and Permeability of Robinson sand, Parker pool, Weger well No. 14 (Fig. 9).

Sample No.	Depth (ft.–in.)	Porosity (per cent)	Saturation (per cent)[1]	Permeability (millidarcys)
1	987–0			0.77
2	988–0	10.5	80.2	1.43
3	989–0			0.25
4	990–0	12.8	82.4	0.42
5	991–0			1.61
6	994–6	12.6	76.8	3.89
7	1001–2	13.6	35.9	42.8
8	1002–8	11.2	46.0	19.4
9	1005–6	12.3	53.2	15.7
10	1010–4	13.5	52.7	30.5
11	1012–5	12.6	60.8	48.2
12	1014–4	15.9	72.2	39.7
13	1017–0	19.7	75.3	341.
14	1018–0			199.
15	1019–0			231.
16	1020–0	19.5	82.4	183.
17	1022–0			39.7
18	1023–0			72.7
19	1024–0	18.3	83.8	324.
20	1025–0			962.
21	1026–0			354.
22	1027–0			165.
23	1028–0	24.2	93.6	968.
24	1029–0			866.
25	1030–0			82.8

[1]Total liquid saturation of the core in terms of bbls. per acre-foot is 807.

Biehl sand

ALLENDALE POOL

The Biehl sand was investigated only in the Allendale pool where three wells were cored, the Lithurland well No. 9, Madden well No. 9, and Madden well No. 10.

J. D. Toomey Estate—Lithurland well No. 9, 200′ from W. line, 850′ from N. line of NW. 1/4 SE. 1/4, sec. 5, T. 1 N., R. 12 W., Wabash County

Surface elevation 475 feet

	Thickness Ft.	In.	Depth Ft.	In.
Beginning of core			1551	0
Pennsylvanian system				
Sandstone, light gray, medium to coarse; occasional pyrite nodules, small quartz pebbles, and thin partings of light gray shale; oil in irregular patches throughout; samples 1–5	4	0	1555	0

Table 14 below shows porosity and saturation results for composite samples of the Biehl sand taken from each run, and the permeability result for the only permeability sample obtained from Lithurland well No. 9 in the Allendale pool.

See figure 10, page 56.

Mahutska Oil Co.—M. Madden well No. 9, NW. 1/4 NW. 1/4 NE. 1/4 sec. 7, T. 1 N., R. 11 W., Wabash County

	Thickness Ft.	In.	Depth Ft.	In.
Beginning of core			1408	0
Pennsylvanian system				
Shale, dark gray, sandy layer at top	6	0	1414	0
Shale, greenish-gray	1	6	1415	6
Sandstone, gray, fine, hard, samples 1 and 2	1	6	1417	0
Sandstone, containing oil; samples 3–16; best sandstone at 1417′ to 1418′–6″ represented by samples 3–5	7	6	1424	6
Sandstone, gray, fine, two 2-inch layers in upper 2 feet containing traces of oil; samples 17–32	8	0	1432	6

Table 15 below shows porosity and permeability results for samples of the Biehl sand taken at six-inch intervals, and saturation results for samples taken at one-foot intervals from Madden well No. 9 in the Allendale pool.

See figure 10, page 56.

Table 14.—Porosity, Saturation, and Permeability of Biehl sand, Allendale pool, Lithurland well No. 9 (Fig. 10).

Sample No.	Depth (ft.–in.)	Porosity (per cent)	Saturation (per cent)[1]	Permeability (millidarcys)
1	1551–0			
2	1552–0	12.5	76.0	
3	1553–0			
4	1554–0			2.10
5	1555–0	11.2	68.8	

[1]Total liquid saturation of the core in terms of bbls. per acre-foot is 668.

Table 15.—Porosity, Saturation, and Permeability of Biehl sand, Allendale pool, Madden well No. 9 (Fig. 10).

Sample No.	Depth (ft.–in.)	Porosity (per cent)	Saturation (per cent)[1]	Permeability (millidarcys)
1	1416–4	6.18	100.	0.00
2	1416–10	10.4		3.33
3	1417–2	9.07	72.7	29.5
4	1417–8	10.8		169.
5	1418–2	9.63	76.1	22.8
6	1418–10	8.38		13.3
7	1419–6	7.68	100.	0.00
8	1420–2	9.81		2.28
9	1420–10	11.5	100.	0.42
10	1421–6	8.53		
11	1422–0	11.9	100.	0.40
12	1422–6	11.5		0.50
13	1423–0	9.80	100.	0.22
14	1423–6	6.82		0.094
15	1424–0	9.57	100.	0.00
16	1424–6	11.7		0.00
17	1425–0	9.24	100.	0.00
18	1425–6	6.88		0.33
19	1426–0	8.45	76.5	61.4
20	1426–6	9.42		3.19
21	1427–0	12.4	100.	142.
22	1427–6	14.2		348.
23	1428–0	15.6	100.	2.45
24	1428–6	12.1		11.4
25	1429–0	12.5	92.7	9.66
26	1429–6	11.5		202.
27	1430–0	13.0	72.1	239.
28	1430–6	16.2		7.25
29	1431–0	20.3	100.	3.98
30	1431–6	16.8		5.57
31	1432–0	16.6	100.	17.0
32	1432–6	16.5		15.0

[1]Total liquid saturation of the core in terms of bbls. per acre-foot is 823.

Table 16.—Porosity, Saturation, and Permeability of Biehl sand, Allendale pool, Madden well No. 10 (Fig. 10).

Sample No.	Depth (ft.–in.)	Porosity (per cent)	Saturation (per cent)[1]	Permeability (millidarcys)
1	1418–0	12.6	95.2	49.4
2	1418–6	13.4		110.
3	1419–0	13.0	92.8	63.0
4	1419–6	15.3		87.7
5	1420–0	14.4	88.2	80.4
6	1420–6	13.5		137.
7	1421–0	14.9	79.6	25.2
8	1421–6	14.4		96.9
9	1422–0	13.0	78.8	44.8
10	1422–6	13.6		120.
11	1423–0	13.0	86.3	8.01
12	1423–6	16.0		227.
13	1424–0	16.3	100.	289.
14	1424–6	12.8		104.
15	1425–0	14.6	91.7	59.1
16	1425–6	13.2		65.4
17	1426–0	14.8	100.	441.
18	1426–6	15.5		247.
19	1427–0	10.9	90.1	11.6
20	1427–6	12.8		48.8
21	1428–0	15.1	100.	102.
22	1428–6	14.1		106.
23	1429–0	16.0	100.	111.
24	1429–6	12.5		40.2
25	1430–0	16.6	100.	206.
26	1430–6	12.9		114.
27	1431–0	14.1	100.	10.4
28	1431–6	13.5		102.
29	1432–0	13.1	83.0	57.8
30	1432–6	13.9		60.8
31	1433–0	15.5	100.	0.00
32	1433–6	10.1		0.00
33	1434–0	17.4	100.	0.00
34	1434–6	7.95		4.17
35	1435–0	17.2	100.	0.00
36	1435–6	15.2		0.00
37	1436–0	14.3	77.0	289.
38	1436–6	14.3		178.
39	1437–0	12.5	97.2	190.
40	1437–6	12.8		200.
41	1438–0	12.2	94.5	143.
42	1438–6	12.1		233.
43	1439–0	14.7	100.	271.
44	1439–6	13.5		118.
45	1440–0	15.5	100.	317.
46	1440–6	14.1		310.
47	1441–0	13.1	100.	39.6
48	1441–6	14.5		102.
49	1442–0	15.5	100.	201.
50	1442–6	16.0		165.
51	1443–0	14.5	100.	172.
52	1443–6	13.0		154.
53	1444–0	15.6	100.	113.
54	1444–6	16.5		1.48
55	1445–0	17.8	100.	0.76
56	1445–6	17.3		2.06
57	1446–0	18.2	100.	2.28
58	1446–6	15.8		1.03
59	1447–0	19.3	100.	1.70

[1]Total liquid saturation of the core in terms of bbls. per acre-foot is **1055.**

Mahutska Oil Co.—M. Madden well No. 10, NW. 1/4 NE. 1/4 sec. 7, T. 1 N., R. 11 W., Wabash County

Surface elevation 498.4 feet

	Thickness Ft.	Thickness In.	Depth Ft.	Depth In.
Beginning of core			1418	0
Pennsylvanian system				
Sandstone, light gray, coarse, containing oil; samples 1–31	15	0	1433	0
Sandstone, light gray, fine, hard; samples 32–36	2	6	1435	6
Sandstone, light gray, coarse, containing oil; samples 37–53	8	6	1444	0
Sandstone, light gray, fine; samples 54–59	3	0	1447	0

Table 16 above shows porosity and permeability results for samples of the Biehl sand taken at six-inch intervals, and saturation results for samples taken at one-foot intervals from Madden well No. 10 in the Allendale pool.

See figure 10, page 56.

Cypress sand

Cores of the Cypress sand were taken from six pools, (1) Bartelso, (2) Carlyle, (3) Lawrence County, (4) Louden, (5) Noble, and (6) Patoka pools.

The Cypress sand is known by various names in different pools. In the Bartelso and Carlyle pools it is called the Carlyle sand, in the Lawrence County pool it is the Kirkwood sand, in the Louden and Noble pools and in other pools in the deepest portions of the basin it is the Weiler sand, and in the Patoka pool it is known as the Stein sand.

For graphic presentation of the tabulated data on the Cypress sand see figures 11-16, pages 57-59.

BARTELSO POOL

The Cypress sand was cored only in Trame well No. 2 in the Bartelso pool.

Ohio Oil Co.—C. Trame well No. 2, SE. 1/4 NE. 1/4 NW. 1/4 sec. 8, T. 1 N., R. 3 W., Clinton County

Surface elevation 479 feet

	Thickness Ft.	Thickness In.	Depth Ft.	Depth In.
Beginning of core			992	6
Cypress sandstone				
Sandstone, slightly calcareous, gray, fine	1	6	994	0
Shale, dark gray	3	0	997	0
Sandstone, greenish-gray, fine, containing traces of oil	8	0	1005	0
Sandstone, brownish - gray, fine, porous, friable, saturated with oil; samples 1-12	17	6	1022	6
Shale, slightly silty, gray, slip-fractured	1	6	1024	0

Table 17 below shows porosity and permeability results for samples taken at six-inch intervals at the top, and one-foot intervals at the bottom, and saturation results for samples taken at one-foot intervals throughout the core from Trame well No. 2 in the Bartelso pool of the Cypress sand.

See figure 11, page 57.

TABLE 17.—POROSITY, SATURATION, AND PERMEABILITY OF CYPRESS SAND, BARTELSO POOL, TRAME WELL NO. 2 (FIG. 11).

Sample No.	Depth (ft.–in.)	Porosity (per cent)	Saturation (per cent)[1]	Permeability (millidarcys)
1	1009–0	20.3	87.7	189.
2	1009–6	21.4		304.
3	1010–0	22.4	94.5	431.
4	1010–6	20.8		191.
5	1011–0	22.0	89.7	438.
6	1011–6	22.5		187.
7	1012–0	20.0	86.8	147.
8	1013–6	20.6	83.5	226.
9	1015–0	19.1	87.5	329.
10	1016–6	18.5	81.8	437.
11	1018–0	20.9	78.2	306.
12	1019–0	18.2	81.9	146.

[1]Total liquid saturation of the core in terms of bbls. per acre-foot is 1369.

CARLYLE POOL

Deters well No. 39 is the only well cored in the Cypress sand in the Carlyle pool.

Ohio Oil Co.—L. Deters well No. 39, Cen. NW. 1/4 SW. 1/4 sec. 2, T. 2 N., R. 3 W., Clinton County

Surface elevation 462 feet

	Thickness Ft.	Thickness In.	Depth Ft.	Depth In.
Beginning of core			1033	6
Cypress sandstone				
Sandstone, dark brown, fine, soft, bleeding core; samples 1–6	5	0	1038	6
Limestone, light gray, hard	0	1	1038	7
Sandstone, dark brown, fine, laminated, bleeding core	0	5	1039	0
Sandstone, light brown, fine, laminated, bleeding core	0	4	1039	4
Sandstone, dark brown, fine, soft, laminated, bleeding core; samples 7–22	20	8	1060	0

Table 18 below shows porosity and permeability results for samples of the Cypress sand taken at one-foot intervals from Deters well No. 39 in the Carlyle pool. This well was cored by the Ohio Oil Company operator. No Survey representative was present at the time of coring to take saturation samples. See figure 12, page 57.

TABLE 18.—POROSITY AND PERMEABILITY OF CYPRESS SAND, CARLYLE POOL, DETERS WELL NO. 39 (FIG. 12).

Sample No.	Depth (ft.–in.)	Porosity (per cent)	Permeability (millidarcys)
1	1033–6	17.7	
2	1034–8	16.7	21.4
3	1035–6	19.1	72.0
4	1036–6	17.0	33.6
5	1037–6	19.9	105.
6	1038–6	17.7	98.7
7	1039–8	21.2	149.
8	1040–7	19.6	
9	1041–10	18.4	
10	1042–8	21.0	
11	1043–8	19.3	106.
12	1045–0	22.4	277.
13	1046–2	20.2	
14	1047–8	19.6	
15	1049–2	17.9	
16	1050–4	15.9	34.6
17	1051–8	17.1	32.7
18	1052–6	19.9	145.
19	1054–6	19.9	
20	1056–0	20.8	
21	1058–6	20.0	
22	1060–0	19.5	162.

LAWRENCE COUNTY POOL

Kirkwood well No. 13 is the only well in the Lawrence County pool which was cored in the Cypress sand.

Warren Hastings, et. al.—R. M. Kirkwood well No. 13, SE. 1/4 NE. 1/4 SW. 1/4 sec. 11, T. 3 N., R. 12 W., Lawrence County

Surface elevation 430 feet

	Thickness Ft.	Thickness In.	Depth Ft.	Depth In.
Cypress sandstone				
Top of Cypress (Kirkwood) sandstone			1555	0
Sandstone, drilled without coring	7	0	1562	0
Sandstone, coarse, porous, containing much oil; sample 1	0	2	1562	2
Shale, dark gray	1	6	1563	8
Sandstone, gray, fine, containing numerous laminae of shale, dark gray, which increase in abundance downward to a basal shale, dark gray, containing a few thin laminae of sandstone, gray, fine, dense	2	10	1566	6

Table 19 below shows duplicate porosity and permeability results, and the saturation result for the only sample of the Cypress sand taken from Kirkwood well No. 13 in the Lawrence County pool.

Data for table 19 are shown in figure 13, page 57.

LOUDEN POOL

The Cypress sand was cored in Koberlein well No. 1, Morrison well No. 1, and Sefton well No. 1 in the Louden pool.

Mabee Drilling Co.—A. F. Koberlein well No. 1, NE. 1/4, NE. 1/4 SE. 1/4 sec. 30, T. 7 N., R. 3 E., Fayette County

	Thickness Ft.	Thickness In.	Depth Ft.	Depth In.
Beginning of core			1546	0
Cypress sandstone				
Sandstone, oil-bearing, brown, very fine, loosely cemented; samples 1–5	4	0	1550	0

Table 20 below shows porosity and permeability results for samples of the Cypress sand taken at one-foot intervals from Koberlein well No. 1 in the Louden pool. This well was cored by the Mabee Drilling Company. No survey representative was present at the time of coring to take saturation samples.

TABLE 19.—POROSITY, SATURATION, AND PERMEABILITY OF CYPRESS SAND, LAWRENCE COUNTY POOL, KIRKWOOD WELL NO. 13 (FIG. 13).

Sample No.	Depth (ft.–in.)	Porosity (per cent)	Saturation (per cent)[1]	Permeability (millidarcys)
1a	1562–0	20.8	78.4	3580.
1b	1562–0	20.8		3960.

[1]Total liquid saturation of the core in terms of bbls. per acre-foot is 1265.

TABLE 20.—POROSITY AND PERMEABILITY OF CYPRESS SAND, LOUDEN POOL, KOBERLEIN WELL NO. 1 (FIG. 14).

Sample No.	Depth (ft.–in.)	Porosity (per cent)	Permeability (millidarcys)
1	1546–0	23.8	323
2	1547–0	20.5	
3	1548–0	20.7	219
4	1549–0	19.7	168
5	1550–0	18.7	

Phayer, et. al.—A. Morrison well No. 1, cen. E. 1/2 NW. 1/4 NE. 1/4 sec. 19, T. 7 N., R. 3 E., Fayette County

	Thickness Ft.	Thickness In.	Depth Ft.	Depth In.
Beginning of core			1490	0
Cypress sandstone				
Sandstone, silty, oil-bearing, brown, very fine, loosely cemented; samples 1 and 2	1	0	1491	0
Sandstone, oil-bearing, brown, very fine, friable, some thin partings of dark brown micaceous shale; samples 3–11	10	0	1501	0

Table 21 below shows porosity and permeability results for samples of the Cypress sand taken at one-foot intervals from Morrison well No. 1 in the Louden pool. This well, and Morrison well No. 2 were both cored by the operator, Phayer et al. No Survey representative was present at the time of coring to take saturation samples.

TABLE 21.—POROSITY AND PERMEABILITY OF CYPRESS SAND, LOUDEN POOL, MORRISON WELL NO. 1 (FIG. 14).

Sample No.	Depth (ft.–in.)	Porosity (per cent)	Permeability (millidarcys)
1	1490–0	21.5	221.
2	1491–0	19.7	78.4
3	1493–0	22.2	
4	1494–0	21.4	
5	1495–0	21.2	
6	1496–0	20.1	45.3
7	1497–0	19.6	
8	1498–0	18.5	64.5
9	1499–0	19.4	
10	1500–0	17.3	121.
11	1501–0	19.6	134.

Phayer et al.—A. Morrison well No. 2, NW. 1/4 NW. 1/4 NE. 1/4 sec. 19, T. 7 N., R. 3 E., Fayette County

	Thickness Ft.	Thickness In.	Depth Ft.	Depth In.
Beginning of core			1519	0
Cypress sandstone				
Sandstone, oil-bearing, brown, very fine, friable, occasional calcite grains; samples 1–3	2	0	1521	0

Table 22 below shows porosity and per meability results for samples of the Cypress sand taken at one-foot intervals from Morrison well No. 2 in the Louden pool. As mentioned above, no saturation samples from this well were available.

Data for tables 20, 21, 22, and 23 are shown in figure 14, page 58.

TABLE 22.—POROSITY AND PERMEABILITY OF CYPRESS SAND, LOUDEN POOL, MORRISON WELL NO. 2 (FIG. 14).

Sample No.	Depth (ft.–in.)	Porosity (per cent)	Permeability (millidarcys)
1	1519–0	21.1	293
2	1520–0	16.6	116
3	1521–0	19.4	168

Canary and Sherman—Sefton well No. 1, NE. cor. sec. 12, T. 7 N., R. 2 E., Fayette County

	Thickness Ft.	Thickness In.	Depth Ft.	Depth In.
Beginning of core			1564	6
Cypress sandstone				
Sandstone, calcareous, argillaceous, gray, very fine, thin partings dark gray micaceous shale; sample 1			1564	6
Sandstone, silty, slightly oil-bearing, grayish-brown, very fine, scattered calcite grains, some irregular openings lined with dark gray clay along bedding planes; sample 2	1	0	1565	6
Sandstone, silty, brownish-gray, very fine, scattered calcite grains, thin partings dark gray micaceous shale; sample 3	1	0	1566	6
Sandstone, argillaceous, silty, gray, very fine, faintly cross-laminated, thin partings of dark gray micaceous shale; sample 4	1	0	1567	6
Sandstone, silty, brownish-gray, very fine, faintly cross-laminated, thin partings of dark gray micaceous shale; sample 5	1	0	1568	6
Sandstone, silty, oil-bearing, brown, very fine, friable, occasional thin partings of dark gray micaceous shale; samples 6–9	4	0	1572	6

Table 23 below shows porosity and permeability results for samples of the Cypress sand taken at one-foot intervals from Sefton well No. 1 in the Louden pool. This well was cored by Canary and Sherman. No Survey representative was present at the time of coring to take saturation samples.

TABLE 23.—POROSITY AND PERMEABILITY OF CYPRESS SAND, LOUDEN POOL, SEFTON WELL NO. 1 (FIG. 14).

Sample No.	Depth (ft.–in.)	Porosity (per cent)	Permeability (millidarcys)
1	1564–6	17.9	74.4
2	1565–6	19.4	202.
3	1566–6	19.1	61.4
4	1567–6	17.3	22.6
5	1568–6	19.6	95.3
6	1569–6	20.5	200.
7	1570–6	20.7	182.
8	1571–6	20.2	138.
9	1572–6	21.6	152.

NOBLE POOL

The Cypress sand in the Noble pool is represented only by the core from Arbuthnot well No. 9.

Ohio Oil Co.—Arbuthnot well No. 9, cen. W. 1/2 SW. 1/4 NE. 1/4 sec. 8, T. 3 N., R. 9 E., Richland County

Surface elevation 480 feet

	Thickness Ft.	Thickness In.	Depth Ft.	Depth In.
Beginning of core			2588	3
Cypress sandstone				
Shale, sandy, gray, interlaminated siltstone, gray	2	7	2590	10
Sandstone, argillaceous, gray, very fine, interlaminated shale, silty to sandy; sample 1	1	2	2592	0
Sandstone, brown, fine, porous, somewhat compact in upper foot, saturated with oil; samples 2–20	18	0	2610	0
Sandstone, light gray, fine, compact	0	3	2610	3
Sandstone, brown, fine, porous, pyritic, saturated with oil; samples 21–30	10	8	2620	11
Sandstone, light gray, fine, porous, pyritic; samples 31–33	3	1	2624	0

Table 24 below shows porosity and permeability results for samples of the Cypress sand taken at one-foot intervals from Arbuthnot well No. 9 in the Noble pool. This well was cored by the Ohio Oil Company. No Survey representative was present at the time of coring to take saturation samples.

Data for table 24 are shown in figure 15, page 58.

Table 24.—Porosity and Permeability of Cypress sand, Noble pool, Arbuthnot well No. 9 (Fig. 15).

Sample No.	Depth (ft.–in.)	Porosity (per cent)	Permeability (millidarcys)
1	2591–0	7.06	1.52
2	2592–0	12.5	37.3
3	2593–0	9.85	18.8
4	2594–0	13.7	165.
5	2595–0	17.5	239.
6	2596–0	15.7	60.6
7	2597–0	17.8	268.
8	2598–0	17.6	525.
9	2599–0	15.2	543.
10	2600–0	17.8	330.
11	2601–0	19.1	595.
12	2602–2	18.1	421.
13	2603–0	15.5	395.
14	2604–0	10.9	25.8
15	2605–0	17.5	474.
16	2606–0	15.1	232.
17	2607–0	16.8	774.
18	2608–0	13.1	149.
19	2609–0	16.7	810.
20	2610–0	16.0	416.
21	2612–0	15.6	385.
22	2613–0	18.3	714
23	2614–0	17.8	577.
24	2615–0	12.3	182.
25	2616–0	14.8	348.
26	2617–0	16.7	552.
27	2618–0	16.1	642.
28	2619–0	17.4	1010.
29	2620–0	5.68	2.33
30	2621–0	17.8	1120.
31	2622–0	14.3	320.
32	2623–0	15.7	615.
33	2624–0	11.2	81.4

PATOKA POOL

Only Merryman well No. 1 was cored in the Cypress sand in the Patoka pool.

Adams Oil and Gas Co.—G. Merryman well No. 1, cen. SE. 1/4 SE. 1/4 sec. 21, T. 4 N., R. 1 E., Marion County

Surface elevation 499 feet

	Thickness Ft.	Thickness In.	Depth Ft.	Depth In.
Beginning of core			1290	0
Cypress sandstone				
Sandstone, calcareous, oil-bearing, light to brownish-gray, fine, friable; samples 1–29	25	8	1315	8

Table 25 below shows porosity and permeability results for samples of the Cypress sand taken at one-foot intervals from Merryman well No. 1 in the Patoka pool. This well was cored by the Adams Oil and Gas Company. No Survey representative was present at the time of coring to take saturation samples. See figure 16, page 59.

TABLE 25.—POROSITY AND PERMEABILITY OF CYPRESS SAND, PATOKA POOL, MERRYMAN WELL NO. 1 (FIG. 16).

Sample No.	Depth (ft.–in.)	Porosity (per cent)	Permeability (millidarcys)
1	1291–0	17.5	62.1
2	1292–0	21.3	138.
3	1293–0	21.0	60.2
4	1294–0	20.8	65.6
5	1295–0	19.6	34.9
6	1296–0	20.7	63.9
7	1297–0	20.4	90.1
8	1298–0	15.5	4.48
9	1298–10	19.1	30.4
10	1299–8	20.3	41.8
11	1300–6	19.5	26.5
12	1301–4	19.3	15.6
13	1302–2	20.4	34.8
14	1303–0	19.5	13.3
15	1303–10	19.3	25.3
16	1304–8	20.0	11.1
17	1305–6	19.3	17.8
18	1306–4	19.4	15.1
19	1307–2	20.6	35.0
20	1308–0	19.9	64.3
21	1308–10	21.8	69.5
22	1309–8	20.6	59.6
23	1310–6	21.0	65.0
24	1311–4	21.9	77.2
25	1312–2	20.3	49.7
26	1313–0	19.5	
27	1313–10	21.7	34.8
28	1314–8	17.8	2.49
29	1315–8	17.2	8.87

BETHEL SAND

Cores of the Bethel sand were taken from four pools, the Louden, Centralia, Patoka, and Salem. In all these pools the Bethel sand is known locally as the Benoist sand.

Tabulated data for the Bethel sand are shown graphically in figures 17, 18, 19, and 20, pages 60 and 61.

LOUDEN POOL

The Bethel sand was cored in Sinclair well No. 2 in the Louden pool.

Jarvis Bros.—Sinclair well No. 2, SW. 1/4 NW. 1/4 NE. 1/4 sec. 29, T. 8 N., R. 3 E., Fayette County

	Thickness Ft.	Thickness In.	Depth Ft.	Depth In.
Beginning of core			1463	0
Bethel sandstone				
Sandstone, calcareous, argillaceous, greenish-gray to gray, very fine, compact, dark gray uneven shale partings; samples 1–3	5	0	1468	0
Sandstone, calcareous, oil-bearing, brown, very fine, friable, gray shaly zone which is non-petroliferous at 1472; samples 4–9	6	0	1474	0

Table 26 below shows porosity and permeability results for samples of the Bethel sand taken at one-foot intervals from Sinclair well No. 2 in the Louden pool. This well was cored by Jarvis Bros. No Survey representative was present at the time of coring to take saturation samples.

See figure 17, p. 60.

TABLE 26.—POROSITY AND PERMEABILITY OF BETHEL SAND, LOUDEN POOL, SINCLAIR WELL NO. 2 (FIG. 17).

Sample No.	Depth (ft.–in.)	Porosity (per cent)	Permeability (millidarcys)
1	1463–0	14.2	
2	1465–0	15.2	
3	1468–0	17.5	5.87
4	1469–0	18.3	70.8
5	1470–0	17.8	220.
6	1471–0	21.0	170.
7	1472–0	19.2	
8	1473–0	20.7	157.
9	1474–0	20.1	

CENTRALIA POOL

Storer well No. 2 and Storer well No. 4 were cored through the Bethel sand in the Centralia pool.

Kesl and Fox—Storer well No. 2, NE. 1/4 NE. 1/4 NE. 1/4 sec. 13, T. 1 N., R. 1 W., Clinton County

Surface elevation 494 feet

	Thickness Ft.	Thickness In.	Depth Ft.	Depth In.
Beginning of core			1362	6
Bethel sandstone				
Sandstone, light gray, containing oil, occasional green, shale partings; samples 1–17	16	4	1378	10
Shale, green	0	4	1379	2
Sandstone, as above; samples 18–21	3	6	1382	8
Shale, green	1	0	1383	8
Sandstone, as above; sample 22	1	6	1385	2
Shale, green	1	2	1386	4

Table 27 below shows porosity and saturation results for composite samples of the Bethel sand taken from each run, and permeability results for samples taken at one-foot intervals from Storer well No. 2 in the Centralia pool.

Table 27.—Porosity, Saturation, and Permeability of Bethel sand, Centralia pool, Storer well No. 2 (Fig. 18).

Sample No.	Depth (ft.–in.)	Porosity (per cent)	Saturation (per cent)[1]	Permeability (millidarcys)
1	1362–6			715.
2	1363–6			572.
3	1364–6			641.
4	1365–6	22.2	73.5	75.0
5	1366–6			204.
6	1367–6			388.
7	1368–2			120.
8	1369–2			
9	1370–2	22.0	79.3	111.
10	1371–2			566.
11	1372–2			
12	1373–2			254.
13	1374–2	21.7	79.3	84.9
14	1375–2			244.
15	1376–2			
16	1377–2			
17	1378–2	21.8	75.0	329.
18	1379–2			260.
19	1380–2			129.
20	1381–0			66.7
21	1382–0	21.4	81.4	0.37
22	1384–8			28.9

[1]Total liquid saturation of the core in terms of bbls. per acre-foot is 1314.

Kesl and Fox—Storer well No. 4, NW. 1/4 NE. 1/4 NE. 1/4, sec. 13, T. 1 N., R. 1 W., Clinton County

Surface elevation 488 feet

	Thickness Ft.	Thickness In.	Depth Ft.	Depth In.
Beginning of core			1358	0
Bethel sandstone				
Sandstone, light gray to greenish-gray, fine to medium grained, numerous green shale partings; samples 1–4	22	6	1380	6

Table 28 below shows porosity and saturation results for composite samples of the Bethel sand taken from each run, and permeability results for samples taken at one-foot intervals from Storer well No. 4 in the Centralia pool.

Data from tables 27 and 28 are shown in figure 18, page 60.

Table 28.—Porosity, Saturation, and Permeability of Bethel sand, Centralia pool, Storer well No. 4 (Fig. 18).

Sample No.	Depth (ft.–in.)	Porosity (per cent)	Saturation (per cent)[1]	Permeability (millidarcys)
1	1358–0			145.
2	1359–0			144.
3	1360–0	21.6	68.3	504.
4	1361–0			591.
5	1362–0			498.
6	1363–0			
7	1364–0			388.
8	1365–0	19.5	71.9	
9	1366–0			290.
10	1367–0			
11	1368–0			107.
12	1369–0			87.1
13	1370–0			110.
14	1371–0	22.0	70.9	72.5
15	1372–0			105.
16	1373–0			
17	1374–0			50.3
18	1375–0			24.3
19	1376–6	21.4	75.6	

[1]Total liquid saturation of the core in terms of bbls. per acre-foot is 1162.

PATOKA POOL

Merryman well No. 1 and Merryman well No. 17 were cored through the Bethel sand in the Patoka pool.

Adams Oil and Gas Co.—G. Merryman well No. 1, Cen. SE. 1/4 SE. 1/4 sec. 21, T. 4 N., R. 1 E., Marion County

Surface elevation 499 feet

	Thickness Ft.	Thickness In.	Depth Ft.	Depth In.
Beginning of core			1393	0
Bethel sandstone				
Sandstone, calcareous, medium to brownish-gray, fine, coherent to friable; samples 30–32	4	0	1397	0

Table 29 below shows porosity and permeability results for four samples of the Bethel sand taken from Merryman well No. 1 in the Patoka pool. No saturation samples were available from this well.

TABLE 29.—POROSITY AND PERMEABILITY OF BETHEL SAND, PATOKA POOL, MERRYMAN WELL NO. 1 (FIG. 19).

Sample No.	Depth (ft.–in.)	Porosity (per cent)	Permeability (millidarcys)
30	1393–0	16.0	120
31	1395–0	15.1	63.5
32	1397–0	11.5	13.6

Adams Oil and Gas Co.—G. Merryman well No. 17, SW. 1/4 SE. 1/4 SE. 1/4 sec. 21, T. 4 N., R. 1 E., Marion County

Surface elevation 501 feet

	Thickness Ft.	Thickness In.	Depth Ft.	Depth In.
Beginning of core			1392	0
Bethel sandstone				
Sandstone, light gray, fine, hard, somewhat shaly; samples 1–3	3	1	1395	1
Shale, sandy, greenish-gray, occasional thin layers sandstone, greenish-gray	4	5	1399	6
Sandstone, shaly, occasional streaks showing oil; samples 4–8	6	0	1405	6
Sandstone, light gray, fine, soft, containing oil, occasional hard lenses in upper 4 feet; samples 9–26	15	0	1420	6
Sandstone, light to dark gray, fine, containing oil, shaly streaks at base; samples 27–30	3	3	1423	9
Renault formation				
Limestone, slightly sandy, light gray, finely crystalline, hard, streaks of shale, light to dark gray	2	0	1425	9
Limestone, light gray, finely crystalline, thin stringers of shale, gray	4	0	1429	9
Shale, bluish-gray, few calcareous streaks	3	0	1432	9
Limestone, gray, some shaly zones	1	0	1433	9
Sandstone, gray, fine, soft, saturated with oil	2	0	1435	9
Limestone, gray, containing shaly layers, interbedded with sandstone containing oil; sample 31	1	0	1436	9
Sandstone, gray, fine, fairly soft, contains oil, interbedded with fossiliferous limestone and dark gray shale; samples 32–35	3	9	1440	6
Limestone, light gray, fine to medium, crystalline, very hard	1	0	1441	6
Shale, calcareous, gray, firm	1	0	1442	6
Shale, red, soft, containing thin lenses of oil-bearing sandstone	2	6	1445	0

TABLE 30A. POROSITY, SATURATION, AND PERMEABILITY OF BETHEL SAND, PATOKA POOL, MERRYMAN WELL NO. 17 (FIGS. 19 AND 38).

Sample No.	Depth (ft.–in.)	Porosity (per cent)	Saturation (per cent)[1]	Permeability (millidarcys)
1	1392–0			165.
2	1393–0	17.4	85.5	240.
3	1394–0			286.
4	1400–0			94.7
5	1401–6			0.68
6	1403–0	12.0	89.0	189.
7	1404–6			71.3
8	1405–6			98.7
9	1406–2			158.
10	1406–10			74.5
11	1407–6	20.5	80.0	127.
12	1408–2			
13	1408–10			54.7
14	1409–6			147.
15	1410–3			245.
16	1411–0	21.9	88.0	163.
17	1411–9			167.
18	1412–6			205.
19	1413–6			148.
20	1414–6	22.1	75.3	14.1
21	1415–6			251.
22	1416–6			118.
23	1417–6			89.5
24	1418–6	19.4	73.9	228.
25	1419–6			268.
26	1420–6			267.
27	1421–4			148.
28	1422–2	14.4	78.3	
29	1423–0			118.
30	1423–9			29.2
31	1436–9	20.3	98.7	
32	1437–8			
33	1438–7	19.3	62.4	83.3
34	1439–6			6.03
35	1440–6			34.2

[1]Total liquid saturation of the core in terms of bbls. per acre-foot is 1149.

Tables 30A and 30B show porosity and saturation results for composite samples of the Bethel sand taken from each run, and permeability results for samples taken at about one-foot intervals from Merryman well No. 17 in the Patoka pool.

Data from tables 29 and 30A are shown in figure 19, page 60.

Table 30B.—Porosity, Oil Content, Saturation, and Permeability of Bethel sand, Patoka pool, Merryman well No. 17.
Tested by "a commeicial laboratory" (Fig. 38)

Sample No.	Depth (ft.)	Porosity (per cent)	Oil Content (Barrels per acre foot)	Saturation (per cent)		Permeability (millidarcys)
				Oil	Water	
1	1392.5	19.5	585	37.5	47.7	283
2	1393.5	21.0	497	30.5	33.3	249
3	1395.0	19.6	454	30.5	37.1	187
4	1396.0					129
5	1400.0	21.4	331	20.0	47.6	121
6	1401.0					176
7	1402.0	18.6	373	25.9	45.7	86
8	1406.0	21.2	469	28.5	34.9	144
9	1407.0	19.3	446	29.0	33.7	152
10	1408.0	20.6	561	35.0	34.4	83
11	1409.0	20.4	611	38.5	30.9	116
12	1410.0	20.6	641	40.4	37.9	301
13	1411.0	23.2	544	30.1	45.6	108
14	1412.0	24.9	446	23.0	45.7	483
15	1413.0	21.1	488	29.9	45.0	350
16	1414.0	22.8	555	31.3	43.0	248
17	1414.5	20.7	475	29.5	35.2	240
18	1415.0	22.5	500	28.6	36.7	329
19	1415.5	23.2	480	26.8	37.0	210
20	1416.0	18.7	363	25.0	33.2	59
21	1417.0	20.7	440	27.4	34.3	103
22	1418.0	14.4	249	22.3	35.4	119
23	1419.0	17.1	379	28.5	38.0	124
24	1420.0	16.4	348	27.3	34.8	102
25	1421.0	16.6	352	27.4	32.9	229
26	1422.0	17.2	439	32.9	37.8	50
27	1423.0					175
28	1434.0	17.3	517	38.6	40.0	374
29	1435.0	18.8	461	31.5	38.3	123
30	1436.0	18.9	589	39.8	40.6	311
31	1438.0	20.4	417	26.3	29.4	271
32	1439.5	18.0	475	34.0	46.0	109
33	1441.0					163

SALEM POOL

The Bethel sand was cored in Tate well No. 1 and West Nation School well No. 1 in the Salem pool.

The Texas Co.—E. Tate well No. 1, E. 1/2 NW. 1/4 NW. 1/4 sec. 5, T. 1 N., R. 2 E, Marion County

	Thickness Ft.	Thickness In.	Depth Ft.	Depth In.
Beginning of core			1692	8
Bethel sandstone				
Sandstone, calcareous, brownish-gray, very fine, compact, micaceous; faint streaks, flakes and grains of green clay; sample 1	0	0	1692	8
Sandstone, oil-bearing, calcareous, brown, fine, fairly compact; numerous scattered masses of calcite up to 3 mm. diameter, brown-gray, translucent, obscurely fine-grained; sample 2	1	0	1693	8
Sandstone, oil-bearing, calcareous, brown, very fine, friable; samples 3 and 4	2	0	1695	8
Sandstone, brownish-gray, very fine, scattered calcite grains, cross-laminations revealed by flakes and thin surfaces of clay, greenish-clay, micaceous; samples 5–11	7	0	1702	8
Same, somewhat porous and oil-bearing; samples 12–15	4	0	1706	8
Sandstone, oil-bearing, brown, fine, cross-laminated, loosely cemented; samples 16–24	9	0	1715	8
Same, with scattered grains brown limestone, crinoid fragments, and fossil casts containing green clay, especially abundant toward top; samples 25–32	8	0	1723	8

Table 31 below shows porosity and permeability results for samples of the Bethel sand taken at one-foot intervals from Tate well No. 1 in the Salem pool. This well was cored by the Texas Company. No Survey representative was present at the time of coring to take saturation samples.

TABLE 31.—POROSITY AND PERMEABILITY OF BETHEL SAND, SALEM POOL, TATE WELL No. 1 (FIG. 20).

Sample No.	Depth (ft.–in.)	Porosity (per cent)	Permeability (millicarcys)
1	1692–8	10.0	2.03
2	1693–8	13.5	235.
3	1694–8	17.3	150.
4	1695–8	17.4	210.
5	1696–8	16.0	42.1
6	1697–8	17.0	33.0
7	1698–8	18.9	89.4
8	1699–8	15.2	19.2
9	1700–8	15.8	22.2
10	1701–8	16.1	31.6
11	1702–8	13.9	7.51
12	1703–8	17.4	152.
13	1704–8	17.6	147.
14	1705–8	15.6	23.7
15	1706–8	15.5	18.7
16	1707–8	14.8	284.
17	1708–8	18.9	776.
18	1709–8	17.1	234.
19	1710–8	20.2	660.
20	1711–8	15.1	178.
21	1712–8	15.7	226.
22	1713–8	17.6	307.
23	1714–8	16.2	236.
24	1715–8	19.1	696.
25	1716–8	13.9	273.
26	1717–8	17.6	420.
27	1718–8	17.8	464.
28	1719–8	18.2	591.
29	1720–8	19.5	994.
30	1721–8	18.7	987.
31	1722–8	18.4	493.
32	1723–8	17.6	245.

Baldwin, et. al.—West Nation School well No. 1, SW. 1/4 SE. 1/4 SE. 1/4 sec. 33, T. 2 N., R. 2 E., Marion County

	Thickness Ft.	Thickness In.	Depth Ft.	Depth In.
Beginning of core			1841	0
Bethel sandstone				
Sandstone, oil-bearing, brown, very fine, scattered calcite grains, friable, some thin partings and faint cross-laminations of green micaceous clay; samples 1–10	11	0	1852	0
Same, but slightly oil-bearing; sample 11	1	0	1853	0

Table 32 below shows porosity and permeability results for samples of the Bethel sand taken at one-foot intervals from West

Nation School well No. 1 in the Salem pool. This well was cored by Baldwin et al. No Survey representative was present at the time of coring to take saturation samples.

Data for tables 31 and 32 are shown in figure 20, page 61.

Table 32.—Porosity and Permeability of Bethel sand, Salem pool, West Nation School well No. 1 (Fig. 20).

Sample No.	Depth (ft.–in.)	Porosity (per cent)	Permeability (millidarcys)
1	1841–0	15.7	274
2	1842–0	16.5	
3	1843–0	16.2	
4	1844–0	18.0	
5	1845–0	17.5	136
6	1846–0	20.2	
7	1849–0	15.9	110
8	1850–0	17.3	89
9	1851–0	19.3	259
10	1852–0	17.7	141
11	1853–0	14.3	

Table 33.—Porosity and Permeability of Aux Vases sand, Salem pool, Tate well No. 1 (Fig. 21).

Sample No.	Depth (ft.–in.)	Porosity (per cent)	Permeability (millidarcys)
33	1760–0	18.9	59.0
34	1761–0	17.1	58.6
35	1762–0	18.5	75.2
36	1770–0	16.7	92.7
37	1771–0	16.1	125.
38	1772–0	14.3	20.1
39	1773–0	13.0	8.70
40	1774–0	14.0	26.4
41	1775–0	13.3	119.
42	1776–0	8.52	30.1
43	1777–0	13.2	20.8
44	1778–0	13.4	24.9
45	1779–0	16.3	122.
46	1780–0	11.3	16.2
47	1781–0	16.7	140.
48	1782–0	12.3	11.3
49	1783–0	14.1	53.3
50	1784–0	10.1	2.98
51	1785–0	17.7	132.
52	1786–0	15.5	173.
53	1787–0	18.8	401.
54	1788–0	16.6	222.
55	1789–0	7.85	2.74
56	1790–0	18.1	164.
57	1791–0	19.2	226.
58	1792–0	14.4	33.4
59	1793–0	14.3	22.3
60	1794–0	11.6	2.36

Aux Vases sand

salem pool

The Aux Vases sand was investigated only in Tate well No. 1 in the Salem pool.

The Texas Co.—E. Tate well No. 1, E. 1/2 NW. 1/4 NW. 1/4 sec. 5, T. 1 N., R. 2 E., Marion County

	Thickness Ft.	Thickness In.	Depth Ft.	Depth In.
Beginning of core			1759	0
Aux Vases sandstone				
Sandstone, calcareous, brownish-gray, very fine, compact, slightly micaceous, numerous green clay and other dark colored grains (gap 1763–1769); samples 33–39	14	0	1773	0
Sandstone, calcareous, light brownish-gray, very fine to fine, compact, dark colored grains, scattered sand grains with green clay coatings; sample 40	1	0	1774	0
Same, but mostly stained dark brown; sample 41	1	0	1775	0
Sandstone, calcareous, somewhat argillaceous, brownish and greenish-gray, very fine to fine, cross-laminated, compact, sample 42	1	0	1776	0
Sandstone, calcareous, brownish-gray, very fine, compact, faint greenish argillaceous streaks and cross-laminations; samples 43–52	10	0	1786	0
Sandstone, calcareous, brown, fine, friable, occasional partings of green waxy micaceous clay; sample 53	1	0	1787	0
Sandstone, calcareous, dark brownish-gray, with some light mottling, fine, compact, black carbonaceous flakes secondarily deposited on sand grains in dark areas; sample 54	1	0	1788	0
Sandstone, calcareous, brownish-gray, very fine, grains of various colors, especially of green clay and some red clay, partings of clay, green, micaceous; sample 55	1	0	1789	0
Same, with faint streaks of green, argillaceous material but no partings of green clay; samples 56–60	5	0	1794	0

Table 33 (left) shows porosity and permeability results for samples of the Aux Vases sand taken at one-foot intervals from Tate well No. 1 in the Salem pool. As shown by the sample depths, there is an eight-foot break in the oil bearing sand in this well. No saturation samples were available from this well. See figure 21, page 62.

McCLOSKY LIME

The Fredonia limestone ("McClosky lime") was cored in four pools, Lawrence County, Noble, Olney, and Salem.

Data for the McClosky lime are shown in figures 22, 23, 24, and 25, pages 63 and 64.

LAWRENCE COUNTY POOL

Christensen well No. 1, Christensen well No. 2, Kirkwood well No. 13, and Rogers well No. 14 were cored in the Lawrence County pool.

Warren Hastings, et. al.—V. Christensen well No. 1, SE. cor. SW. 1/4 SW. 1/4 sec. 11, T. 3 N., R. 12 W., Lawrence County

Surface elevation 430 feet

	Thickness Ft.	Thickness In.	Depth Ft.	Depth In.
Beginning of core			1753	0
Fredonia limestone				
Limestone, oolitic, gray, fossiliferous, very porous, "containing green oil and estimated 150,000 to 200,000 cubic feet of gas, containing much hydrogen sulphide; first pay"; samples 1–7	6	8	1759	8
Limestone, light gray, lithographic, containing dark gray, argillaceous layers	0	4	1760	0
Drilled without coring	25	6	1785	6
Limestone, gray, fine, compact, very slight oil show; "second pay"; samples 8–11	3	6	1789	0
Limestone, gray, fine, compact, slightly argillaceous	7	0	1796	0

TABLE 34.—POROSITY, SATURATION, AND PERMEABILITY OF McCLUSKY LIME, LAWRENCE COUNTY POOL, CHRISTENSEN WELL NO. 1 (FIG. 22).

Sample No.	Depth (ft.–in.)	Porosity (per cent)	Saturation (per cent)[1]	Permeability (millidarcys)
1	1753–0	20.5	74.9	3150.
2	1754–0	21.5	73.2	3630.
3	1755–0	20.5	75.0	2030.
4	1756–0	19.9	100.	900.
5	1757–0	15.6	76.5	152.
6	1758–0	12.2	100.	19.7
7	1759–0	10.3	99.7	16.1
8	1786–0	26.1	93.7	3.72
9	1787–0	23.3	96.2	2.18
10	1788–0	23.1	92.6	2.55
11	1789–0	16.6	100.	1.90

[1]Total liquid saturation of the core in terms of bbls. per acre-foot is 1323.

Table 34 above shows porosity, saturation, and permeability results for samples of the McClosky lime taken at one-foot intervals from Christensen well No. 1 in the Lawrence County pool. As shown by the sample depths, there is a 27-foot break in the oil-bearing lime in this well.

See figure 22, page 63.

Warren Hastings, et. al.—Christiansen well No. 2, NE. 1/4 SW. 1/4 SW. 1/4, sec. 11, T. 3 N., R. 12 W., Lawrence Co.

Surface elevation 432 feet

	Thickness Ft.	Thickness In.	Depth Ft.	Depth In.
Beginning of core			1755	0
Fredonia limestone				
Limestone, oolitic, brownish-gray, medium grained, well sorted, porous, oil-bearing; samples 1–9	8	6	1763	6
Limestone, silty, finely sandy, gray, fine grained, compact, pyritic, partings of shale, silty, greenish-gray, brittle; sample 10	1	0	1764	6

Table 35 below shows porosity and saturation results for composite samples of the McClosky lime taken from each run, and permeability results for samples taken at one-foot intervals from Christensen well No. 2 in the Lawrence County pool.

See figure 22, page 63.

TABLE 35.—POROSITY, SATURATION, AND PERMEABILITY OF McCLOSKY LIME, LAWRENCE COUNTY POOL, CHRISTENSEN WELL NO. 2 (FIG. 22).

Sample No.	Depth (ft.–in.)	Porosity (per cent)	Saturation (per cent)[1]	Permeability (millidarcys)
1	1755–0			319.
2	1756–0			162.
3	1757–0	18.5	75.7	
4	1758–0			1300.
5	1759–0			450.
6	1760–0			8.12
7	1761–0			0.24
8	1762–0	14.3	67.6	0.00
9	1763–0			0.00
10	1764–0			0.00

[1]Total liquid saturation of the core in terms of bbls. per acre-foot is 912.

Warren Hastings, et. al.—R. M. Kirkwood well No. 13, SE. 1/4 NE. 1/4 SW. 1/4 sec. 11, T. 3 N., R. 12 W., Lawrence County

Surface elevation 430 feet

	Thickness Ft.	Thickness In.	Depth Ft.	Depth In.
Beginning of core			1754	0
Fredonia limestone				
Limestone, oolitic, brownish-gray, fine	0	2	1754	2
Limestone, oolitic, sandy, brownish-gray, fine	7	10	1762	0
Sandstone, very calcareous, oolitic, brownish-gray, very fine	2	0	1764	0
Limestone, oolitic, brownish-gray, medium grained; sample 2	1	0	1765	0
Same, containing oil; samples 3 and 4	1	2	1766	2
Limestone, silty, greenish-gray, grading to siltstone at base; sample 5	1	2	1767	4
Siltstone, calcareous, greenish-gray; sample 6	1	2	1768	6
Drilled without coring; oil struck at 1788 feet	27	6	1796	0
Sandstone, calcareous, light gray, fine, containing no oil; samples 7 and 8	1	0	1797	0

Table 36 below shows porosity, saturation, and permeability results for samples of the McClosky lime taken at one-foot intervals from Kirkwood well No. 13 in the Lawrence County pool. As shown, samples were not taken for a distance of about 30 feet near the bottom of the sand, as most of the sand was not oil-bearing.

See figure 22, page 63.

Table 36.—Porosity, Saturation, and Permeability of McClosky lime, Lawrence County pool, Kirkwood well No. 13 (Fig. 22).

Sample No.	Depth (ft.–in.)	Porosity (per cent)	Saturation (per cent)[1]	Permeability (millidarcys)
2	1764–0	2.45	100	19.1
3	1765–0	4.71	100	0.00
4	1766–0	2.32	100	0.00
5	1767–0	2.87	100	0.00
6a	1768–0	7.45	100	0.00
6b		7.99		0.00
7a	1796–0	23.3	100	2.26
7b		23.4		2.21
8	1796–6	20.6	100	1.30

[1]Total liquid saturation of the core in terms of bbls. per acre-foot is 822.

W. C. McBride, Inc.—N. H. Rogers well No. 14, NE. 1/4 NW. 1/4 NW. 1/4 sec. 14, T. 3 N., R. 12 W., Lawrence County

Surface elevation 427.5 feet

	Thickness Ft.	Thickness In.	Depth Ft.	Depth In.
Beginning of core			1738	0
Fredonia limestone				
Limestone, oolitic, gray, medium-grained, fossiliferous, slightly porous, containing a few streaks of oil; "first pay"; samples 1–3	2	6	1740	6
Drilled without coring	9	6	1750	0
Limestone, very oolitic, gray, fine, fossiliferous, very porous, containing gas and slight oil show; "second pay"; samples 4–6	2	0	1752	0
Limestone, very oolitic, gray, fine to medium, fossiliferous, contairing oil shows	0	2	1752	2
Limestone, medium to dark gray, fine to lithographic, compact	15	4	1767	6
Drilled without coring	10	6	1778	0
Dolomite, light gray, soft, very slightly porous, containing slight show of oil; samples 7–10	4	0	1782	0
Same with no oil show	4	0	1786	0
Limestone, light gray, soft, very slightly porous	2	6	1788	6

Table 37 below shows porosity and saturation results for composite samples taken from each run, and permeability results for samples of the McClosky lime taken at one-foot intervals from Rogers well No. 14 in the Lawrence County pool. In this well not all of the McClosky lime was oil-bearing.

See figure 22, page 63.

Table 37.—Porosity, Saturation, and Permeability of McClosky lime, Lawrence County pool, Rogers well No. 14 (Fig. 22).

Sample No.	Depth (ft.–in.)	Porosity (per cent)	Saturation (per cent)[1]	Permeability (millidarcys)
1	1738–0			14.9
2	1739–0	9.07	100.	13.9
3	1740–0			4.44
4	1750–0			259.
5	1751–0	15.1	43.2	470.
6	1752–0			1.09
7	1778–6			2.56
8	1779–6	25.9	87.6	2.92
9	1780–6			6.67
10	1781–6			4.14

[1]Total liquid saturation of the core in terms of bbls. per acre-foot is 996.

NOBLE POOL

Arbuthnot well No. 9 and Schilling well No. 1 were cored in the Noble pool.

Ohio Oil Co.—Arbuthnot well No. 9, Cen. W.1/2 SW. 1/4 NE. 1/4 sec. 8, T. 3 N., R. 9 E., Richland County

Surface elevation 480 feet

	Thickness Ft.	Thickness In.	Depth Ft.	Depth In.
Beginning of core			2940	0
Rosiclare sandstone				
Shale, calcareous, greenish-black	0	8	2940	8
Limestone, sandy, oolitic, brownish-gray	3	2	2943	10
Shale, dark green	0	9	2944	7
Limestone, very sandy, slightly oolitic, brownish-gray; sample 34	2	5	2947	0
Fredonia limestone				
Limestone, oolitic, brown to gray, crystalline calcite in interstices, porous, saturated with oil except in a few compact streaks; samples 35–49	15	0	2962	0
Limestone, oolitic, brown to gray, compact to porous, some oil saturation	2	2	2964	2
Sandstone, very calcareous, light brownish-gray, very fine, compact	3	1	2967	3
Limestone, very sandy, oolitic, brownish-gray streaks of sandstone	4	4	2971	7
Limestone, oolitic, brownish-gray, crystalline calcite interstices, compact	1	5	2973	0

See table 38 below.

TABLE 38.—POROSITY AND PERMEABILITY OF McCLOSKY LIME, NOBLE POOL, ARBUTHNOT WELL NO. 9 (FIG. 23).

Sample No.	Depth (ft.–in.)	Porosity (per cent)	Permeability (millidarcys)
34	2946–9	8.24	26.3
35	2947–9	9.38	49.2
36	2948–9	14.2	902.
37	2949–9	5.29	
38	2950–9	10.8	301.
39	2951–9	16.0	2390.
40	2952–0	21.0	4950.
41	2953–0	17.4	
42	2954–0	11.5	53.2
43	2955–0	13.8	
44	2956–0	5.00	0.00
45	2957–0	14.4	135.
46	2958–0	17.8	615.
47	2959–0	16.8	1550.
48	2960–0	11.1	81.0
49	2961–0	6.57	2.56

Ohio Oil Co.—Schilling well No. 1, SE. 1/4 SE. 1/4 SE. 1/4 sec. 32, T. 4 N., R. 9 E., Richland County

Surface elevation 499 feet

	Thickness Ft.	Thickness In.	Depth Ft.	Depth In.
Beginning of core			2951	0
Fredonia limestone				
Limestone, very oolitic, oil-bearing, light brownish-gray, coarse, porous, saturated; samples 1 and 2	1	4	2952	4
Same, but fairly compact, bleeding; sample 3	0	10	2953	2
Limestone, very oolitic, oil-bearing, light brownish-gray, coarse, compact; sample 4	2	5	2955	7
Limestone, very oolitic, oil-bearing, light brownish-gray, very fine to coarse, bleeding; sample 5	0	5	2956	0
Limestone, very oolitic, oil-bearing, light gray, fine, porous, saturated; samples 6–19	14	0	2970	0

Table 39 below shows porosity and permeability results for samples taken at one-foot intervals from Schilling well No. 1 in the Noble pool of the McClosky lime. This well was cored by the Ohio Oil Company. No Survey representative was present at the time of coring to take saturation samples.

Data from tables 38 and 39 are shown in figure 23, page 63.

TABLE 39.—POROSITY AND PERMEABILITY OF McCLOSKY LIME, NOBLE POOL, SCHILLING WELL NO. 1 (FIG. 23).

Sample No.	Depth (ft.–in.)	Porosity (per cent)	Permeability (millidarcys)
1	2951–0	10.4	80.1
2	2952–0	9.19	31.4
3	2953–0	6.23	31.4
4	2955–0	5.69	8.41
5	2956–0	15.2	1580.
6	2957–0	16.7	803.
7	2958–0	16.3	793.
8	2959–0	16.0	1340.
9	2960–0	15.6	1150.
10	2961–0	18.1	1990.
11	2962–0	19.0	880.
12	2963–0	18.9	2300.
13	2964–0	15.4	266.
14	2965–0	12.9	416.
15	2966–0	14.0	357.
16	2967–0	15.4	530.
17	2968–0	14.2	263.
18	2969–0	13.9	106.
19	2969–6	12.7	149.

OLNEY POOL

Sager well No. 3 was the only well in the Olney pool cored through the McClosky lime.

J. V. Wicklund Development Co.—Sager Well No. 3, SW. 1/4, NE. 1/4, SE. 1/4, sec. 22, T. 4 N., R. 10 E., Richland County

	Thickness Ft.	Thickness In.	Depth Ft.	Depth In.
Beginning of core			2990	0
Rosiclare sandstone				
Sandstone, argillaceous, calcareous, dark gray	2	11	2992	11
Limestone, sandy, oolitic, brownish-gray, glauconitic, containing shale pebbles	3	2	2996	1
Shale, oolitic, sandy, green, containing thin laminae of sandstone, calcareous, oolitic, brown	0	6	2996	7
Fredonia limestone				
Limestone, oolitic, grayish-brown, medium grained, compact, saturated	0	6	2997	1
Same, but very porous; samples 1–6	4	11	3002	0
Same, but mostly compact with porous streaks; samples 7–8	2	0	3004	0

Table 40 below shows porosity and permeability results for samples of the McClosky lime taken at one-foot intervals from Sager well No. 3 in the Olney pool. This well was cored by the Wicklund Development Company. No Survey representative was present at the time of coring to take saturation samples.

See figure 24, page 63.

Table 40.—Porosity and Permeability of McClosky lime, Olney pool, Sager well No. 3 (Fig. 24).

Sample No.	Depth (ft.–in.)	Porosity (per cent)	Permeability (millidarcys)
1	2997–0	9.47	97.2
2	2998–0	12.8	1205.
3	2999–0	13.1	700.
4	3000–0	12.4	465.
5	3001–0	10.0	190.
6	3002–0	9.41	52.0
7	3003–0	8.89	21.3
8	3004–0	9.48	63.4

SALEM POOL

Tate well No. 1 provided the only core of the McClosky lime in the Salem pool.

The Texas Co.—E. Tate well No. 1, E. 1/2 NW. 1/4 NW. 1/4 sec. 5, T. 1 N., R. 2 E., Marion County

	Thickness Ft.	Thickness In.	Depth Ft.	Depth In.
Beginning of core			1899	0
Fredonia limestone				
Limestone, oolitic, light gray, medium - grained, porous (especially at base); varying amounts interstitial clear crystalline calcite; samples 61–63	3	0	1902	0
Gap	1	0	1903	0
Limestone, as above, but compact, much crystalline calcite; sample 64	1	0	1904	0
Gap	2	0	1906	0
Limestone, oolitic, light gray, porous, coarse, more or less interstitial crystalline calcite; samples 65 and 66	2	0	1908	0
Limestone, oolitic, light gray, very fine to coarse, fossiliferous, somewhat porous, interstitial crystalline calcite; sample 67	1	0	1909	0
Limestone, oolitic, light gray, medium, porous, some interstitial crystalline calcite; sample 68	1	0	1910	0
Limestone, oolitic, light gray, very fine to very coarse, fossiliferous, porous, interstitial calcite; samples 69 and 70	2	0	1912	0

Table 41 below shows porosity and permeability results for samples of the McClosky lime taken at one-foot intervals. No saturation samples were available.

See figure 25, page 64.

Table 41.—Porosity and Permeability of McClosky lime, Salem pool, Tate well No. 1 (Fig. 25).

Sample No.	Depth (ft.–in.)	Porosity (per cent)	Permeability (millidarcys)
61	1900–0	10.4	87.0
62	1901–0	9.70	19.7
63	1902–0	14.1	653.
64	1904–0	5.13	0.00
65	1907–0	13.6	679.
66	1908–0	11.9	188.
67	1909–0	9.78	30.4
68	1910–0	11.5	42.3
69	1911–0	10.9	21.0
70	1912–0	11.2	37.6

Niagaran lime

CRAWFORD—MAIN POOL

The "Niagaran" lime was investigated in the Crawford—Main pool only, where Athey well No. 1 was cored.

Warren Hastings—Athey well No. 1, N. 1/2 NE. 1/4 NE. 1/4, sec. 18, T. 8 N., R. 12 W., Crawford County

Surface elevation 577 feet

	Thickness Ft.	Thickness In.	Depth Ft.	Depth In.
Devonian limestone				
Top of limestone			2780	0
Limestone	111	0	2891	0
Limestone, light to dark brownish-gray, finely crystalline, fossiliferous, few tiny solution cavities giving oil shows; cherty at 2918 to 2919 feet	30	0	2921	0
Limestone, similar to above, but slightly sandy	13	0	2934	0
Limestone, sandy, brown, finely crystalline, compact, slight saturation; samples 1–4	4	0	2938	0
Limestone, sandy, gray, medium to coarsely crystalline, compact, no oil show; sample 5	1	0	2939	0
Limestone, sandy, with 40% sand, brown, finely crystalline, fossiliferous, saturated spots; samples 6–11	6	0	2945	0
Limestone, sandy, with 40% sand, brown to gray, very finely crystalline, porous to compact, irregularly saturated throughout; samples 12–14	3	0	2948	0
Sandstone, calcareous, fine, white, friable to medium cemented, porous, few well saturated cemented streaks; hole filled several hundred feet with salt water containing hydrogen sulphide	2	0	2950	0

Table 42 below shows porosity and permeability results for samples of the Niagaran lime taken at one-foot intervals from Athey well No. 1 in the Crawford—Main pool. No saturation results were obtained from this well which was a test hole and did not become a producer.

Data from table 42 are shown in figure 26, page 64.

Table 42.—Porosity and Permeability of Devonian limestone (Niagaran lime), Crawford—Main pool, Athey well No. 1 (Fig. 26).

Sample No.	Depth (ft.–in.)	Porosity (per cent)	Permeability (millidarcys)
1	2935–0	5.52	0.445
2	2936–0	7.78	0.580
3	2937–0	9.10	1.37
4	2938–0	10.2	8.42
5	2939–0	7.47	
6	2940–0	9.51	1.84
7	2941–0	8.74	3.21
8	2942–0	10.8	11.7
9	2943–0	11.8	22.5
10	2944–0	10.8	5.38
11	2945–0	6.89	
12	2946–0	6.76	2.40
13	2947–0	4.33	0.597
14	2948–0	3.77	0.338

Hoing sand

COLMAR—PLYMOUTH POOL

The Hoing sand was investigated in only the Colmar—Plymouth pool where Binney well No. 24, Jarvis well No. 14, and McFadden well No. 31 were cored.

Data for cores from all three wells are plotted in figure 27, page 64.

Ohio Oil Co.—J. Binney well No. 24, SW. 1/4 SE. 1/4 NW. 1/4 sec. 16, T. 4 N., R. 4 W., McDonough County

Surface elevation 510 feet

	Thickness Ft.	Thickness In.	Depth Ft.	Depth In.
Beginning of core			414	10
Devonian system				
Sandstone, dolomitic, light brownish-gray, very fine to fine, compact; sample 1	0	10	415	8
Sandstone, dolomitic, light brownish - gray, partly quartzitic	0	1	415	9
Sandstone, dolomitic, brown, fine, downward increasingly porous and saturated with oil; samples 2 and 3	1	9	417	6
Sandstone, dolomitic, brownish-gray to brown, varying porosity and oil saturation; samples 4–9	6	6	424	0
Quartzite, white, fine-grained	0	3	424	3
Sandstone, dolomitic, brown, fine, porous, saturated with oil; samples 10–11	1	3	425	6
Quartzite, white, fine-grained	0	2	425	8

Table 43 below shows duplicate porosity and permeability results and saturation results for samples of the Hoing sand taken at one-foot intervals from Binney well No. 24 in the Colmar—Plymouth pool.

TABLE 43.—POROSITY, SATURATION, AND PERMEABILITY OF HOING SAND, COLMAR—PLYMOUTH POOL, BINNEY WELL NO. 24 (FIG. 27).

Sample No.	Depth (ft.–in.)	Porosity (per cent)	Saturation (per cent)[1]	Permeability (millidarcys)
1.....	415–2	7.8	48.6	1.84
2a....	416–2	19.6	61.1	1800.
2b....		19.4		2020.
3a....	417–2	17.9	100.	1210.
3b....				768.
4a....	418–4	11.3	85.0	2.63
4b....		11.4		5.02
5a....	419–4	20.9	100.	1220.
5b....				346.
6a....	420–4	20.9	100.	57.5
6b....				50.3
7a....	421–2	19.4	98.5	1060.
7b....		19.4		901.
8a....	422–2	20.3	100.	250.
8b....				90.0
9a....	423–2	19.0	100.	906.
9b....				468.
10a....	424–2	18.6	100.	674.
10b....				787.
11.....	425–6	5.7	100.	0.00

[1]Total liquid saturation of the core in terms of bbls. per acre-foot is 700.

Ohio Oil Co.—Jarvis well No. 14, SW. 1/4 NW. 1/4 SE. 1/4 sec. 16, T. 4 N., R. 4 W., McDonough County

	Thickness Ft.	Thickness In.	Depth Ft.	Depth In.
Beginning of core...........			456	6
Devonian system				
Sandy limestone and sandstone in thin interlaminations; samples 1–2........	1	0	457	6
Sandstone, fine, soft, brown, saturated, thin laminations of shale; samples 3–10.....	7	0	464	6

Table 44 below shows porosity and permeability results for samples of the Hoing sand taken at one-foot intervals from Jarvis well No. 14 in the Colmar—Plymouth pool. This well was cored by the Ohio Oil Company. No Survey representative was present at the time of coring to take saturation samples.

Data from tables 43, 44, and 45A are given in figure 27, page 64.

TABLE 44.—POROSITY AND PERMEABILITY OF HOING SAND, COLMAR—PLYMOUTH POOL, JARVIS WELL NO. 14 (FIG. 27).

Sample No.	Depth (ft.–in.)	Porosity (per cent)	Permeability (millidarcys)
1............	456–6	14.9	65.6
2............	457–6	16.7	597.
3............	458–6	18.8	2270.
4............	459–6	17.7	2250.
5............	460–6	16.2	1100.
6............	461–4	18.2	2080.
7............	462–0	17.2	734.
8............	463–0	16.7	1050.
9............	464–0	19.7	2690.
10............	464–6	16.1	2730.

Ohio Oil Co.—T. F. McFadden well No. 31, NW. 1/4 NE. 1/4 sec. 15, T. 4 N., R. 4 W., McDonough County

Surface elevation 576 feet

	Thickness Ft.	Thickness In.	Depth Ft.	Depth In.
Beginning of core...........			485	6
Devonian system				
Limestone, very sandy, dolomitic, light brownish-gray, coarse; samples 1–9.......	3	2	488	8
Sandstone, dolomitic, light gray, grading down to brown, porous to compact, containing oil; samples 10–40.....................	5	4	494	0
Sandstone, slightly dolomitic, brown, buff, and white, porous, irregular areas containing oil; samples 41–64.	3	6	497	6
Sandstone, slightly dolomitic, white to light gray, fine, porous, some mottling of argillaceous material toward base; samples 65–105....................	6	2	503	8
Ordovician system				
Maquoketa shale				
Shale, gray with scattered brown specks..........	4	4	508	0

Tables 45A and 45B show porosity and permeability results for samples of the Hoing sand taken at about two-inch intervals from McFadden well No. 31 in the Colmar—Plymouth pool. This well was cored before the Survey started the practice of weighing the saturation samples in the field and therefore the saturation results are considered unreliable (due to evaporation) and are not included in this report.

Table 45A.—Porosity and Permeability of Hoing sand, Colmar—Plymouth pool, McFadden well No. 31 (Figs. 27, 35, and 39).

Sample No.	Depth (ft.–in.)	Porosity (per cent)	Permeability (millidarcys)	Sample No.	Depth (ft.–in.)	Porosity (per cent)	Permeability (millidarcys)
1	485–6	8.7	0.40	54	495–11	21.8	2180.
2	486–6	10.6	0.58	55	496–0	19.1	346.
3	487–4	13.3	8.3	56	496–4	19.1	946.
4	487–6	14.4	59.6	57	496–6	20.0	1004.
5	487–9	14.2	58.2	58	496–7	17.2	631.
6	488–0	16.4	278.	59	496–8	18.5	780.
7	488–4	14.5	41.5	60	496–9	17.5	666.
8	488–6	15.3	82.8	61	496–10	21.1	1190.
9	488–8	10.6	4.8	62	497–0	19.5	945.
10	488–10	16.7	71.3	63	497–2	15.1	43.3
11	488–11	13.2	24.7	64	497–5	19.8	892.
12	489–0	17.1	254.	65	497–7	20.4	920.
13	489–3	15.3	26.2	66	497–9	18.3	940.
14	489–5	14.7	46.4	67	497–10	19.0	506.
15	490–0	23.5	1230.	68	497–11	19.8	806.
16	490–2	22.4	681.	69	498–0	18.1	67.1
17	490–3	23.1	1140.	70	498–1	19.0	273
18	490–6	20.5	842.	71	498–2	18.6	495.
19	490–8	22.1	1120.	72	498–5	18.3	420.
20	490–10	20.3	296.	73	498–7	18.5	1270.
21	490–11	22.0	1690.	74	499–2	18.7	734.
22	491–2	20.8	1350.	75	499–3	20.1	1320.
23	491–6	22.0	925.	76	499–8	19.5	888.
24	491–8	23.8	1750.	77	499–9	18.5	787.
25	491–10	21.1	436.	78	500–2	20.1	866.
26	491–11	20.6	115.	79	500–4	18.5	735.
27	492–0	21.3	753.	80	500–5	19.1	553.
28	492–1	20.8	578.	81	500–7	20.8	686.
29	492–3	19.7	535.	82	500–9	18.7	247.
30	492–5	23.9	2530.	83	500–11	19.5	410.
31	492–6	19.4	336.	84	501–3	18.8	66.6
32	492–9	21.2	886.	85	501–5	19.0	318.
33	492–11	19.7	332.	86	501–8	18.1	346.
34	493–0	20.9	980.	87	501–9	17.9	358.
35	493–3	22.3	1800.	88	501–10	18.8	447.
36	493–6	20.4	456.	89	501–11	19.6	302.
37	493–7	21.4	1780.	90	502–1	18.3	149.
38	493–8	20.6	1390.	91	502–2	19.1	241.
39	493–11	18.7	520.	92	502–3	17.9	261.
40	494–0	17.7	635.	93	502–4	19.0	359.
41	494–1	18.3	475.	94	502–5	17.5	328.
42	494–2	17.7	191.	95	502–6	17.2	282.
43	494–4	19.0	219.	96	502–8	16.8	64.6
44	494–6	21.6	1648.	97	502–9	18.1	56.9
45	494–7	22.6	303.	98	502–11	17.1	89.7
46	494–8	19.5	592.	99	503–0	20.0	1070.
47	494–10	22.2	586.	100	503–1	17.9	522.
48	495–0	18.8	693.	101	503–2	18.5	487.
49	495–2	18.3	377.	102	503–3	20.6	289.
50	495–3	20.4	812.	103	503–4	19.5	574.
51	495–4	19.4	281.	104	503–5	14.4	89.0
52	495–8	20.4	1330.	105	503–6	8.7	1.8
53	495–10	21.7	1290.				

Table 45B.—Porosity of Hoing sand, Colmar—Plymouth pool, McFadden well No. 31.

Tested by the United States Bureau of Mines

Sample Number	Porosity (per cent)
23a	23.0
23b	20.4
48a	22.8
48b	22.3
75a	18.8
75b	20.8
77a	21.4
77b	20.3

Kimmswick lime

dupo pool

Dyroff well No. 27 in the Dupo pool was the only well cored in the Kimmswick lime.

Ohio Oil Co.—M. Dyroff well No. 27, SW. 1/4 NW. 1/4 SE. 1/4 sec. 28, T. 1 N., R. 10 W., St. Clair County

Surface elevation 405.5 feet

	Thickness Ft.	Thickness In.	Depth Ft.	Depth In.
Beginning of core			401	0
Kimmswick limestone				
Limestone, light brownish-gray, very fine, some coarse areas, containing oil along stylolites and in more coarse-grained areas; sample 1	0	9	401	9
Limestone, light brownish-gray to gray, very fine to very coarse, crinoidal, oil in tubular areas in lowest 9 inches; samples 2–4	2	3	404	0
Limestone, brownish-gray, coarsely crystalline, porous with fossil impressions, containing oil	0	9	404	9
Limestone, grayish-brown, very fine to coarse, crystalline, compact; samples 5 and 6	2	0	406	9
Limestone, grayish-brown, coarse, crystalline, somewhat porous; samples 7 and 8	1	9	408	6
Limestone, brown, very coarse, crystalline, porous; samples 9 and 10	1	6	410	0
Limestone, grayish-brown, coarse, crystalline, compact; samples 11–13	3	6	413	6
Limestone, brown to grayish-brown, very coarse, more or less porous; samples 14–18	4	6	418	0
Limestone, brown with dark brown bituminous specks, coarse, crystalline, compact	0	2	418	2
Limestone, speckled brownish-gray and gray, medium to coarse, crystalline, thin layer of phosphatic nodules at base; sample 19	0	10	419	0
Limestone, speckled light brownish gray and gray, very fine to coarse, crystalline	0	4	419	4
Limestone, brown, coarse, crystalline, somewhat porous, containing oil; samples 20–22	2	8	422	0
Limestone, light gray and brown speckled, coarse, crystalline, compact except near base; samples 23–25	3	0	425	0
Limestone, light gray and brown speckled, very coarse, porous; samples 26–28	3	9	428	9
Limestone, brown, coarse, crystalline, more or less porous, containing oil; samples 29–40	12	3	441	0
Limestone, brownish-gray, coarse, crystalline, somewhat porous; samples 41–42	2	0	443	0
Limestone, grayish-brown, medium to coarse, fairly compact; sample 43	1	1	444	1
Limestone, buff with brown specks, very fine, conodonts	0	1	444	2
Limestone, speckled light brownish-gray and brown, coarse, porous	0	5	444	7
Limestone, light brownish-gray, brown specks, very fine, compact, conodonts	0	1	444	8
Limestone, light to medium brown, coarse, crystalline, porous; sample 44	0	8	445	4
Limestone, brown, fine to coarse, crystalline, compact, areas of clear crystalline calcite filling former cavities, show of oil	0	8	446	0

Table 46 (p. 49) shows porosity and permeability results for samples of the Kimmswick lime taken at one-foot intervals from Dyroff well No. 27 in the Dupo pool. Saturation results are omitted for the same reason as noted for McFadden well No. 31.

Data for table 46 are shown in figure 28, page 66.

Table 46.—Porosity and Permeability of Kimmswick lime, Dupo pool, Dyroff well No. 27 (Fig. 28).

Sample No.	Depth (ft.–in.)	Porosity (per cent)	Permeability (millidarcys)
1	401–0	5.0	0.30
2	402–0	1.9	0.00
3	403–0	10.0	0.00
4	404–0	13.0	60.9
5	405–0	6.7	4.4
6	406–0	2.6	0.00
7	407–0	13.0	12.9
8	408–0	14.6	16.8
9	409–0	13.5	9.5
10	410–0	10.4	3.4
11	411–0	7.8	0.80
12	412–0	9.6	1.8
13	413–0	9.8	7.7
14	414–0	14.2	12.3
15	415–0	14.7	11.1
16	416–0	11.9	6.2
17	417–0	17.0	11.5
18	418–0	7.6	0.90
19	419–0	4.3	0.00
20	420–0	8.3	0.40
21	421–0	10.1	3.3
22	422–0	6.1	0.00
23	423–0	9.5	4.9
24	424–0	4.4	0.00
25	425–0	9.8	4.9
26	426–0	7.3	1.0
27	427–0	6.3	0.0
28	428–0	14.0	1.8
29	430–0	15.3	10.9
30	431–0	16.6	9.0
31	432–0	15.9	12.1
32	433–0	16.0	17.9
33	434–0	16.3	19.4
34	435–0	10.5	1.4
35	436–0	16.5	13.9
36	437–0	15.0	13.9
37	348–0	15.9	21.5
38	439–0	16.6	24.5
39	440–0	11.1	3.3
40	441–0	11.4	1.1
41	442–0	5.8	0.40
42	443–0	12.5	9.9
43	444–0	8.5	1.6
44	445–0	8.1	1.7

Vertical and Horizontal Permeability

A one-cm. cube was cut from each sample to test the relative vertical and horizontal permeabilities (tables 47-52). In addition to these permeabilities, the horizontal permeability was tested for 1 by 1 by 2 cm. pieces from the same samples (tables 2-46). The order of presentation by sands and pools is the same as that used for porosity, saturation, and permeability results.

Data from tables 47-52 are plotted in figures 29-34, pages 67-69.

Robinson sand

Cores of the Robinson sand for relative vertical and horizontal permeability tests were taken from two wells, one in the Crawford—Main pool and the other in the Lawrence County pool.

CRAWFORD—MAIN POOL

Henry well No. 14.—Table 47 below shows the relative vertical and horizontal permeability results for samples of the Robinson sand taken at one-foot intervals from Henry well No. 14 in the Crawford—Main pool. The horizontal permeability results for the 1 by 1 by 2 cm. pieces are the same as those given for this well in table 6.

Table 47.—Vertical and Horizontal Permeability of Robinson sand, Crawford—Main pool, Henry well No. 14 (Fig. 29).

Depth (ft.–in.)	Permeability (millidarcys)		
	Vertical	Horizontal	
	1x1x1 cm.	1x1x1 cm.	1x1x2 cm.
956–0	0.905	3.57	22.9
957–0	5.05	7.22	3.76
958–0	41.5	80.2	58.4
959–0	7.26	21.5	12.3
960–0	51.5	69.1	83.3
961–0	6.16	50.0	46.8
962–0	60.5	112.0	114.
963–0	88.9	157.0	153.
964–0	11.5	98.7	97.8
965–0	18.0	93.2	84.3
966–0	158.0	198.0	227.
967–0	148.0	272.0	238.
968–0	34.4	99.9	100.
969–0	18.2	42.4	44.1
970–0	140.0	314.0	358.
971–0	78.5	174.0	185.
972–0	91.5	158.0	156.
973–0	150.0	199.0	119.
974–0	52.5	112.0	118.
975–0	112.0	126.0	122.
977–0	1.13	2.10	1.81
978–0	0.46	1.36	0.58
979–0	0.39	0.27	0.40
981–0	0.34	1.14	
982–0	1.66	2.6	2.70
983–6	1.67	1.92	1.11

LAWRENCE COUNTY POOL

Crump well No. 27.—Table 48 below shows the relative vertical and horizontal permeability results for samples taken at one-foot intervals from Crump well No. 27. The horizontal permeability results for the 1 by 1 by 2 cm. pieces are the same as those given for this well in table 11.

TABLE 48.—VERTICAL AND HORIZONTAL PERMEABILITY OF ROBINSON SAND, LAWRENCE COUNTY POOL, CRUMP WELL No. 27 (FIG. 30).

Depth (ft.–in.)	Permeability (millidarcys)		
	Vertical	Horizontal	
	1x1x1 cm.	1x1x1 cm.	1x1x2 cm.
880–0	2.833	2.855	2.76
881–0	0.0	0.090	0.00
882–0			0.00
883–0	13.42	15.7	27.8
884–0	77.4	100.2	118.
885–0	346.0	451.0	361.
886–0	70.9	99.6	148.
887–0	60.6	98.8	1002.
888–0	772.0	1055.0	1270.
889–0	1790.0	2696.0	2760.
890.0	679.0	980.0	1490.
891.0	0.18	0.33	6.10
892–0	2698.0	3875.0	4250.
893–0	1635.0	2250.0	3290.

BIEHL SAND

ALLENDALE POOL

The Biehl sand was investigated for relative vertical and horizontal premeability in only Madden well No. 10 in the Allendale pool.

Madden well No. 10.—Table 49 below shows the relative vertical and horizontal permeability results for samples taken at six-inch intervals from Madden well No. 10. The horizontal permeability results for the 1 by 1 by 2 cm. pieces are the same as those given for this well in table 16.

CYPRESS SAND

BARTELSO POOL

Trame well No. 2 is the only well from the Bartelso pool in the Cypress sand whose core was tested for relative vertical and horizontal permeability.

TABLE 49.—VERTICAL AND HORIZONTAL PERMEABILITY OF BIEHL SAND, ALLENDALE POOL, MADDEN WELL No. 10 (FIG. 31).

Depth (ft.–in.)	Permeability (millidarcys)		
	Vertical	Horizontal	
	1x1x1 cm.	1x1x1 cm.	1x1x2 cm.
1418–0	26.5	48.3	49.4
1418–6			110.
1419–0	20.05	47.1	63.0
1419–6	51.0	86.3	87.7
1420–0	10.9	85.8	80.4
1420–6	32.3		137.
1421–0	20.4	39.2	25.2
1421–6	27.4	99.2	96.9
1422–0	22.4	38.0	44.8
1422–6			120.
1423–0	3.02	8.06	8.01
1423–6	220.0	312.2	227.
1424–0	300.0	332.0	289.
1424–6	42.1	125.5	104.
1425–0	25.2	59.1	59.1
1425–6	8.21	53.1	65.4
1426–0	388.0	441.0	441.
1426–6	159.2	196.0	247.
1427–0	8.34	9.54	11.6
1427·6	39.0	56.2	48.8
1428–0	35.1	82.5	102.
1428.6	76.9	131.2	106.
1429–0	85.0	142.3	111.
1429–6	8.95	22.4	40.2
1430–0	231.5	140.7	206.
1430–6	71.8	164.0	114.
1431–0	6.11	8.77	10.4
1431–6	25.8	80.1	102.
1432–0	46.0	91.0	57.8
1432–6	30.1	44.2	60.8
1433–0	0.0	0.334	0 00
1433–6	0.0	0.0	0 00
1434–0	0.0	0.0	0 00
1434–6	0.165	2.234	4.17
1435–0	0.0	0.0	0 00
1435–6	0.161	0 0	0.C0
1436–0	177.0	235.8	289.
1436–6	114.7	206 0	178.
1437–0	109.3	151.7	190.
1437–6	116.7	132.3	200.
1438–0	54.8	65.6	143.
1438–6	184 0	232.0	233.
1439–0	172.0	259.4	271.
1439–6	71.4	122.7	118.
1440–0	336 0	316.4	317.
1440–6	328.0	482.0	310.
1441–0	28.8	40.4	39.6
1441–6	83.6	102.0	102.
1442-0	163.0	223.0	201.
1442–6	123.5	150.2	165.
1443-0	115.0	161.2	172.
1443–6	99.3	151.2	154.
1444–0	76.3	111.0	113.
1444–6	0.246	1.423	1.48
1445–0	0.408	0.769	0.76
1445–6	1.865	2.64	2.06
1446–0	1.530	2.055	2.28
1446–6	0.590	0.591	1.03
1447–0	1.243	0.748	1.70

Trame well No. 2.—Table 50 below shows the relative vertical and horizontal permeability results for samples taken at six-inch intervals at the top and about one-foot intervals at the bottom of the Cypress sand from Trame well No. 2. The horizontal permeability results for the 1 by 1 by 2 cm. test pieces are the same as those given for this well in table 17.

TABLE 50.—VERTICAL AND HORIZONTAL PERMEABILITY OF CYPRESS SAND, BARTELSO POOL, TRAME WELL NO. 2 (FIG. 32).

Depth (ft.–in.)	Permeability (millidarcys)		
	Vertical	Horizontal	
	1x1x1 cm.	1x1x1 cm.	1x1x2 cm.
1009–0	128.0	179.0	189.
1009–6	235.3	349.5	304.
1010–0	363.0	448.0	431.
1010–6	29.5	157.2	191
1011–0	187.3	363.7	438.
1011–6	104.3	151.3	187.
1012–0	97.7	148.0	147.
1013–6	154.5	215.0	226
1015–0	200.8	260.0	329.
1016–6	278.5	398.5	437.
1018–0	172.0	230.5	306.
1019–0	104.0	186.0	146.

HOING SAND

COLMAR—PLYMOUTH POOL

Binney well No. 24 is the only well from the Colmar—Plymouth pool whose core was tested for relative vertical and horizontal permeability in the Hoing sand.

Binney well No. 24.—Table 51 below shows the relative vertical and horizontal permeability results for samples of the Hoing sand taken at one-foot intervals from Binney well No. 24. The horizontal permeability results for the 1 by 1 by 2 cm. test pieces were taken from table 43 as those values of the duplicate samples most nearly correspond with the values found for the 1 by 1 by 1 cm. test pieces.

KIMMSWICK LIME

DUPO POOL

Dyroff well No. 27 is the only well from the Dupo pool in the Kimmswick lime whose core was tested for relative vertical and horizontal permeability.

Dyroff well No. 27.—Table 52 below shows the relative vertical and horizontal permeability results for samples taken at two-foot intervals from Dyroff well No. 27. The horizontal permeability results for the 1 by 1 by 2 cm. test pieces are the same as those given for this well in table 46.

TABLE 51.—VERTICAL AND HORIZONTAL PERMEABILITY OF HOING SAND, COLMAR—PLYMOUTH POOL, BINNEY WELL NO. 24 (FIG. 33).

Depth (ft.–in.)	Permeability (millidarcys)		
	Vertical	Horizontal	
	1x1x1 cm.	1x1x1 cm.	1x1x2 cm.
415–2	4.79	0.21	1.84
416–2	1386.0	1261.0	1800.
417–2	702.0	1138.0	1210.
418–4	2.68	1.74	2.63
419–4	885.0	917.0	1220.
420–4	3.29	21.3	50.3
421–2	1720.0	1748.0	1060.
422–2	160.3		90.0
423–2	745.0	714.0	906.
424–2	1013.0	938.0	787.
425–6	0.42	0.12	0.00

TABLE 52.—VERTICAL AND HORIZONTAL PERMEABILITY OF KIMMSWICK LIME, DUPO POOL, DYROFF WELL NO. 27 (FIG. 34).

Depth (ft.–in.)	Permeability (millidarcys)		
	Vertical	Horizontal	
	1x1x1 cm.	1x1x1 cm.	1x1x2 cm.
401–0		0.0	0.30
403–0	0.0	0.161	0.00
405–0	0.464	0.220	4.4
407–0	18.1	16.8	12.9
409–0	11.4	11.92	9.5
411–0	0.678	1.083	0.80
413–0			7.7
415–0	12.93	17.2	11.1
416–0	2.88	3.675	6.2
418–0	0.720	0.833	0.90
420–0	0.648	1.648	0.40
422–0	0.354	0.456	0.00
424–0	0.136	0.289	0.00
426–0	0.258	0.568	1.0
428–0	0.887	1.003	1.8
431–0	2.02	5.20	9.0
433–0	8.17	9.43	17.9
435–0	1.315	1.013	1.4
437–0	12.43	13.45	13.9
438–0	9.07	8.42	21.5
440–0	0.770	1.004	3.3
442–0	0.503	11.0	0.40
444–0	1.198	0.829	1.6
445–0	2.89	4.27	1.7

DISCUSSION OF RESULTS

This section includes (a) comparison of porosity, saturation, and permeability results by pools for each of the ten Illinois oil sands investigated, (b) comparison of vertical with horizontal permeability results for cores from six pools in five oil sands, (c) comparison of porosity and permeability results for four cores, each of which was tested by one other laboratory and the Survey laboratory, and (d) relation of permeability to porosity.

Comparison of Results

In order to permit ready comparison of results for various cores in the same pool of an oil sand, a separate graph is made for each pool. Their order of presentation is the same as that used for the presentation of pools.

The porosity and saturation values are plotted in units of per cent; the permeability values, in units of millidarcys.

Upper Partlow sand

north johnson pool

Figure 3 (data from table 2) is a graph of porosity, saturation, and permeability results for Howe well No. 30 in the North Johnson pool of the Upper Partlow sand. The first part of the core recovered has been omitted from the graph in order to preserve the same scale for all the graphs, as it contained very little oil. The average of the permeability values for this pool and sand is 392 millidarcys, and the average deviation from the mean permeability is 82 per cent.

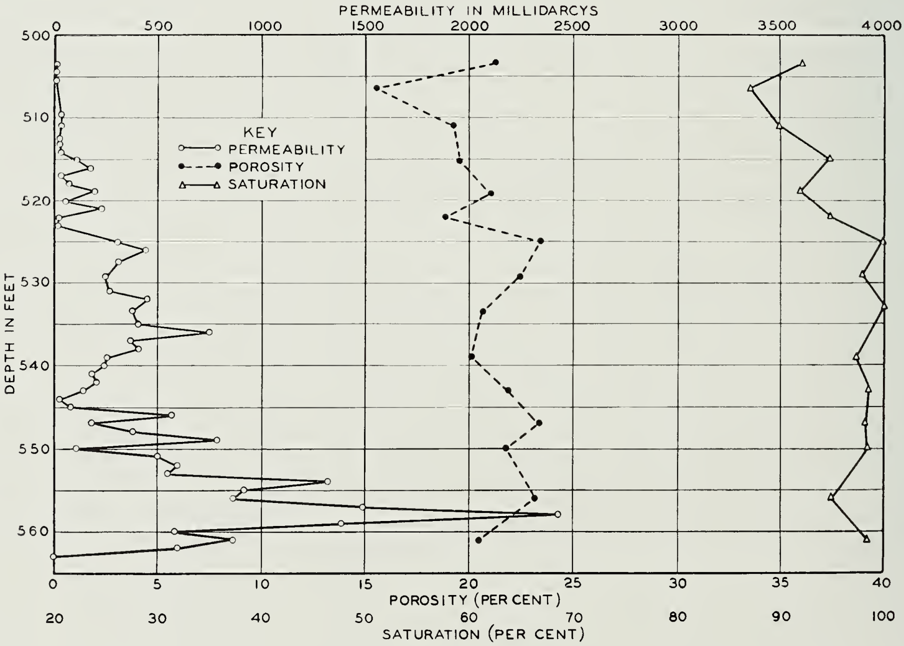

Fig. 3.—Upper Partlow sand, North Johnson pool; Howe well No. 30 (table 2, p. 18). As the first run contained very little oil it is omitted from this graph.

Robinson sand

CRAWFORD—MAIN POOL

Two graphs are used to present results of tests on the seven cores from the Crawford—Main pool of the Robinson sand. Figure 4 (data from tables 3 to 6 inclusive) shows results for Clark well No. 19, Clark well No. 20, Furman well No. 10 and Henry well No. 14. The first sample of Clark well No. 20 is omitted from the graph as it is an isolated sample containing little oil.

Figure 5 (data from tables 7 to 9 inclusive) is a similar graph for Snyder well No. 6, Stifle well No. 23, and Wattleworth well No. 18.

An inspection of these two graphs indi-

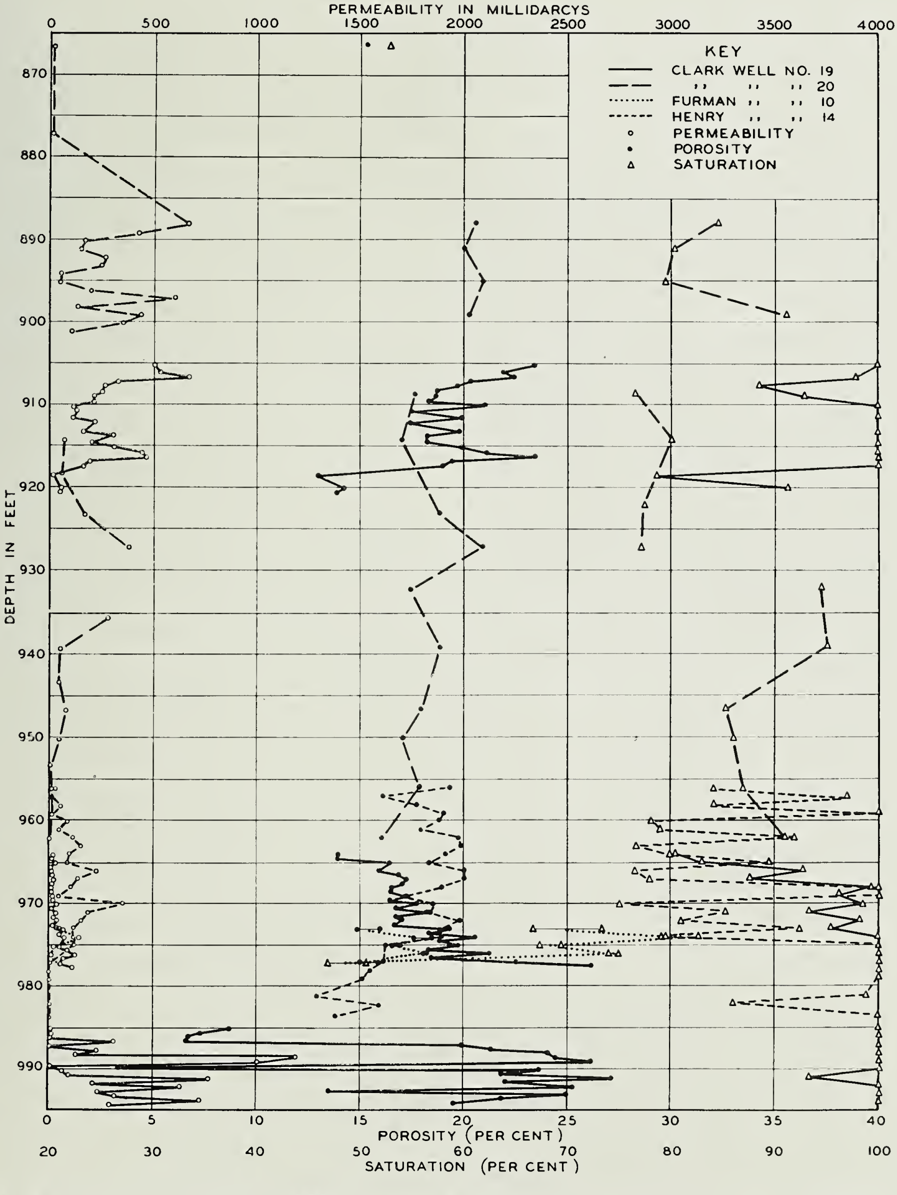

FIG. 4.—Robinson sand, Crawford—Main pool; Clark wells No. 19 and No. 20, Furman well No. 10, and Henry well No. 14 (tables 3, 4, 5, and 6A, pp. 19–21).

cates that the corresponding results for these seven wells in the Crawford—Main pool of the Robinson sand are of about equal magnitudes. The average of the permeability values for this pool of the Robinson sand is 146 millidarcys, and the average deviation from the mean permeability is 74 per cent.

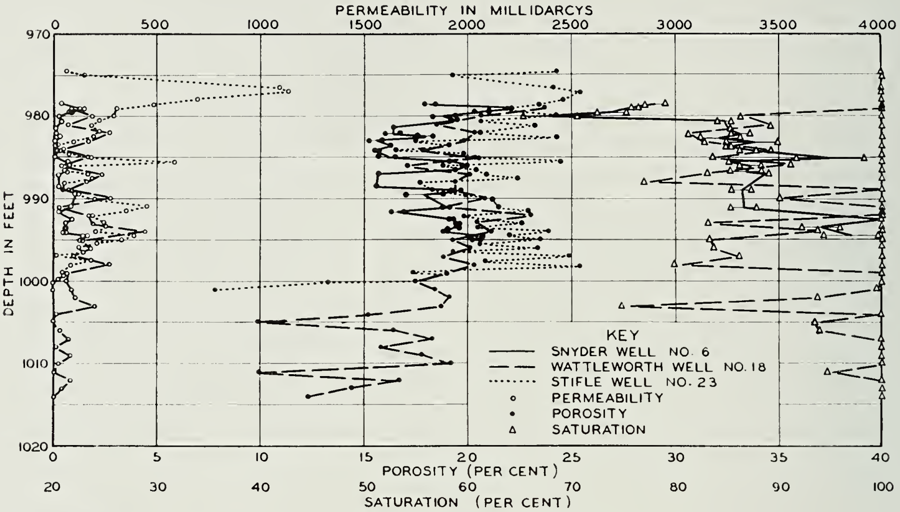

FIG. 5—Robinson sand, Crawford—Main pool; Snyder well No. 6, Stifle well No. 23, and Wattleworth well No. 18 (tables 7A, 8, and 9, pp. 22–24.)

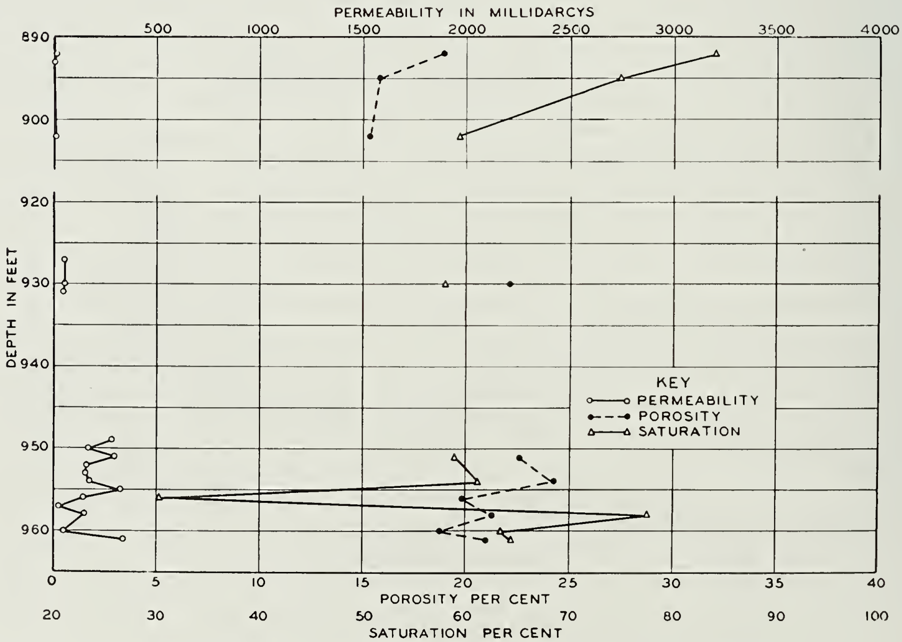

FIG. 6.—Robinson sand, Flat Rock pool; Cochran well No. 1 (table 10, p. 25).

FLAT ROCK POOL

Figure 6 (data from table 10) is a graph of results for Cochran well No. 1 which was cored in the Flat Rock pool of the Robinson sand. The average of the permeability values for this pool of the Robinson sand is 138 millidarcys, and the average deviation from the mean permeability is 67 per cent.

LAWRENCE COUNTY POOL

Figure 7 (data from table 11) is a graph of results for Crump well No. 27 which was cored in the Lawrence County pool of the Robinson sand. The average of the permeability values for this pool of the Robinson sand is 1052 millidarcys, and the average deviation from the mean permeability is 106 per cent.

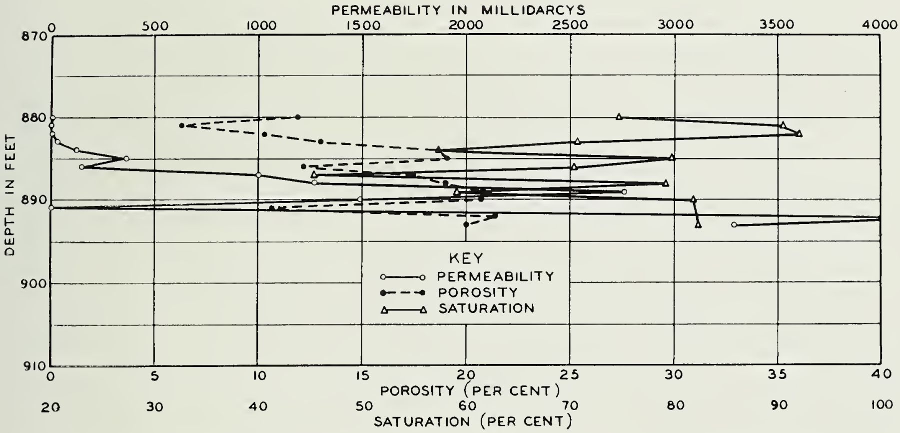

Fig. 7.—Robinson sand, Lawrence County pool; Crump well No. 27 (table 11, p. 26).

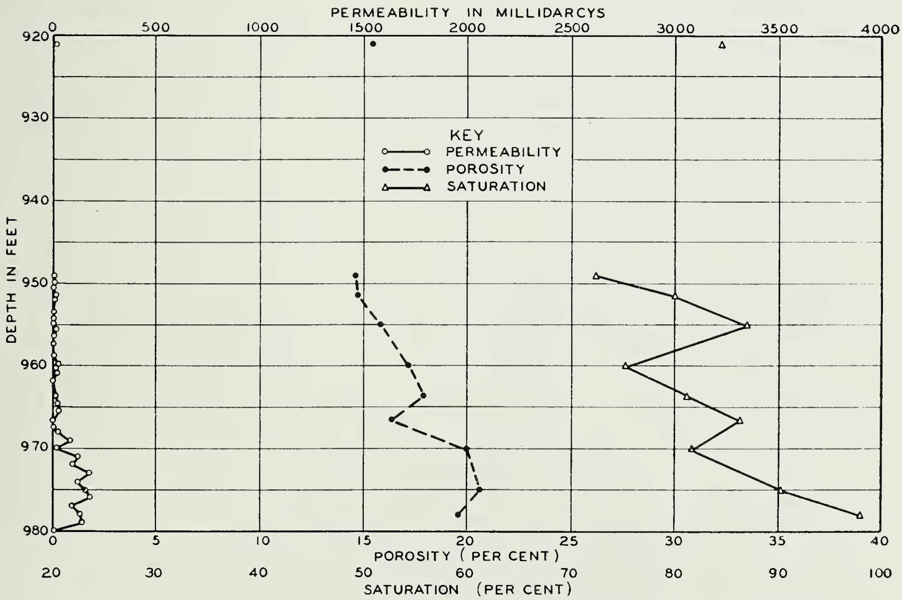

Fig. 8.—Robinson sand, New Hebron pool; Mohler well No. 15 (table 12, p. 27).

NEW HEBRON POOL

Figure 8 (data from table 12) is a graph of results for Mohler well No. 15 which was cored in the New Hebron pool of the Robinson sand. The average of the permeability values for this pool of the Robinson sand is 46 millidarcys, and the average deviation from the mean permeability is 108 per cent.

PARKER POOL

Figure 9 (data from table 13) is a graph of results for Weger well No. 14 which was cored in the Parker pool of the Robinson sand. The average of the permeability values for this pool of the Robinson sand is 200 millidarcys, and the average deviation from the mean permeability is 106 per cent.

Inspection of the graphs showing the results for the various pools in the Robinson sand indicates good agreement of results for all the pools with the exception of three very high permeability values for Crump well No. 27 in the Lawrence County pool.

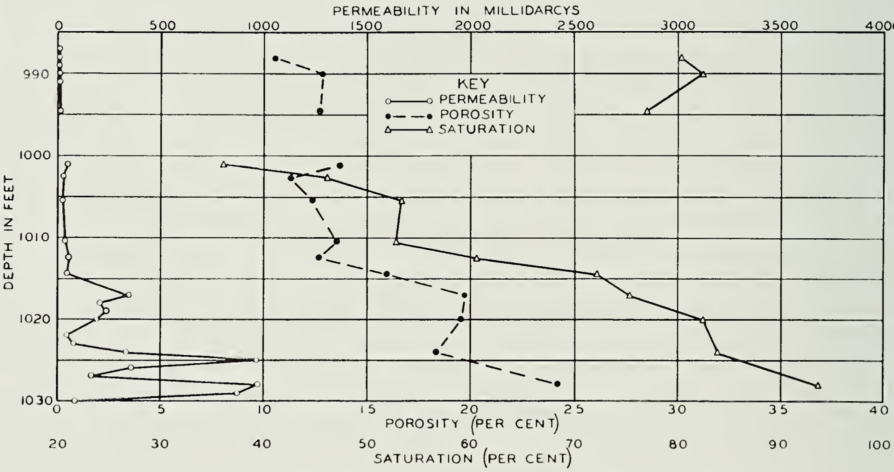

FIG. 9.—Robinson sand, Parker pool; Weger well No. 14 (table 13, p. 28).

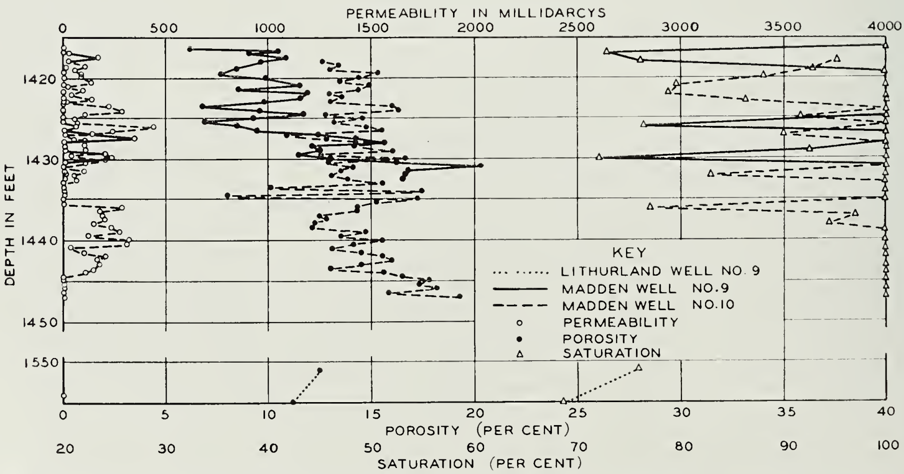

FIG. 10.—Biehl sand, Allendale pool; Lithurland well No. 9, Madden wells No. 9 and No. 10 (tables 14, 15, and 16, pp. 29–30).

BIEHL SAND

ALLENDALE POOL

Figure 10 (data from tables 14 to 16 inclusive) is a graph of results for Lithurland well No. 9, Madden well No. 9, and Madden well No. 10 which were cored in the Allendale pool of the Biehl sand. Lithurland well No. 9 and Madden well No. 9 passed through tight portions of the Biehl sand and did not become producing wells. The average of the permeability values for this pool and sand is 109 millidarcys, and the average deviation from the mean permeability is 69 per cent. The results for Lithurland well No. 9 and Madden well No. 9 have not been included in the above averages since they were not representative of the sand.

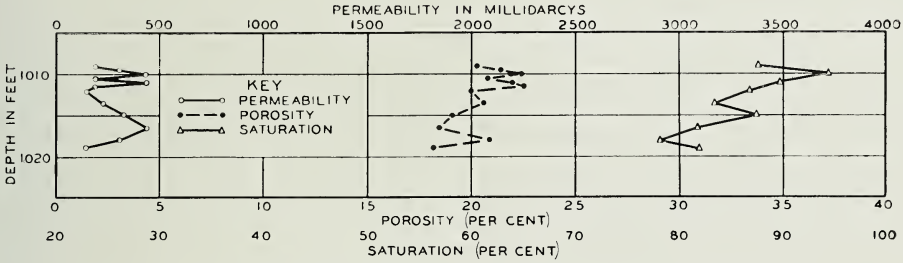

FIG. 11.—Cypress sand, Bartelso pool; Trame well No. 2 (table 17, p. 31).

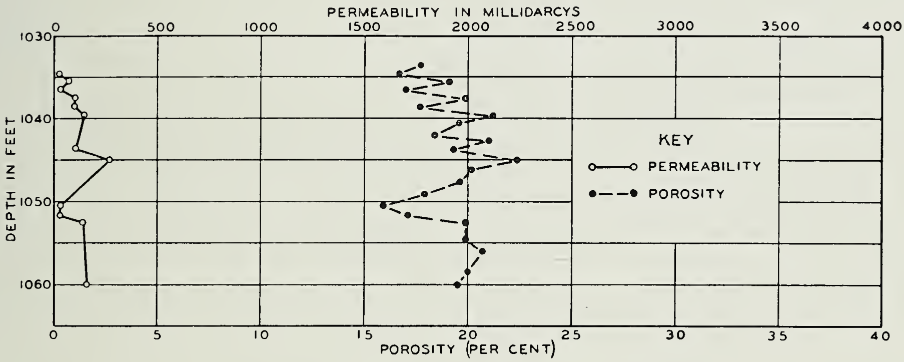

FIG. 12.—Cypress sand, Carlyle pool; Deters well No. 39 (table 18, p. 31).

CYPRESS SAND

BARTELSO POOL

Figure 11 (data from table 17) is a graph of results for Trame well No. 2 which was cored in the Bartelso pool of the Cypress sand. The average of the permeability values for this pool of the Cypress sand is 278 millidarcys, and the average deviation from the mean permeability is 35 per cent.

CARLYLE POOL

Figure 12 (data from table 18) is a graph of results for Deters well No. 39 which was cored in the Carlyle pool of the Cypress sand. The average of the permeability values for this pool of the Cypress sand is 103 millidarcys, and the average deviation from the mean permeability is 53 per cent.

LAWRENCE COUNTY POOL

Figure 13 (data from table 19) is a graph of results for the only sample taken in the Cypress sand from Kirkwood well No. 13, Lawrence County pool.

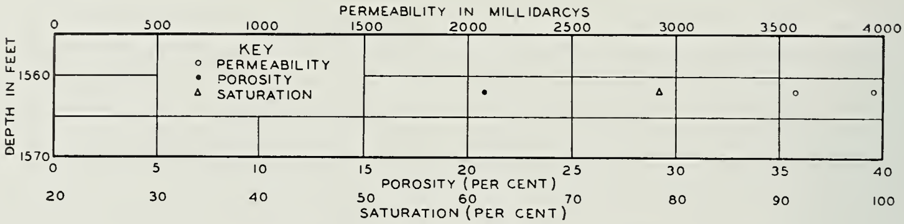

FIG. 13.—Cypress sand, Lawrence County pool; Kirkwood well No. 13 (table 19, p. 32).

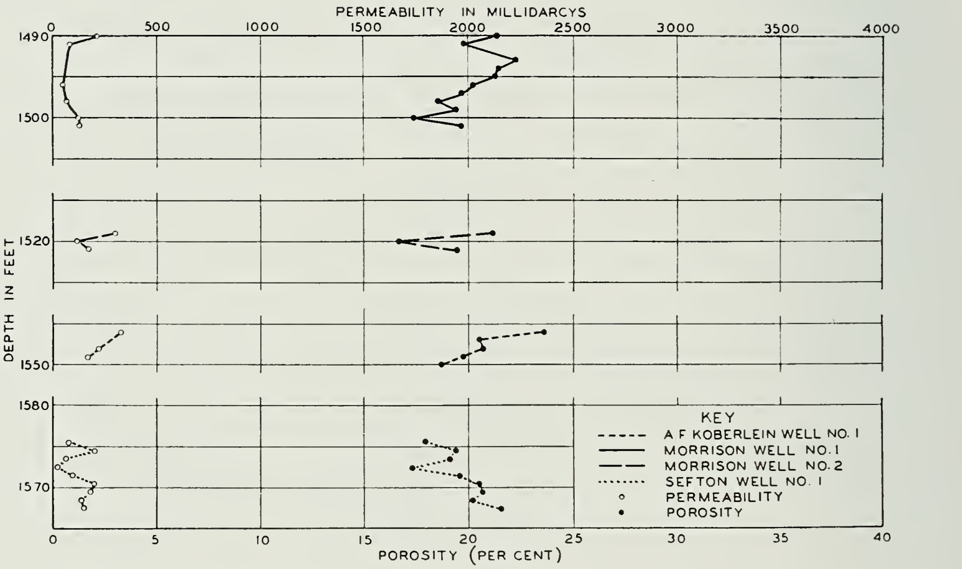

FIG. 14.—Cypress sand, Louden pool; Koberlein well No. 1, Morrison wells No. 1 and No. 2, and Sefton well No. 1 (tables 20, 21, 22, and 23, pp. 32–33).

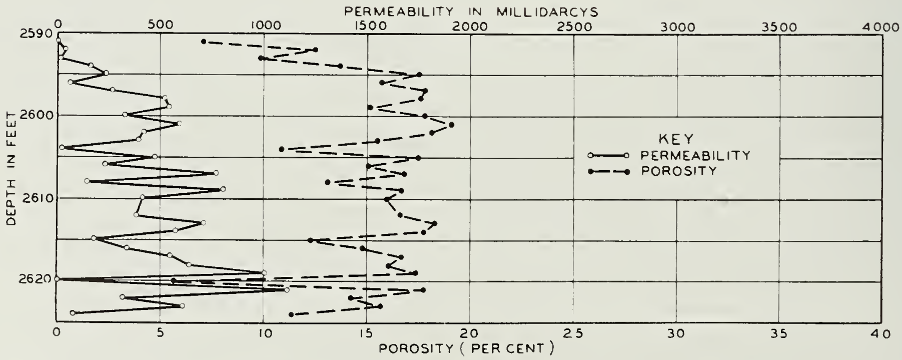

FIG. 15.—Cypress sand, Noble pool; Arbuthnot well No. 9 (table 24, p. 34).

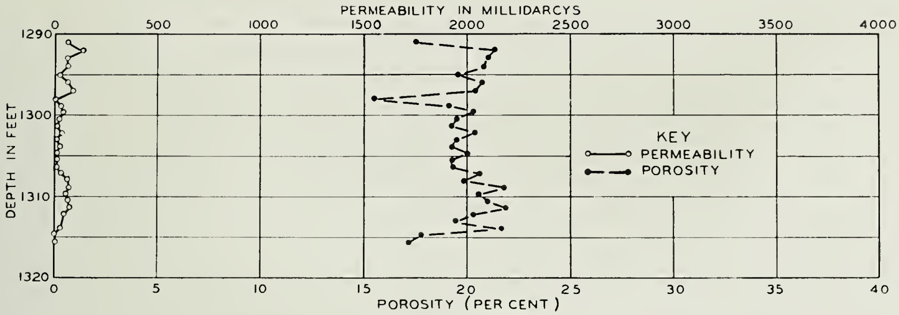

FIG. 16.—Cypress sand, Patoka pool; Merryman well No. 1 (table 25, p. 35).

LOUDEN POOL

Figure 14 (data from tables 20 to 23 inclusive) is a graph of results for Koberlein well No. 1, Morrison well No. 1, Morrison well No. 2, and Sefton well No. 1 which were cored in the Louden pool of the Cypress sand. The average of the permeability values for this pool of the Cypress sand is 148 millidarcys, and the average deviation from the mean permeability is 36 per cent.

NOBLE POOL

Figure 15 (data from table 24) is a graph of results for Arbuthnot well No. 9 which was cored in the Noble pool of the Cypress sand. This well is located in a deep part of the Illinois basin. The average of the permeability values for this pool of the Cypress sand is 395 millidarcys, and the average deviation from the mean permeability is 59 per cent.

PATOKA POOL

Figure 16 (data from table 25) is a graph of results for Merryman well No. 1 which was cored in the Patoka pool of the Cypress sand. The average of the permeability values for this pool of the Cypress sand is 44 millidarcys and the average deviation from the mean permeability is 46 per cent.

Comparison of results may now be made between the various pools in the Cypress sand.

Results for the five shallow pools which are the Bartelso, Carlyle, Lawrence County, Louden, and Patoka pools show good agreement with the exception of the very high permeability value for the sample from Kirkwood well No. 13 in the Lawrence County pool. The average porosity of the eight shallow wells is 19.8 per cent, and their average permeability (omitting the sample from Kirkwood well No. 13 as not representative) is 122 millidarcys.

The core from Arbuthnot well No. 9 in the Noble pool, which came from a much deeper part of the basin, shows an average porosity of 15.1 per cent and an average permeability of 395 millidarcys. It is seen that the average porosity of the core from the Cypress sand in a deep part of the basin is considerably lower than the average porosity of the cores of this sand taken from the shallow wells, and that the average permeability of the core from the deep well is greater than that of the cores from the shallow wells.

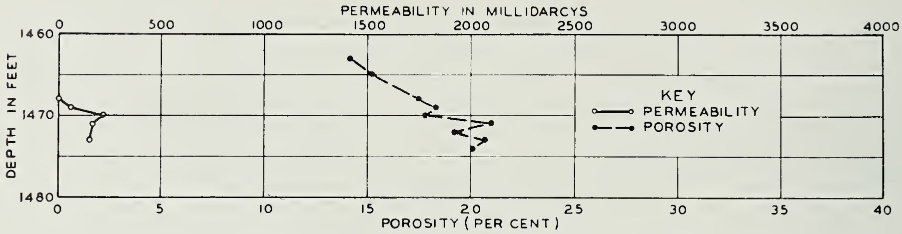

FIG. 17.—Bethel sand, Louden pool; Sinclair well No. 2 (table 26, p. 35).

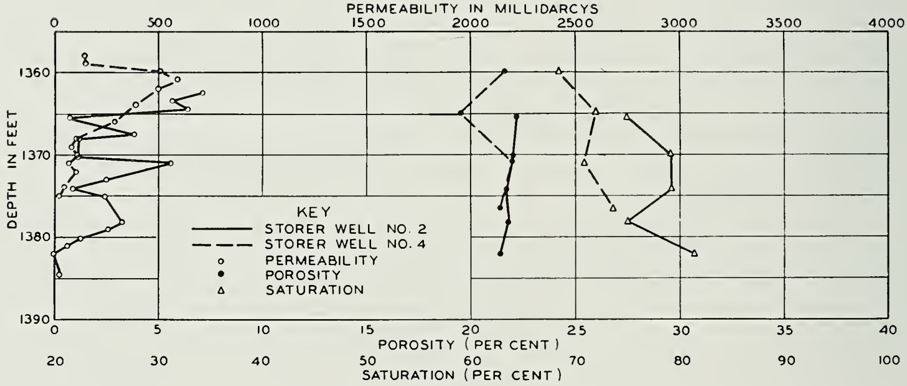

FIG. 18.—Bethel sand, Centralia pool; Storer wells No. 2 and No. 4 (tables 27 and 28, p. 36).

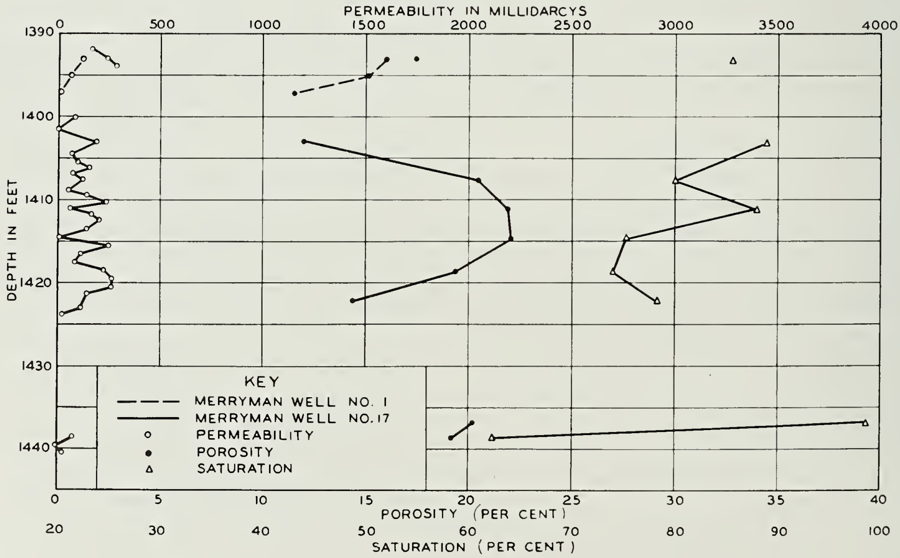

FIG. 19.—Bethel sand, Patoka pool; Merryman wells No. 1 and No. 17 (tables 29 and 30A, p. 37).

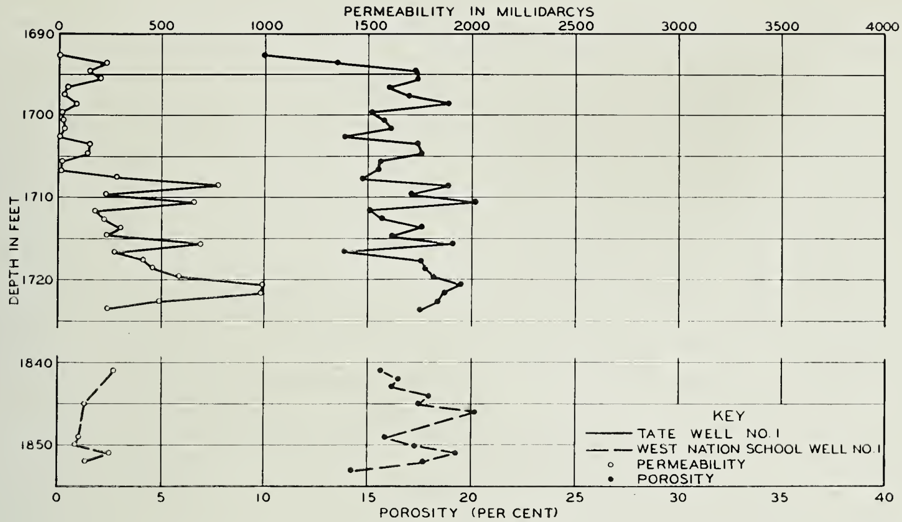

FIG. 20.—Bethel sand, Salem pool; Tate well No. 1 and West Nation School well No. 1 (tables 31 and 32, pp. 39–40).

Bethel sand

LOUDEN POOL

Figure 17 (data from table 26) is a graph of results for Sinclair well No. 2 which was cored in the Louden pool of the Bethel sand. The average of the permeability values for this pool of the Bethel sand is 125 millidarcys, and the average deviation from the mean permeability is 135 per cent.

CENTRALIA POOL

Figure 18 (data from tables 27 and 28) is a graph of results for Storer well No. 2 and Storer well No. 4 which were cored in the Centralia pool of the Bethel sand. The average of the permeability values for this pool of the Bethel sand is 247 millidarcys, and the average deviation from the mean permeability is 71 per cent.

PATOKA POOL

Figure 19 (data from tables 29 and 30) is a graph of results for Merryman well No. 1 and Merryman well No. 17 which were cored in the Patoka pool of the Bethel sand. The results of these two wells show excellent agreement. The average of the permeability values for this pool of the Bethel sand is 131 millidarcys, and the average deviation from the mean permeability is 50 per cent.

SALEM POOL

Figure 20 (data from tables 31 and 32) is a graph of results for Tate well No. 1 and West Nation School well No. 1 which were cored in the Salem pool of the Bethel sand. The average of the permeability values for this pool of the Bethel sand is 270 millidarcys, and the average deviation from the mean permeability is 58 per cent.

Good correspondence of results for the four pools in the Bethel sand is shown.

Aux Vases sand

SALEM POOL

Figure 21 (data from table 33) is a graph of results for Tate well No. 1 which was cored in the Salem pool of the Aux Vases sand. The average of the permeability values for this pool of the Aux Vases sand is 85 millidarcys, and the average deviation from the mean permeability is 82 per cent.

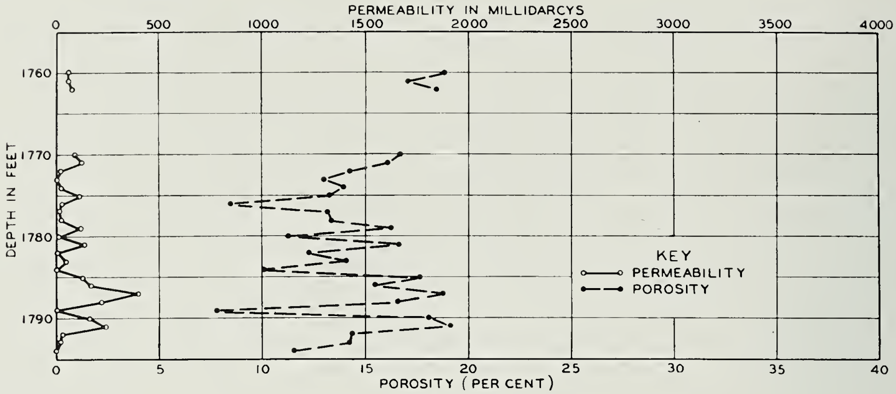

Fig. 21.—Aux Vases sand, Salem pool; Tate well No. 1 (table 33, p. 40).

McCLOSKY LIME

LAWRENCE COUNTY POOL

Figure 22 (data from tables 34 to 37 inclusive) is a graph of results for Christensen well No. 1, Christensen well No. 2, Kirkwood well No. 13 and Rogers well No. 14 which were cored in the Lawrence County pool of the McClosky lime. Inspection of this figure reveals that the Christensen well No. 1 has three very high permeability values, and that Kirkwood well No. 13 cut through a tight portion of the McClosky lime. The average of the permeability values for this pool of the McClosky lime is 332 millidarcys, and the average deviation from the mean permeability is 129 per cent.

NOBLE POOL

Figure 23 (data from tables 38 and 39) is a graph of results for Arbuthnot well No. 9 and Schilling well No. 1 which were cored in the Noble pool of the McClosky lime. These wells cut through the McClosky lime in a deep part of the Illinois basin. The average of the permeability values for this pool of the McClosky lime is 754 millidarcys, and the average deviation from the mean permeability is 99 per cent.

OLNEY POOL

Figure 24 (data from table 40) is a graph of results for Sager well No. 3 which was cored in the Olney pool of the McClosky lime. This well also represents the McClosky lime in a deep part of the Illinois basin. The average of the permeability values for this pool of the McClosky lime is 349 millidarcys, and the average deviation from the mean permeability is 95 per cent.

SALEM POOL

Figure 25 (data from table 41) is a graph of results for Tate well No. 1 which was cored in the Salem pool of the McClosky lime. The average of the permeability values for this pool of the McClosky lime is 176 millidarcys, and the average deviation from the mean permeability is 113 per cent.

Comparison of results for the four pools in the McClosky lime shows that the average of the porosity values for the five wells located in the two shallow pools, the Lawrence County, and Salem pools, which is 14.2 per cent, is greater than the average of the porosity values for the three wells located in the two deep pools, the Noble and Olney pools, which is 12.8 per cent. The average of the permeability values for the five shallow wells is 227 millidarcys as compared with the average permeability of 673 millidarcys for the three deep wells. These results indicate that the average porosity of the shallow wells is greater than that of the deep wells, and that the average permeability of the shallow wells is less than that of the deep wells in the McClosky lime. The behavior of these results for shallow and deep wells in the McClosky lime is similar to that of the results for shallow and deep wells in the Cypress sand.

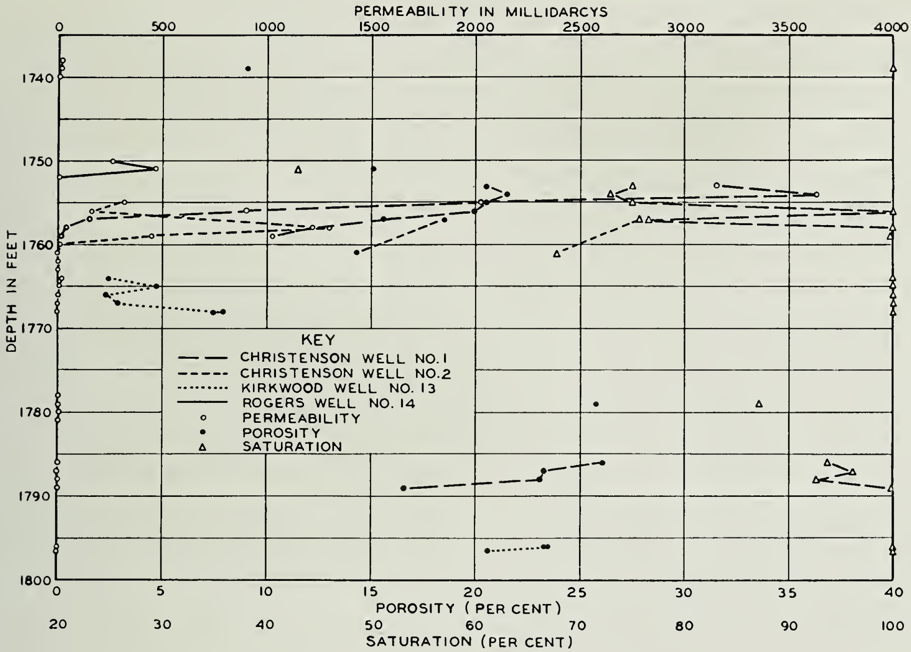

FIG. 22.—McClosky lime, Lawrence County pool; Christensen wells No. 1 and No. 2, Kirkwood well No. 13, and Rogers well No. 14 (tables 34, 35, 36 and 37, pp. 41–42).

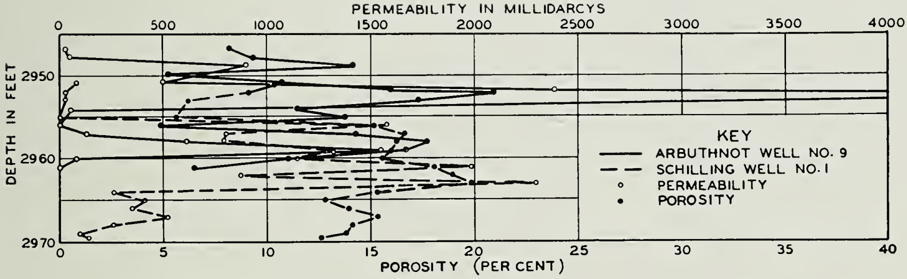

FIG. 23.—McClosky lime, Noble pool; Arbuthnot well No. 9 and Schilling well No. 1 (tables 38 and 39, p. 43).

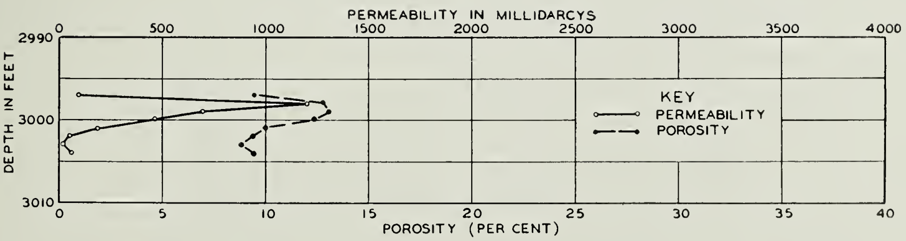

FIG. 24.—McClosky lime, Olney pool; Sager well No. 3 (table 40, p. 44).

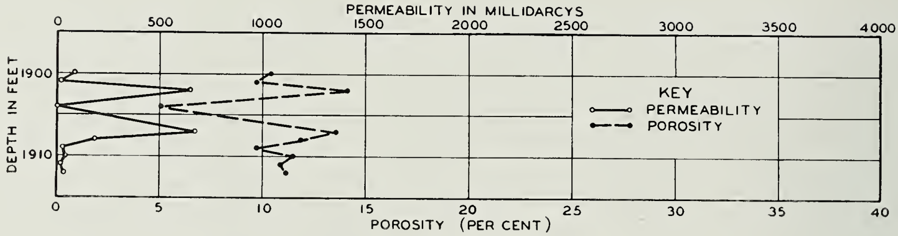

Fig. 25.—McClosky lime, Salem pool; Tate well No. 1 (table 41, p. 44).

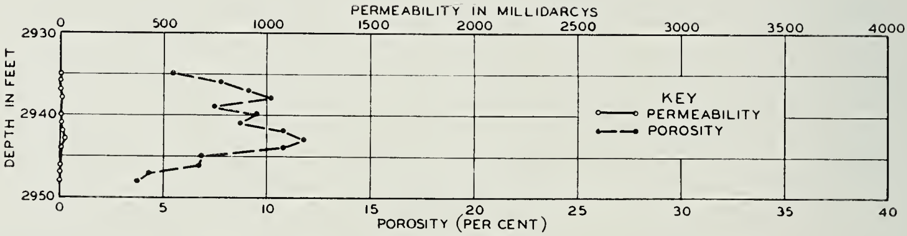

Fig. 26.—Niagaran lime, Crawford—Main pool; Athey well No. 1 (table 42, p. 45).

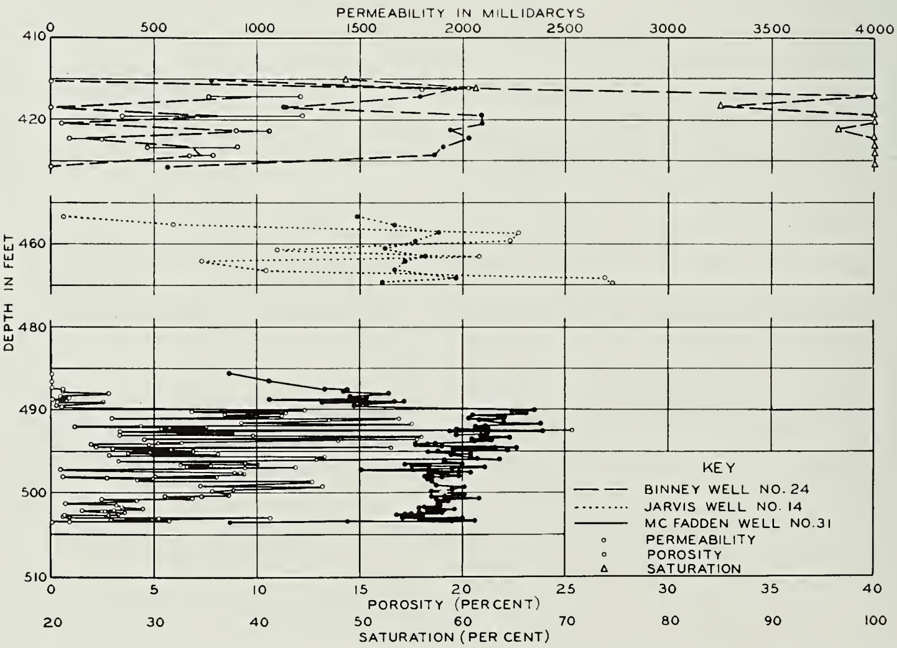

Fig. 27.—Hoing sand, Colmar—Plymouth pool; Binney well No. 24, Jarvis well No. 14, McFadden well No. 31 (tables 43, 44, 45A, pp. 46–47).

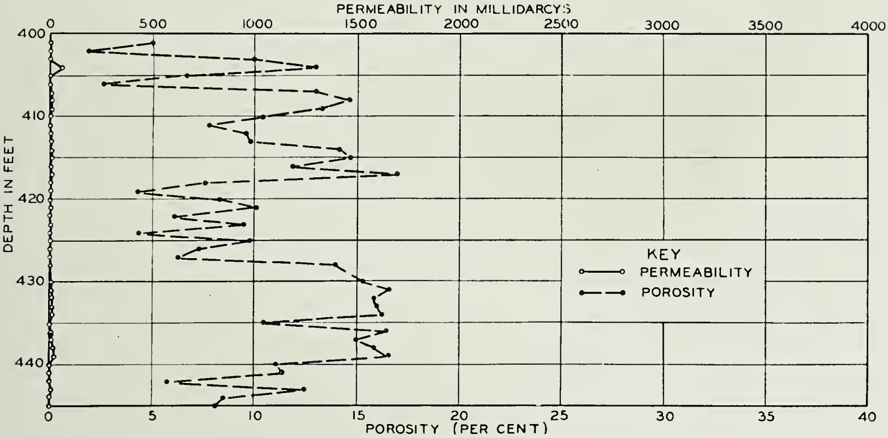

Fig. 28.—Kimmswick lime, Dupo pool; Dyroff well No. 27 (table 46, p. 49).

Niagaran lime

crawford—main pool

Figure 26 (data from table 42) is a graph of results for Athey well No. 1 which was cored in the Crawford—Main pool of the Niagaran lime. As previously stated, this well was a test hole and did not become a producer. The average of the permeability values for this pool of the Niagaran lime is 4.9 millidarcys, and the average deviation from the mean permeability is 49 per cent.

Hoing sand

colmar—plymouth pool

Figure 27 (data from tables 43 to 45 inclusive) is a graph of results for Binney well No. 24, Jarvis well No. 14 and McFadden well No. 31 which were cored in the Colmar—Plymouth pool of the Hoing sand. There is good agreement of results. The average of the permeability values for this pool of the Hoing sand is 683 millidarcys, and the average deviation from the mean permeability is 67 per cent.

Kimmswick lime

dupo pool

Figure 28 (data from table 46) is a graph of results for Dyroff well No. 27 which was cored in the Dupo pool of the Kimmswick lime. The average of the permeability values for this pool of the Kimmswick lime is 7.7 millidarcys, and the average deviation from the mean permeability is 93 per cent.

A comparison of results for the various sands shows that the average porosity of the wells cored in the Niagaran lime, the Biehl sand, and the Kimmswick lime, is lower than the average porosity for the other sands. The total liquid saturation is shown to be high for all the sands. The Hoing sand and the Niagaran lime have relatively high and relatively low permeability, respectively. The greatest variation in permeability occurs in the McClosky lime, which is characteristic of limestone oil sands.

The only cores available to the Survey, at the time this report was written, from the deeper part of the Illinois basin are from Arbuthnot well No. 9, Schilling well No. 1, and Sager well No. 3. These three cores showed relatively low porosity and very high permeability for the sands from deep wells as compared with results for the same sands from shallow wells.

Comparison of permeability results for Illinois oil sands with the permeability results for Bradford sand[8] shows that the average of the permeability values of Illinois oil sands investigated in this report,

[8]Fancher, G. H., Lewis, J. A., and Barnes, K. B., Min. Ind. Exp. Sta., Penn. State College Bull. 12, pp. 142–146, 1933.

which is 273 millidarcys, is considerably higher than the average permeability of Bradford sand which ranges from two to five millidarcys for representative samples.

The actual average permeability of any core is higher than the average of the permeability results herein reported. This is due to the fact that the core which was tested represented about 60 to 90 per cent complete recovery, and the portions of the sand which were broken up during the coring operation were undoubtedly more permeable than the samples which were recovered.

One of the features of a sand which makes it suitable for air repressuring or water flooding is fairly uniform permeability for various layers of the sand.

The sands studied in this investigation, listed in order of the uniformity of permeability of their cores are: Cypress, Niagaran, Hoing, Biehl, Bethel, Upper Partlow, Aux Vases, Robinson, Kimmswick, and McClosky. In this listing, the results for Madden well No. 9 in the Biehl sand have not been considered since it passed through a tight portion of the sand and did not become a producer. Also the one sample each from Lithurland well No. 9 in the Biehl sand and Kirkwood well No. 13 in the Cypress sand were not considered since they were not representative of the sands. The degree of uniformity of permeability of a sand is obtained by taking the average of the per cent average deviation from the mean permeability for the various pools in that sand. Small deviations indicate a high degree of uniformity and higher deviations indicate a lesser degree of uniformity of permeability.

Considerable variation is found among the different pools in the same sand. The average uniformity of permeability of the Robinson sand cores from the Crawford—Main pool places the Robinson sand from the Crawford—Main pool between the Biehl and Bethel sands in the above list, but the average uniformity of permeability of the Robinson sand cores from the Lawrence County, New Hebron, and Parker pools places the Robinson sand from these pools between the Kimmswick and McClosky limes.

Air and gas repressuring have proved successful in the Upper Partlow sand in the North Johnson pool, the Robinson sand in the Crawford—Main and the New Hebron pools, the Biehl sand in the Allendale pool, and the Hoing sand in the Colmar—Plymouth pool.

Natural water floods in the Cypress and Bethel sands and McClosky lime have resulted in increased production from these sands. Because of their uniformity of permeability with depth, the Cypress and Bethel sands should prove very amenable to the application of air and gas repressuring or controlled water flooding.

Comparison of Vertical with Horizontal Permeability

In order to show the comparison of vertical with horizontal permeability results for the different sands and pools, these results are plotted for each pool. The order of presentation is the same as that previously used, by sands and pools. The vertical permeability results and one set of horizontal permeability results were obtained from a 1-cm. cube test piece. The other sets of horizontal permeability results are those previously reported for the 1 by 1 by 2 cm. test pieces.

Robinson sand

Cores from the Crawford—Main pool and the Lawrence County pool in the Robinson sand were investigated for vertical and horizontal permeability.

Crawford—Main pool

The only core from the Crawford—Main pool of the Robinson sand which was tested for vertical and horizontal permeability was from the Henry well No. 14.

Figure 29 (data from table 47) is a graph of relative vertical and horizontal permeability results for Henry well No. 14. An inspection of this graph indicates that the ratio of horizontal to vertical permeability for this well is about 2:1.

Lawrence County pool

The only core from the Lawrence County pool of the Robinson sand which was tested for vertical and horizontal permeability was from Crump well No. 27.

Figure 30 (data from table 48) is a graph of relative vertical and horizontal permeability results for Crump well No. 27. Inspection of this graph reveals that the ratio of horizontal to vertical permeability for this well is about 3:2.

Comparison of figure 29 with figure 30 shows that the horizontal permeability is from one and one-half to two times the vertical permeability for the Robinson sand.

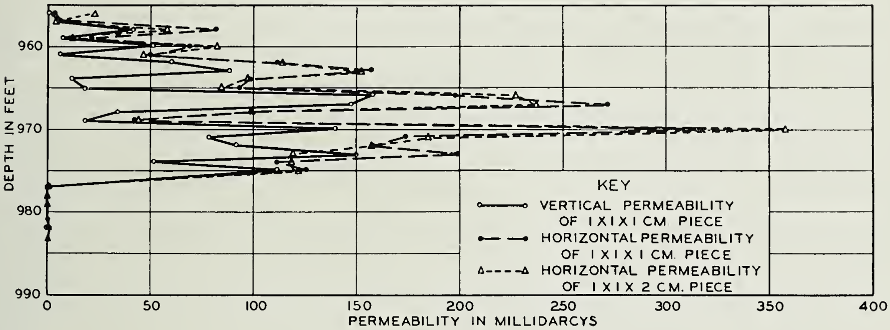

FIG. 29.—Robinson sand, Crawford—Main pool; Henry well No. 14 (table 47, p. 49).

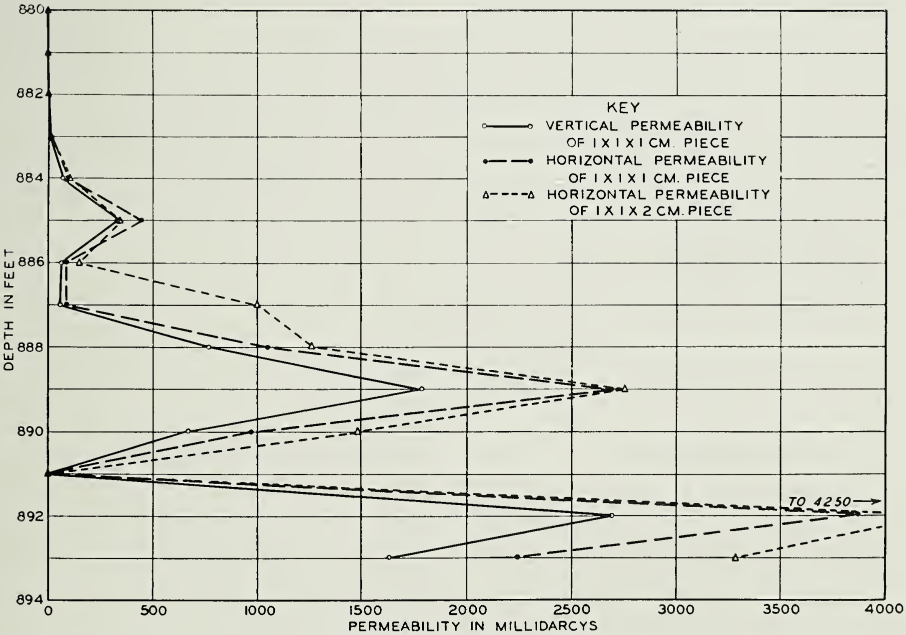

FIG. 30.—Robinson sand, Lawrence County pool; Crump well No. 27 (table 48, p. 50).

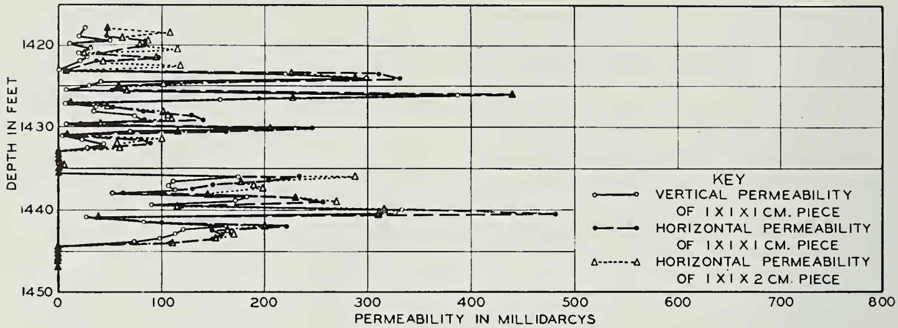

FIG. 31.—Biehl sand, Allendale pool; Madden well No. 10 (table 49, p. 50).

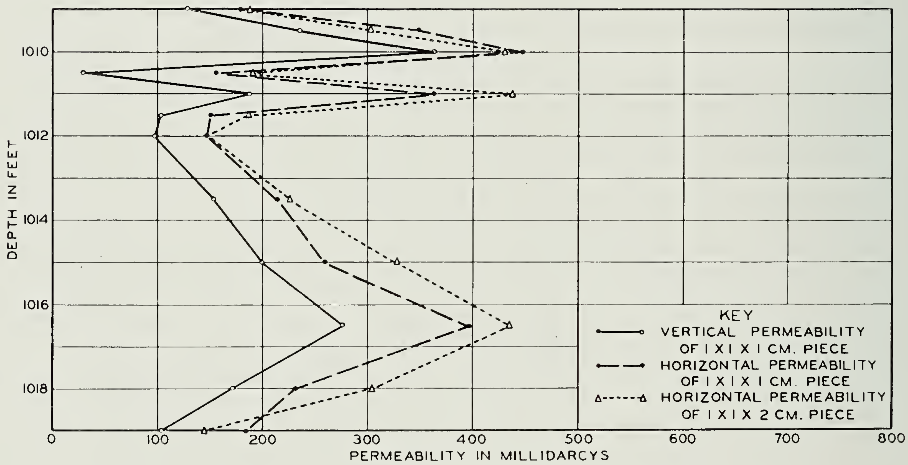

FIG. 32.—Cypress sand, Bartelso pool; Trame well No. 2 (table 50, p. 51).

BIEHL SAND

ALLENDALE POOL

The only core from the Biehl sand which was tested for relative vertical and horizontal permeability was from Madden well No. 10.

Figure 31 (data from table 49) is a graph of relative vertical and horizontal permeability results for Madden well No. 10. This graph shows that the ratio of horizontal to vertical permeability for this core from the Biehl sand is about 5:3.

CYPRESS SAND

BARTELSO POOL

The only core from the Cypress sand which was tested for relative vertical and horizontal permeability was from Trame well No. 2.

Figure 32 (data from table 50) is a graph of relative vertical and horizontal permeability results for Trame well No. 2. This graph shows that the ratio of horizontal to vertical permeability for the core from the Cypress sand is about 3:2.

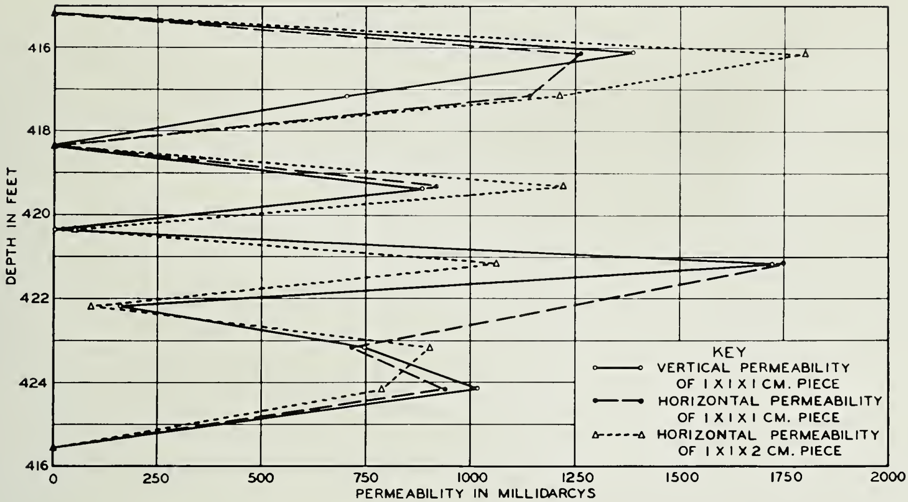

FIG. 33.—Hoing sand, Colmar—Plymouth pool; Binney well No. 24 (table 51, p. 51).

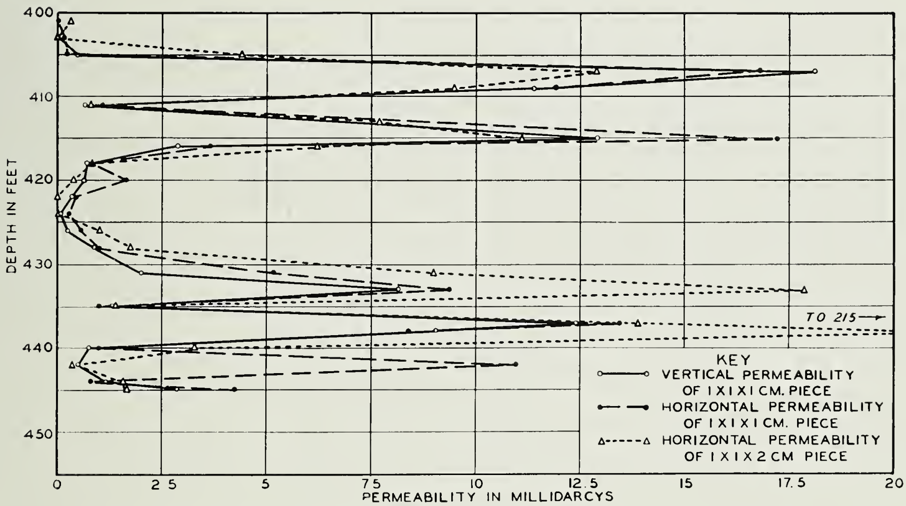

FIG. 34.—Kimmswick lime, Dupo pool; Dyroff well No. 27 (table 52, p. 51).

HOING SAND

COLMAR—PLYMOUTH POOL

The only core from the Hoing sand which was tested for relative vertical and horizontal permeability was from Binney well No. 24. Figure 33 (data from table 51) is a graph of relative vertical and horizontal permeability results for Binney well No. 24. This graph shows that on the average, the horizontal permeability is equal to the vertical permeability for this core from the Hoing sand.

KIMMSWICK LIME

DUPO POOL

The only core from the Kimmswick lime which was tested for relative vertical and horizontal permeability was from Dyroff well No. 27 in the Dupo pool.

Figure 34 (data from table 52) is a graph of relative vertical and horizontal permeability results for Dyroff well No. 27. This graph shows that, on the average, the horizontal permeability is equal to the verti-

Table 53.—Ratio of Horizontal to Vertical Permeability.
Summary of tables 47 to 52, inclusive

County	Pool	Name of "sand"	Well name and no.	Text figure no.	Text table no.	Ratio of horizontal to vertical perme-ability
Crawford	Crawford—Main	Robinson	Harry No. 14	29	47	2:1
Lawrence	Lawrence County	Robinson	Crump No. 27	30	48	3:2
Wabash	Allendale	Biehl	Madden No. 10	31	49	5:3
Clinton	Bartelso	Cypress	Trame No. 2	32	50	3:2
McDonough	Colmar—Plymouth	Hoing	Binney No. 24	33	51	1:1
St. Clair	Dupo	Kimmswick	Dyroff No. 27	34	52	1:1

cal permeability for the core from the Kimmswick lime.

Table 53 shows a summary of ratio of horizontal to vertical permeability for the six cores investigated.

Checks with Other Laboratories

In the course of this investigation, in addition to the test pieces calibrated for porosity and permeability by the U. S. Bureau of Mines, results were obtained for four cores, each of which was tested by one other laboratory and the Survey laboratory. These laboratories are: (1) U. S. Bureau of Mines laboratory, (2) Tide Water Laboratory, (3) Core Testing Laboratories, Inc., and (4) a "commercial laboratory".

In all instances, the Survey and the other laboratory used different samples. Thus it would be expected that at any depth there would be about the same variation in results between the two laboratories as that between adjacent samples tested by either laboratory.

U. S. BUREAU OF MINES

Figure 35 is a graph of comparative porosity results for McFadden well No. 31 as found by the U. S. Bureau of Mines and the Survey laboratory. The U. S. Bureau of Mines results are from four sets of two samples each; in all instances the two samples were taken from adjoining core biscuits. The U. S. Bureau of Mines made no permeability tests on samples from this core.

TIDE WATER LABORATORY

Figure 36 is a graph of comparative porosity and permeability results for Henry well No. 14 as found by the Tide Water Laboratory and the Survey laboratory.

CORE TESTING LABORATORIES, INC.

Figure 37 is a graph of comparative porosity and permeability results for Snyder well No. 6 as found by the Core Testing Laboratories, Inc., and the Survey laboratory. The Survey laboratory made porosity and permeability determinations on two adjacent samples from each sample tested. The values of permeability of these duplicate samples are so close that they cannot be distinguished from each other on this graph.

A "COMMERICAL LABORATORY"

Figure 38 is a graph of comparative porosity and permeability results for Merryman well No. 17 as found by a "commercial laboratory" and the Survey laboratory. On this graph, results for the lowest part of the sand are not included, since samples taken by the two laboratories from this portion of the core were not at approximately the same depths.

An inspection of the four graphs on check results shows that the agreement between the five laboratories is within experimental deviation found for results from two adjacent samples.

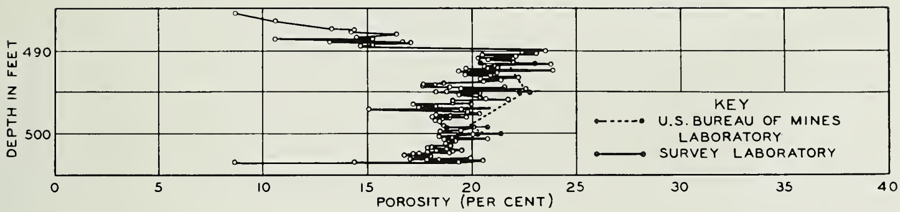

FIG. 35.—Comparative porosity results of U. S. Bureau of Mines and Survey laboratories for McFadden well No. 31. (Survey data from table 45A; Bur. of Mines data from table 45B, pp. 47–48).

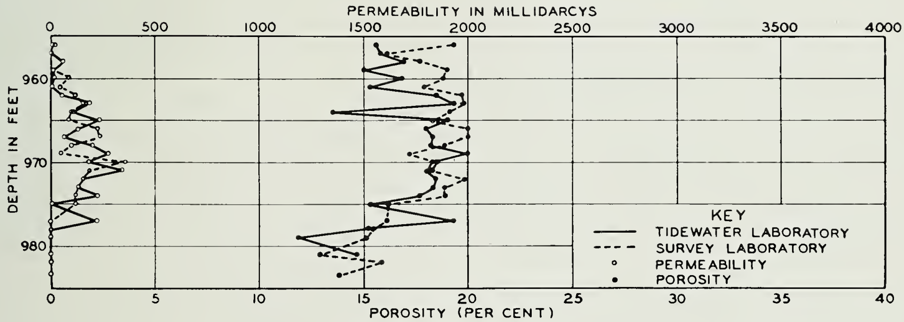

FIG. 36.—Comparative porosity and permeability results of tests by Tide Water Laboratory and Survey Laboratory for Henry well No. 14 (tables 6A and 6B, pp. 21–22).

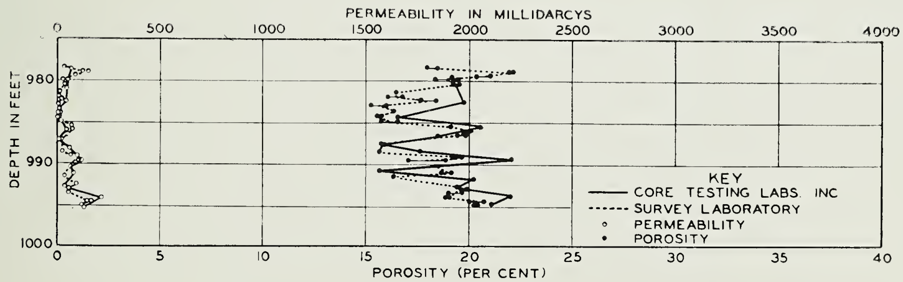

FIG. 37.—Comparative porosity and permeability results of tests by Core Testing Laboratories Inc. and Survey laboratory for Snyder well No. 6 (tables 7A and 7B, pp. 22–23).

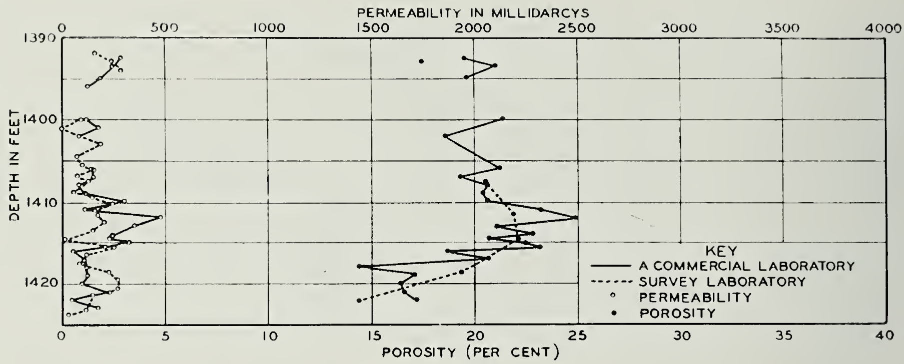

FIG. 38.—Comparative porosity and permeability results of tests by a "commercial laboratory" and Survey laboratories for Merryman well No. 17 (tables 30A and 30B, pp. 37–38).

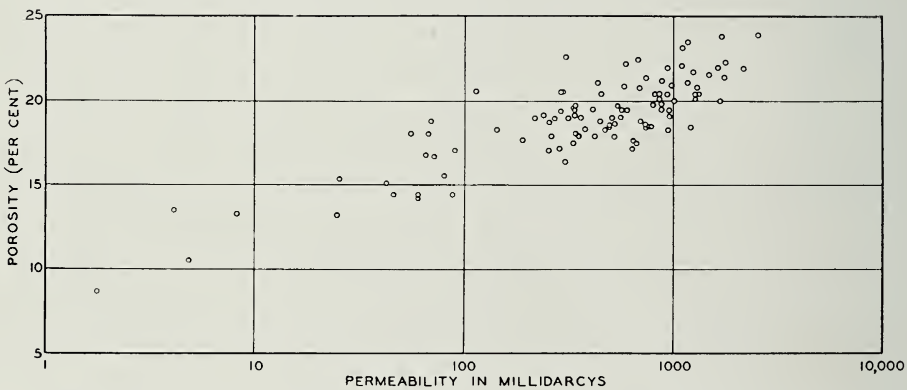

FIG. 39.—Relation of permeability to porosity for Hoing sand, Colmar—Plymouth pool; McFadden well No. 31 (table 45A, p. 47).

Relation of Permeability to Porosity

It has been reported previously that an approximate straight-line relationship exists between the porosity and the logarithm of the permeability of any one particular type of Illinois oil sand.[9] Figure 39 (data from table 45) is a graph which shows this relationship for samples from the McFadden well No. 31. An inspection of this graph shows some deviation from the linear relationship for the McFadden core. Even greater deviation is to be found among the results from sands of widely different grain sizes and various degrees of cementation.

The ratio of the average permeability to the average porosity for all the samples from the wells herein reported which were located in shallow parts of the Illinois basin is 14.7, whereas the ratio for all the samples from the three wells located in deeper parts of the basin is 51.6. The ratio of permeability to porosity for samples from wells located in the deeper parts of the basin is more than three times that for samples from wells located in the shallower parts of the basin. When more cores from the deeper parts of the Illinois basin become available for testing, this discrepancy between the permeability to porosity ratios for shallow and for deep wells can be further investigated to determine whether or not it is a general rule.

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[9]Piersol, R. J., Flow of fluids through oil sands: a paper presented at the Fourth Mineral Industries Conference of Illinois, April 24, 1936. Illinois Geol. Survey unpublished Mss.