STUDY OF ORDOVICIAN ROCKS FROM DEEP WELLS IN THE HILLSDALE, NORTHVILLE AND ADJACENT AREAS IN SOUTHEAST MICHIGAN

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STUDY OF ORDOVICIAN ROCKS FROM DEEP WELLS IN THE HILLSDALE, NORTHVILLE AND ADJACENT AREAS IN SOUTHEAST MICHIGAN

By

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ABSTRACT

A detailed study of the lithology of the pertinent wells in the Hillsdale, Northville and intervening areas along with the radioactivity log studies, has made possible a rather satisfactory correlation of the Middle and Lower Ordovician units throughout this area. The radioactivity logs were very helpful in showing composition differences and contacts which were difficult to establish on lithology alone.

During the study seven units were established to classify the interval from the top of the Trenton to the bottom of the Upper Cambrian sandstones. These were designated A to F. The assignments were also made in terms of the standard section, thus it is hoped that the subdivisions will be of aid in future subsurface studies.

The Trenton and Black River carbonates of this area are extremely important because of the present oil and gas production as well as the future possibilities they offer. The occurrence of dolomite and its relationship to oil production was found to be of primary significance throughout the area. The structure was found to control dolomitization, but the dolomite occurrence itself controlled oil production.

ACKNOWLEDGEMENTS

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INTRODUCTION

General

The accumulation of data and more extensive information concerning a producing field is extremely important to the geologic knowledge of an area. This information may be an aid to future exploration in other areas in the search of oil and gas.

This study of the Scipio, Northville and intermediate areas in southeastern Michigan is concerned mostly with the Middle Ordovician Trenton and Black River units. In a few deeper wells older rocks were studied. Secondary dolomitization occurring in portions of the Middle Ordovician carbonates of this area is of greater importance, economically, due to the oil and gas accumulation where the porosity is advantageous.

With each new well drilled in this area, more information is added to that already at the geologist's disposal. The completeness of the information available produces a direct effect on the percentage of successful wells drilled at a later time.

Purpose

The description of well cuttings, the knowledge of lithologic breaks and the information concerning structure and dolomitization are not complete in the area studied. Thus it is the intent of this study to add to the information already available.

It is also the intention of the study that detailed microscopic and radioactive log examination will establish good lithologic differentiation which will be of value to future exploration in Ordovician rocks of other areas of Michigan.

Locations

This subsurface study of the Middle Ordovician sediments was concerned with information gathered in Hillsdale, Washtenaw and Wayne Counties, located in the southeastern portion of the southern peninsula of Michigan. (Fig. 1)

The Scipio Field is located in Scipio Township, Hillsdale County, Township 3 West, Range 4 South, southeast of the hamlet of Mosherville. Wells have been drilled in sections 3, 4, 8, 9, 10, 11, 14, and 15 in this township.

The Northville Field is located at the juncture of Washtenaw and Wayne Counties, extending slightly into Oakland County, to the north. The northwest section of the field is in Salem Township, Washtenaw County, Township 1 South, Range 7 East. Wells are located in sections 1, 2, 3, and 12. The southeast portion of the field is located in Northville Township, Wayne County, Township 1 South,

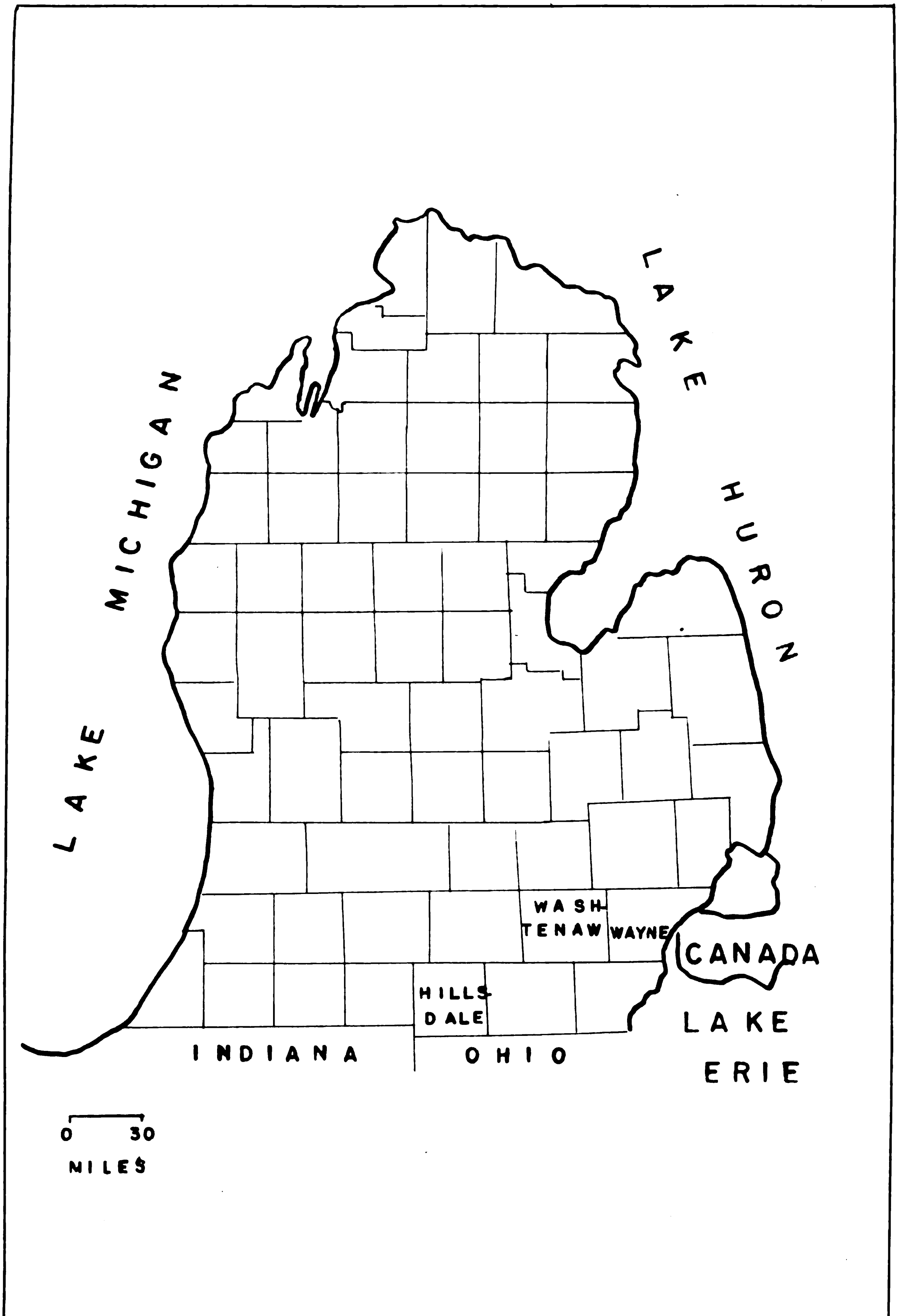

Figure 1. Location of Area In Michigan

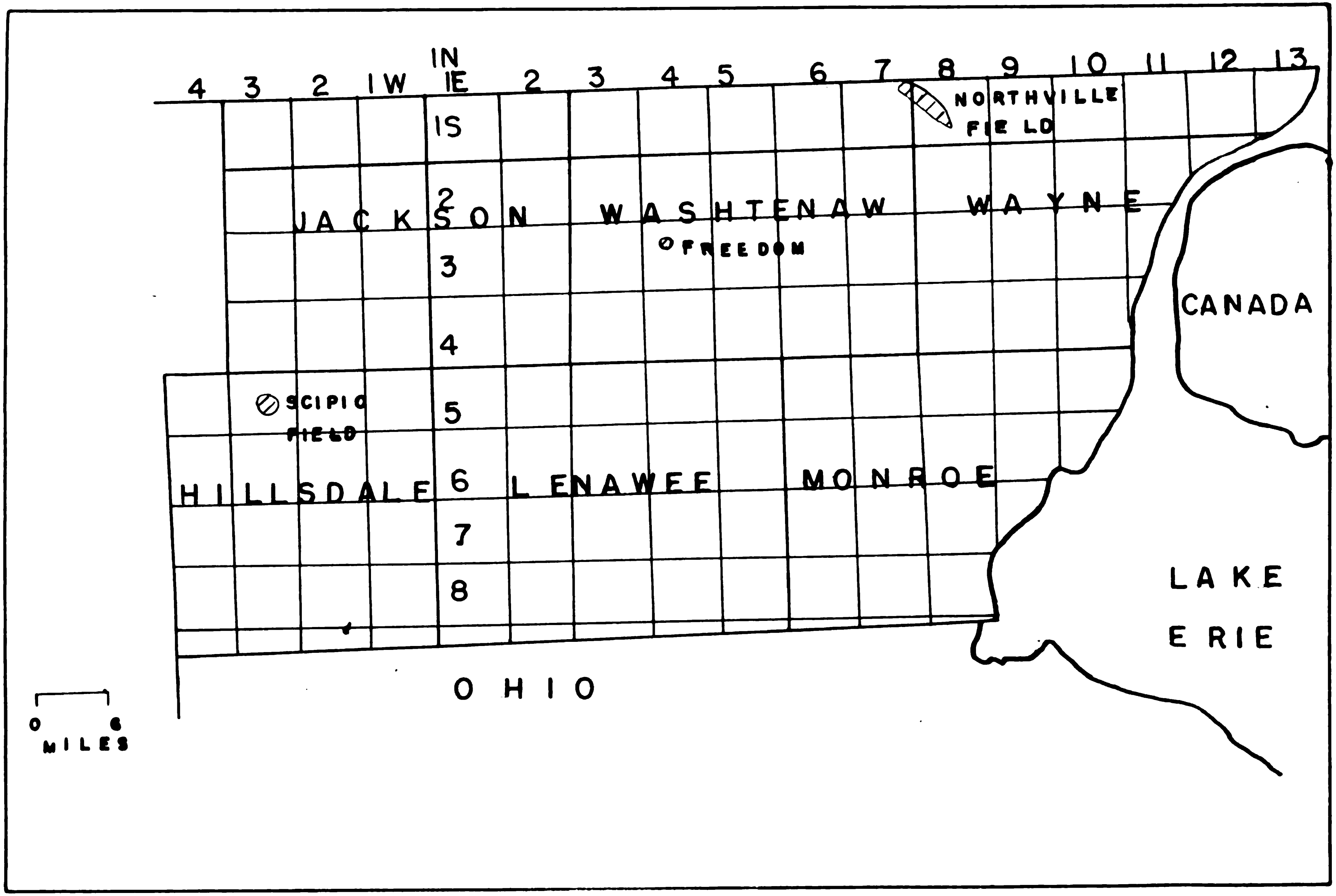

Figure 2. Locations of the Fields of the Study

Range 7 East, approximately 2½ miles west of the city of Northville. Wells are located in sections 4, 5, 6, 7, 8, 16, 17, 18, 21, 22, and 23.

Selected wells were also studied from intermediate locations in Washtenaw County.

The names and locations of the wells studied are found in The Inventory of Samples and may be located on the specific maps of the fields and intermediate areas. (Fig. 1 and Fig. 2)

Physiography

The surface features of the area of interest are largely glacial. Relief is slight with the topography gently undulating, due in part to occasional drumlins and eskers.

Average surface elevations in the Scipio area are from 1020 feet to 1130 feet above sea level; in the Northville area from 880 feet to 950 feet above sea level.

The land is devoted primarily to farming, on the small scale.

HISTORY AND DEVELOPMENT OF AREAS STUDIED

Production in both the Scipio and Northville Fields is quite recent and an interesting history is known for both fields.

Northville[1]

During the middle 1930's the presence of the Northville Anticline was realized by R. A. Smith, State Geologist of Michigan at that time. He mapped the Northville area as an extension of the Howell Anticline of Livingstone County. Certain fault patterns were noted. The area was not investigated in detail though it's potentialities structurally were evident from gravity surveys and maps.

Operations were begun in 1937 on the Kehrl #1 well, financed by a Mrs. Brown. Gas was found but the owners had some financial trouble and the well was plugged, rather than receive a loss.

Thus the field remained unexploited until January 15, 1954, when W. C. Taggart drilled in the LeMaster #1, near Northville, about 18 miles northwest of Detroit. This discovery well became the most prolific producer in the entire Northville field. A restrictive gage was used on the well and it has produced a minimum of 200 barrels of oil per day.

Production is from the Trenton-Black River rocks from a depth of 4397 feet. The well is located only 2000 feet from the Kehrl well, which was 200 feet higher structurally on the top of the Trenton.

Geologists, engineers, and operators were confronted with a very difficult task in answering many questions concerning the production of the field due to the variability of the pay. Offsets to good wells were found to be dry in many places. Many theories developed to explain the field. The tendency was to try to drill along the dolomitization zone, where possible to predict.

Both oil and gas wells are found in the area and the extent of the resources seem to be quite well established at this time. As to future plans, the city of Detroit hopes to turn the Northville field into a gas storage reservoir for the city's gas reserves.

Scipio[1]

As a result of a gravity survey an anomaly was established in Scipio Township, Hillsdale County. It is located in the north central part of the county about 25 miles north of the Indiana line (Fig. 1). Aurora-McClure Company leased the gravity highs while C. A. Perry obtained leases on the gravity lows.

Perry's Houseknecht #1 (Nw¼, SE¼, NE¼ Section 10), was spudded in May of 1955 on a non-technical location between two gravity highs. The first show of gas was reported at a depth of 3650 feet in the Trenton in September of 1956. It was not until January, 1957 that oil was encountered, at 3776 feet. Increases in oil were recorded all the way to the total depth but high pressures along with four-inch cable tools hindered drilling and the well bottomed at 3900 feet. The well produces 2.5 to 10 barrels of oil per hour and gas between 2 and 5 million cubic feet per day. Before the completion of the discovery well, a 20-acre spacing had been established and another well completed.

The fourth well to be drilled in the area, Aurora and McClure's Stevens #1 (SE¼, SW¼, NE¼ Section 10), lost circulation at 3770 feet and blew out of control for 25 hours. The well was shut in when the zone was encountered, but the surface began to crater under the pressure. In order to save the drilling rig it was necessary to open the well. It was estimated that 4000 barrels of oil and 15 million cubic feet of gas were produced during this 25 hour period. The well was successfully shut in with salt water, and 5-inch casing was run with initial tests showing 2410 barrels of oil per day. Production was later reduced to 150 barrels per day.

Development proceeded slowly with the completion of several good wells. In March of 1958 Aurora and McClure's Haven #1 (NE¼, NW¼, Section 14) blew out of control for seven hours but was brought under control upon correction of mechanical difficulties. The test was later deepened to 3950 feet and completed for 150 barrels of oil per day, with a gas-oil ratio of 311.

At the present time the field is about 1½ miles long and ½ mile wide trending in a northwest-southeast direction. The northwest or southeast limits of the pool have not as yet been established.

Production is being obtained from the Middle Ordovician Trenton-Black River rocks at a depth of between 3770 and 3950 feet. Pays are in secondary dolomite and confined to a fracture zone. The nearest previous Trenton production was located about 40 miles to the northeast in the now-abandoned Freedom Pool of Washtenaw County.

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1. Information concerning the history and development of the Scipio and Northville Fields was obtained from personal communication with G. D. Ells and R. E. Ives of the Petroleum Section of the Michigan Geological Survey.

INVENTORY OF SAMPLES USED IN EXAMINATION

Hillsdale County

Permit No.	Operator	Well Name	Location
20422	Aurora & McClure	Rowe #1	SE¼,NW¼,NE¼, Sec. 10 T.5S,R.3W.
20674	Clifford A. Perry	Hornczi & Huraczy #1	NW¼,NW¼,SE¼, Sec. 10 T.5S,R.3W.
20733	Aurora & McClure	Barnett #1	SE¼,NE¼,SW¼, Sec. 10 T.5S,R.3W.
20776	Olen D. Sharp	Fowler #1	SE¼,NE¼,NE¼, Sec. 3 T.5S,R.3W.
20676	Aurora & McClure	Stephens #1	SE¼,SW¼,NE¼, Sec. 10 T.5S,R.3W.
20851	Adolph E. Rovsek	Daugherty et al #1	SE¼,SW¼,SW¼, Sec. 11 T.5S,R.3W.
20773	Dee Drilling Co.	Domack #1	NW¼,SE¼,NE¼, Sec. 15 T.5S,R.3W.
20748	Clifford A. Perry	Nelligan #1	SE¼,SE¼,NE¼, Sec. 9 T.5S,R.3W.
19607	Clifford A. Perry	Ferne Housnecht #1	NW¼,SE¼,NE¼, Sec. 10 T.5S,R.3W.
20787	Perry Fulk	Van Wert #1	SE¼,NE¼,NW¼, Sec. 8 T.5S,R.3W.
20890	Adolph E. Rovsek	Karr et al #1	NW¼,NE¼,NE¼, Sec. 14 T.5S,R.3W.
20703	Clifford A. Perry	Martin #1	NW¼,SW¼,NW¼, Sec. 11 T.5S,R.3W.

Jackson County

Permit No.	Operator	Well Name	Location
19359	Aurora & McClure	Kintigh #1	NE¼,NE¼,SE¼, Sec. 20 T.3S,R.3W.
19444	Taggert Co.	Watkins Farms #1	SE¼,SW¼,SE¼, Sec. 13 T.4S.R.3W.

Washtenaw County

Permit No.	Operator	Well Name	Location
18983	Sun Oil Co.	Niehaus #1	SW, NE¼, SW¼,Sec. 8 T.3S.R.4E.
18796	Taggert Co.	LeMaster #1	NW¼,SE¼,SE¼, Sec. 1 T.1S.R.7E.
19231	Sun Oil Co.	Buss, Haab #1	SW¼,SE¼,NW¼, Sec. 8 T.3S.R.4E.
19608	Sun Oil Co.	Haab-Grau-Buss #1	SW¼,NW¼,SW¼, Sec. 8,T.3S.R.4E.
18968	Evans Oil Co.	Merritt #1	NW¼,NW¼,SW¼, Sec. 1 T.1S.R.7E.
10792	I. C. Chamnes	Troy-Roddenberry #1	NE¼,SE¼,NE¼, Sec. 27 T.1S.R.7E.

Wayne County

19541	Consumer's Power	Unit 21-A	NE¼,NW¼,NW¼, Sec. 21, T.1S,R.7E.
19201	Consumer's Power	Terril et al #1	SW¼,NE¼,SW¼, Sec. 7, T.1S,R.7E.
19496	Consumer's Power	Detroit House of Corr.#3	SW¼,NE¼,SE¼, Sec. 17, T.1S,R.8E.
20794	C. & O. R.R.	C. & O. #1	SW¼,NW¼,SW¼, Sec. 23, T.1S,R.8E.
19421	Consumer's Power	County of Wayne #1	NE¼,SW¼,SW¼, Sec. 16, T.1S,R.8E.
19348	Sun Oil Co.	Maybury Sanitorium #1	SE¼,SE¼,SW¼, Sec. 6, T.1S,R.8E.

LABORATORY METHODS

Samples

The samples used in this study were obtained from two sources, the State Geological Survey in Lansing, Michigan (the principle source) and the collection donated to Michigan State University by the Gulf Oil Company. A complete inventory of samples used in this study is found in Table 1.

Examination

Methods of examination and recording were established before beginning the microscopic examination. This consisted of making a standard sheet listing in separate columns such pertinent data as texture, color, porosity, composition, presence of chert or other minerals, oolites, laminations and other relative characteristics. With these standards in mind, the extensive microscopic examination began with a detailed study of each sample.

The equipment used during the study is as follows:

1. Binocular microscope-ranging in power from 9x to 36x.
2. Porcelain dish (12 depressions)
3. Scoop tray
4. Small pair of forceps
5. (00) Small watercolor brush

6. Steel needle
7. 6 Normal hydrochloric acid
8. Small beaker (for water)
9. Table lamp
10. Small magnet

With this equipment each sample was examined to determine the various properties which would describe it thoroughly.

A small horseshoe magnet was used to determine whether the sample possessed magnetism or impurities from the drilling operation. A paper between the sample and the magnet prevented the magnetic particles from collecting on the magnet.

The samples were readied for microscopic study by being spread evenly on the scoop tray under reflected light. The majority of the study was performed under the magnification of 9x to 12x. If necessary, for finer inspection, the oculars were changed to increase the magnification to 27x.

To establish the hardness of a sample it was necessary to remove the sample from the tray with forceps and test it with a steel needle.

To test the approximate calcium-magnesium composition of the carbonate samples, a twelve-hole porcelain plate had each hole filled with about 1.16 ml. of water, into which the sample was placed with either the forceps or the (oo) small watercolor brush. After the sample had been immersed in the water, one drop of 6N hydrochloric acid was placed in the water. From the reaction which occurred the composition of the sample was estimated. If a violent effervescence took place the sample was called a limestone. By the degree of violence of the reaction the percentage of calcium present was inferred. If a reaction did not occur with the addition of one drop of acid, the concentrate of the solution was increased by the addition of more acid, a drop at a time. If a slight reaction began to take place, the sample was called a dolomite.

From this point the sample received intense microscopic study to determine the other characteristics which it might possess. A standard was set to describe these visual properties based on a reduction of Low's <u>Examination of Well Cuttings</u> (1951). The descriptions were based on color, grain, size, shape, and accessories.

A. Carbonate rocks (dolomite and limestone)

1. Color - brown, gray, white, buff, tan, pink

2. Grain size or crystallinity

a. Coarse crystalline ... over 2.00mm
b. Medium crystalline ... .25 to 2.00mm
c. Fine crystalline ..... .05 to .25mm
d. Very fine crystalline. below .05mm

3. Porosity (if present)
   a. Vuggy
   b. Interstitial
   c. Tubular to cavernous
   d. Pinpoint

4. Composition - shaley, sandy, fossiliferous

B. Fine clastic rocks (shale)

1. Colors - gray, brown, black

2. Composition - dolomitic or calcareous

3. Induration - degree of stability

C. Coarse-medium clastic rocks (sandstones)

1. Colors - red, white, pink, etc.

2. Grain size

   a. Course .... above ½mm
   b. Medium .... ¼-½mm
   c. Fine ...... below ¼mm

3. Grain shape

   a. Sharp-sharp edges (conchoidal)
   b. Angular
   c. Subangular
   d. Rounded
   e. Globular

D. Miscellaneous minerals such as pyrite, glauconite, chert and gypsum were recorded when they occurred.

The description of the sample was recorded on the previously constructed data sheet following each examination. Each well was finished and then the formational breaks and lithologic separations were made, based on the information from the study.

Radioactivity Logs

Radioactivity logs, where available, were used hand in hand with the microscopic descriptions of the samples. At least formational contacts would be very difficult to pick without the use of radioactivity logs. These logs were studied and reproduced from the logs of the Michigan State Geological Survey. Some logs were also obtained from the Michigan Well Log Service, Mount Pleasant, Michigan. The logs proved to be of much value during the interpretations.

A radioactivity log consists of two curves, a gamma-ray curve (left column) and a neutron curve (right column). The gamma-ray curve is a relative measurement of the natural radioactivity occurring in the strata. Measurable quantities are found in all kinds of igneous, metamorphic, and sedimentary rocks. Figure 3 demonstrates the relative radioactivity values of various formations encountered in well logging. Anhydrite, salt, and coal are very low in radioactivity, while shale, bentonite, ash and organic shale have the highest values of radioactivity. Producing formations such as sand, limestone and dolomite are relatively low in radioactivity.

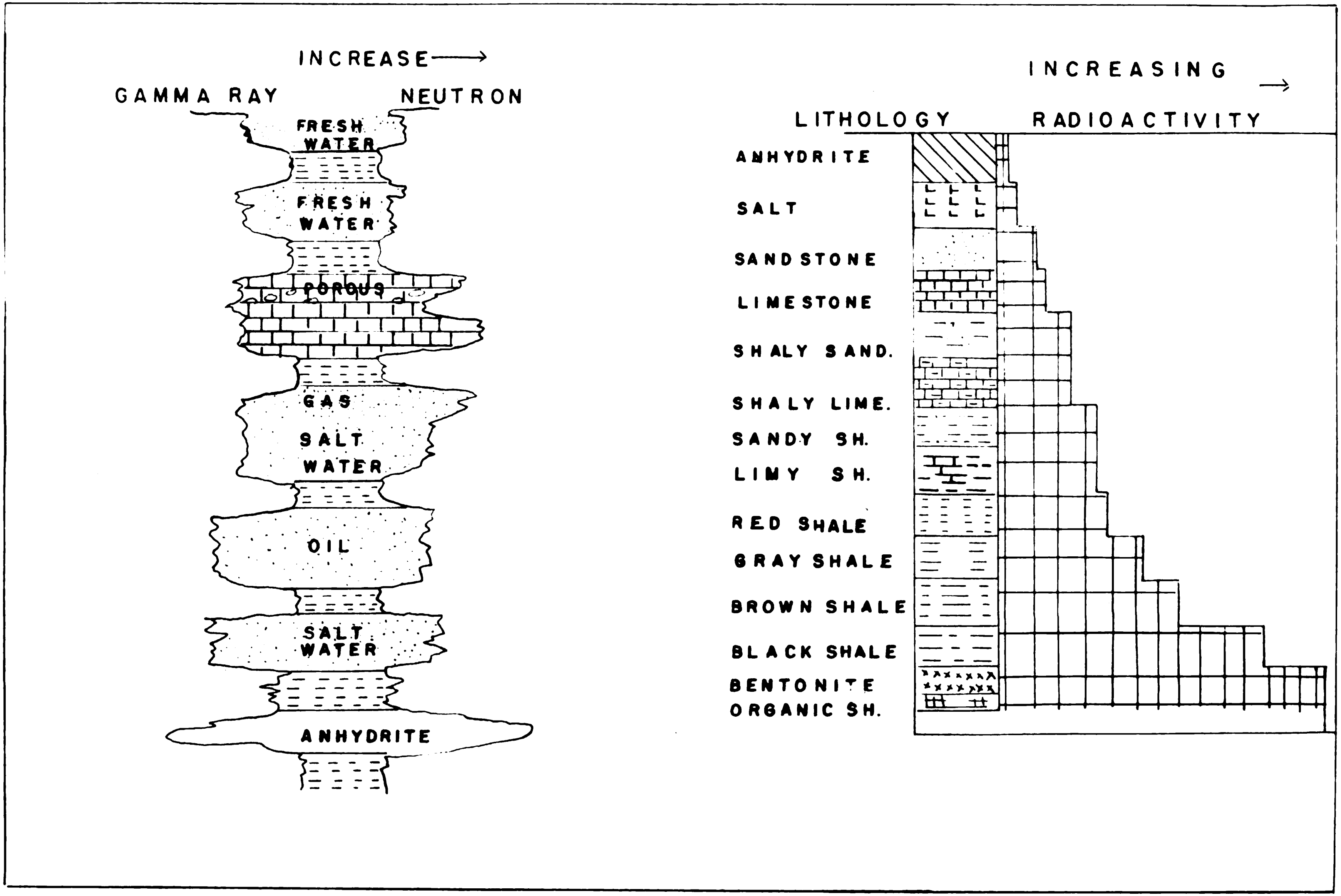

Figure 3. Idealized Radioactivity Log Reactions (After Julian Low).

The neutron curve might well be referred to as a "fluid content or hydrogen curve", since hydrogen is the controlling factor on the behavior of the curve. Neutron well logging is the process of bombarding the strata with a strong source of fast moving neutrons and recording the secondary gamma-rays that have been excited by the neutron bombardment. Where hydrogen is present in the strata, the neutrons are slowed down or stopped, and this in turn gives a low reading on the curve. Where there is little or no hydrogen present the reading is high. It matters not in what form the hydrogen occurs, whether gas, oil, water or shale, the curve is characterized by a low reading. However, the neutron curve used in combination with the gamma-ray can be interpreted to locate possible porous zones in producing strata very accurately. A working knowledge of the local stratigraphy is necessary for the correct geologic interpretation of the gamma-ray log. Figure 3 shows the idealized reaction of the gamma-ray and neutron curve to certain conditions.

Advantages of the radioactivity well log over other methods include its ability to log through steel casing. Thus old wells and fields may be studied and additional information gained. Other advantages are its ability to locate casing, establishing cementing effectiveness, and the fact that it may be used to log in holes with salt and oil base muds. Disadvantages are that neither oil and water nor limestone and sandstone can be distinguished. Also, regional coverage by radioactivity logs is not complete.

This is but a brief analysis of radioactivity logging; a more complete description may be found in LeRoy's *Subsurface Geologic Methods* (pp. 419 to 436).

STRATIGRAPHY

During this study, the names used in nearby wells were also used in defining and identifying these particular lithologic horizons. The depths of the wells in the Hillsdale and Northville sections varied considerably due to the tendency to abandon drilling operations upon contacting oil in comparative abundance in a particular stratum, thereby capitalizing on the production. If shallower horizons proved dry drilling operations continued to greater depth with the hope of production and to gain information on the deeper rocks.

This lack of constancy in well depths in the area studied makes the drawing of isopach maps difficult for lack of acceptable control. It was possible, however, to draw the isopach maps (Fig. 6) for the Trenton in the Scipio Field, but the control is a bit implied in the central productive portion of the field where the entire thickness of the Trenton was not tested. Proper control could not be established in the Northville Field for an isopach map.

The Appendix of this paper contains the microscopic descriptions of certain wells selected from the study to better exemplify the lithology and the variation in well

System-Series			Group	Formation	Zones of Report
ORDOVICIAN	Cincinnatian		Richmond	Queenston	
				Big Hill	
				Stonington	
				Bill's Creek	
			Maysville-Eden	Lorraine	
				Utica	
				Collingwood	
	Mohawkian		Trenton	Trenton	A Zone B Zone
			Black River	Black River	C Zone D Zone
			Chazyan	Stones River	D_1 Zone
				Glenwood	
				St. Peter	
	Canadian	Hermansville	Prairie du Chien	Shakopee	
				New Richmond	
				Oneota	
CAMBRIAN	St. Croixan		Trempealeau	Jordan	E Zone
				Lodi	
				St. Lawrence	
		Lake Superior Sandstone	Munising	Franconia	F Zone
				Dresbach	
				Eau Clair	
				Mount Simon	
				Jacobsville	

Figure 4. The Cambrian-Ordovician Column of Michigan (compiled from several sources).

depths, throughout these fields. These well descriptions show the lithology from the top of the Trenton to the bottom of the hole. Figure 4 shows the idealized Michigan Column for the Cambrian and Ordovician which can serve as a standard for this area. The following describes the composite lithology found in the wells, using the established names. In a later section of this paper descriptive zones have been established to better facilitate work in these rocks.

Upper Ordovician

The Upper Ordovician, Cincinnatian, rocks of the Scipio, Northville and intermediate area in southeastern Michigan are predominantly composed of shale. In this area, this shale is divided into the Queenston, Lorraine, and Utica shales in descending order.

The Queenston shale, which is from 110 to 200 feet thick in this area, consists of light gray to gray shale, calcareous in part with red shale and some limestone and dolomite interbedded. In most of the samples the base of the Queenston is a red shale.

The Lorraine shale consists of gray to dark gray calcareous shale and thin beds of limestone and dolomite, in this area. The thickness varies from 290 to 390 feet.

The underlying Utica shale is very dark gray to black and non-calcareous. The Utica appears more calcareous to the north and more difficult to separate from the Lorraine. Thickness varies from 150 to 200 feet.

In discussing this interval of Upper Ordovician shales, the three formations are usually grouped together and referred to as the Cincinnatian shales.

Middle Ordovician

The Middle Ordovician rocks of the Scipio and Northville are the Trenton and Black River limestones. The rocks, in general, are brown to gray limestone with minor amounts of argillaceous limestone, shale, and dolomite. The Trenton varies in thickness from about 330 to 420 feet.

In all the wells studied in this area, a few feet of dolomite may be found at the top of the Trenton. The general composition of the remainder of the Trenton is dependent upon the conditions which the rocks underwent in the particular area. In certain wells, the lithology is predominantly a secondary dolomite. It is also evident that the Black River has usually been dolomitized where the Trenton is largely dolomite. Where the Black River is a limestone it is generally fine crystalline buff brown in color. The boundary between the Trenton and the Black River is quite difficult to pick from the cuttings, but the argillaceous limestone at the base of the Trenton may be picked readily from the radioactivity logs.

In a few wells (see Barnett #1) an impure dolomitic, brown sandstone was found. It is in the same stratigraphic position as the Glenwood shale of Iowa, Wisconsin and Illinois (Cohee, 1947), though it may not be the same time equivalent. Thus this lowest of the Middle Ordovician rocks has been called the Glenwood. It occurs only infrequently in this area. The Glenwood seems to be largely sandy where overlying the St. Peter, rather than dolomitic.

Lower Ordovician[2]

The Lower Ordovician is generally absent in the Scipio and Northville areas. The St. Peter sandstone and the Prairie du Chien group comprise the Lower Ordovician, when present. The St. Peter is a white, medium to coarse sandstone with well rounded grains. The Prairie du Chien group consists of buff to light brown dolomite, with chert. Much of the chert is oolitic. It was inferred that the St. Peter sandstone was present in the Barnett #1, due to the oolitic dolomite, which was underlying the rather impure sandstone.

Cambrian

The wells which drilled into the Cambrian are quite infrequent, but those that did encountered the Trempealeau, Franconia, Dresbach, Eau Claire and Mt. Simon formations in descending sequence, all of Upper Cambrian age.

The Trempealeau formation, which underlies the Black River formation in many locations is a gray, white or pink dolomite with dark shale and white-gray glauconitic sandstone in the top 175 feet. Underlying this is approximately 150 feet of pinkish-white crystalline dolomite. Beneath this the remainder of the Trempealeau is glauconitic, dolomitic sandstone and a predominant sandy dolomite lithology. The base of the Trempealeau dolomite is quite glauconitic. The Trempealeau is about 500 feet thick in this section.

Underlying the Trempealeau formation in some locations is the Franconia sandstone. It is a fine to medium-grained, glauconitic, dolomitic sandstone. The quartz grains are frosted and pitted. If present the thickness of the Franconia is less than 15 feet.

The Dresbach sandstone, where it is present, consists of fine to medium, angular to rounded, frosted and pitted quartz grains. It is between 60 and 100 feet thick. Sometimes white dolomit occurs in thin beds, in parts of the Dresbach.

The Upper Cambrian Eau Claire sandstone in the area of interest consists of dolomite and dolomitic sandstone. The upper 30 or 40 feet is glauconitic, pink, brown, gray, dolomite. The lower part of the Eau Claire is dolomitic sandstone with some glauconite. The Eau Claire is from 200 to 260 feet thick.

Beneath the Eau Claire formation, the Mt. Simon sandstone consists of fine to medium, angular to rounded quartz grains. Most of the lower sand stone is pink or brown in color. The Mt. Simon is usually over 200 feet in thickness. The separation between the Eau Claire and the Mt. Simon is difficult to establish. Some dolomite occurs in the upper part of the Mt. Simon. The Mt. Simon overlies granite.

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2. George V. Cohee (1947)

STRUCTURE

The structure of the Trenton in the Scipio Field is shown in Figure 5. It is a small syncline trending in a northwest-southeast direction. The local distribution of the dolomite nearer the axis of the syncline (Fig. 8) would infer fracturing or faulting to have played a part in offering channelways for magnesium bearing salts for the dolomitization. The occurrence of oil is coincident with the presence of dolomite and porosity in the well. The eastern, western and southern extent of the dolomite in the Scipio Field have been determined by the dry holes found on the flanks of the syncline, which are in limestone. The northern extent of the field has not been completely determined.

The isopach map (Fig. 6) does not show much thickening of the Trenton, with an overall variance of approximately 20 feet.

Figure 7 is a structure contour map drawn on the top of the Trenton group for the Northville Field. It shows the Northville anticline with a northwest-southeast trend. The trend of production is also along the anticline in a zone of dolomitization. The dolomitization seems to have occurred here also along faults and fractures, producing the porosity present in certain wells. The extent of this

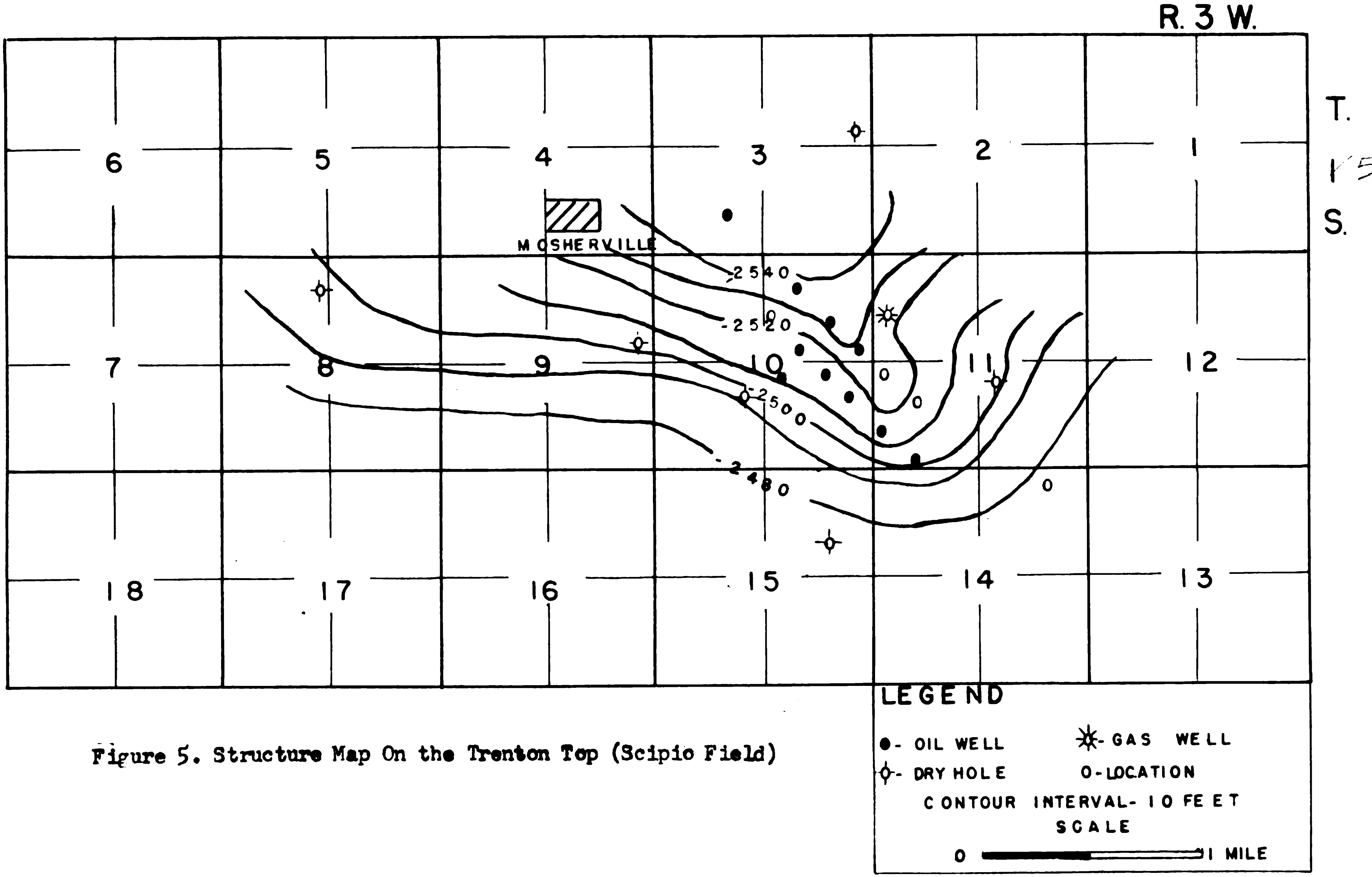

Figure 5. Structure Map On the Trenton Top (Scipio Field)

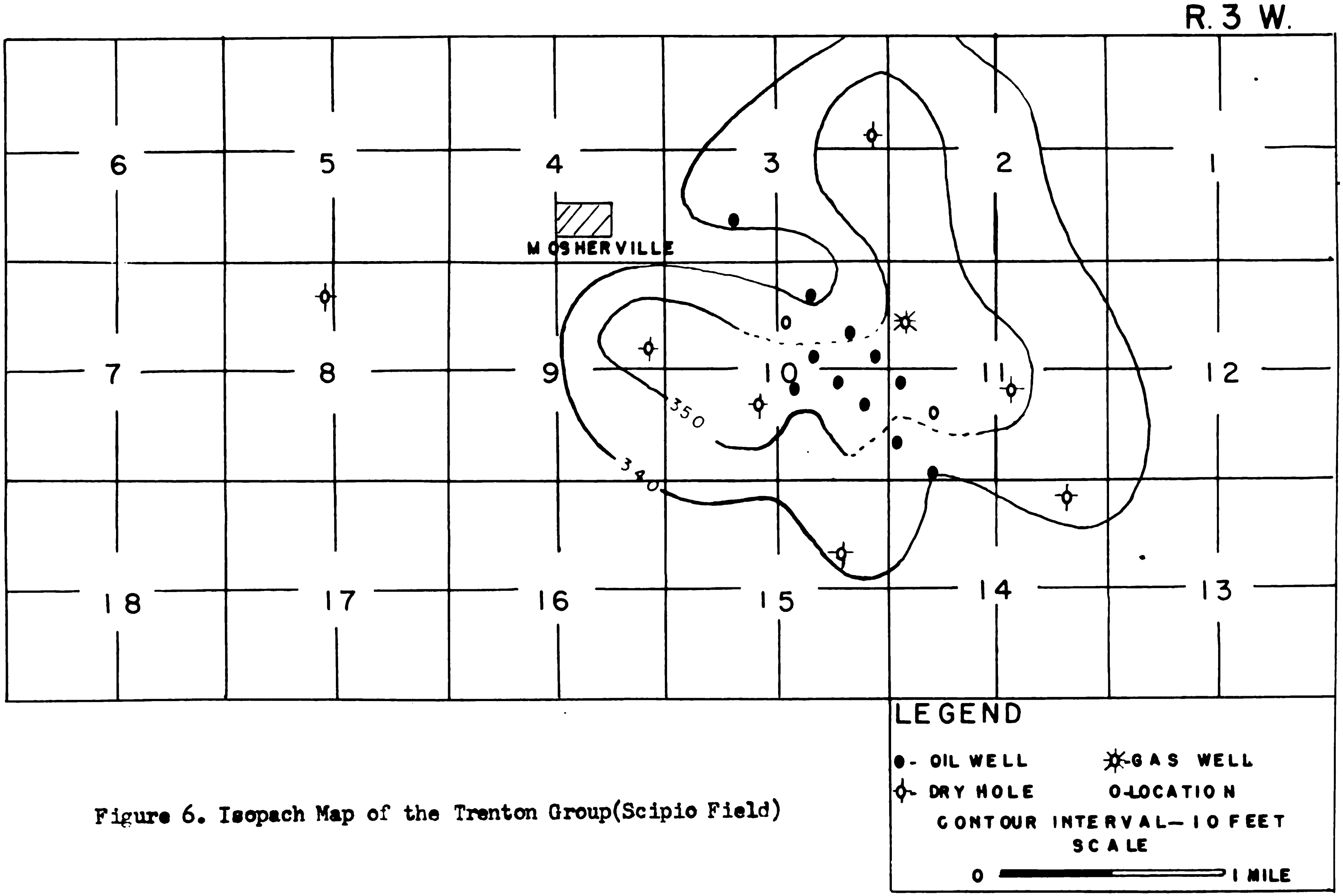

Figure 6. Isopach Map of the Trenton Group(Scipio Field)

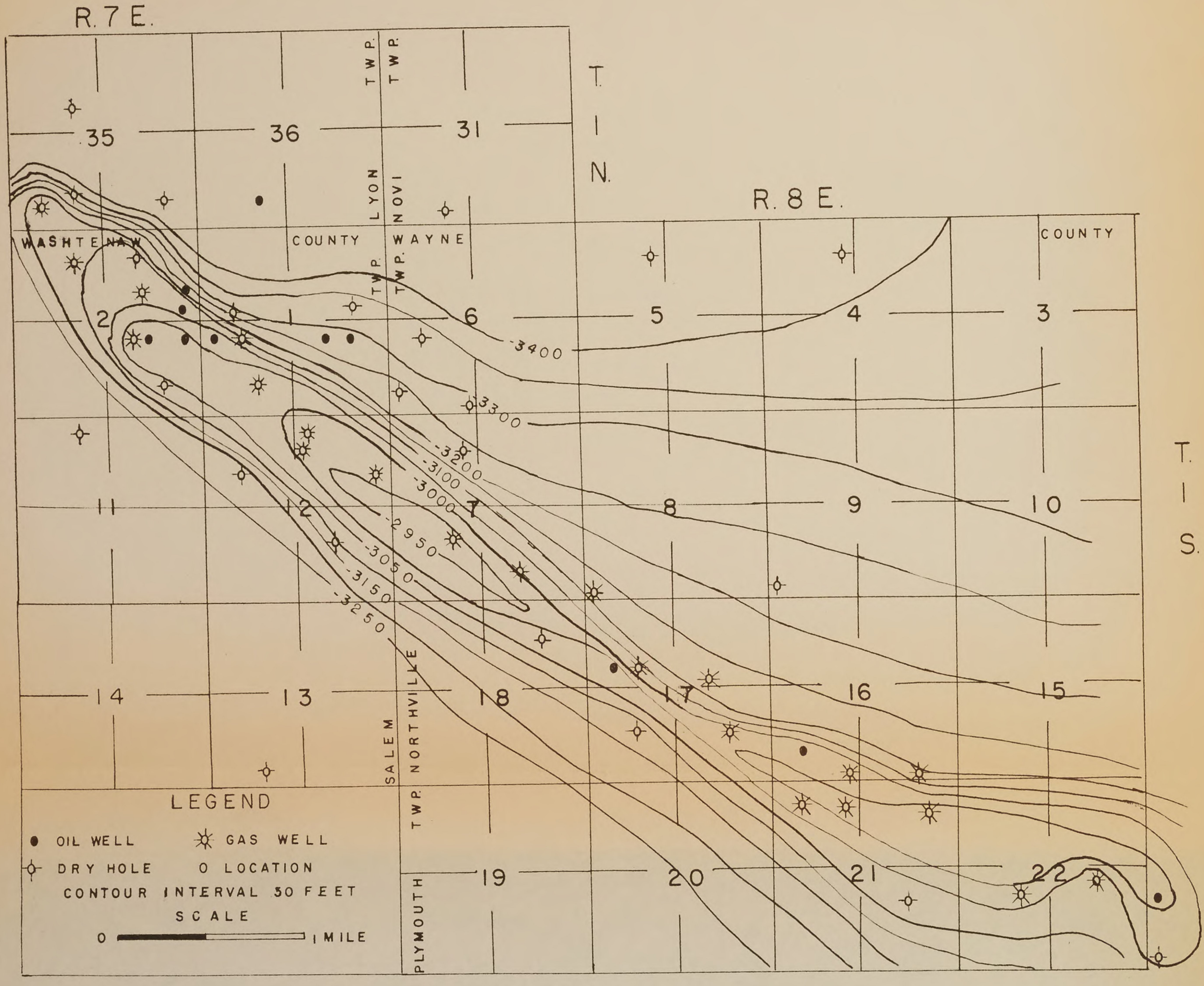

Figure 7. Structure Map on the Trenton Top (Northville Field)

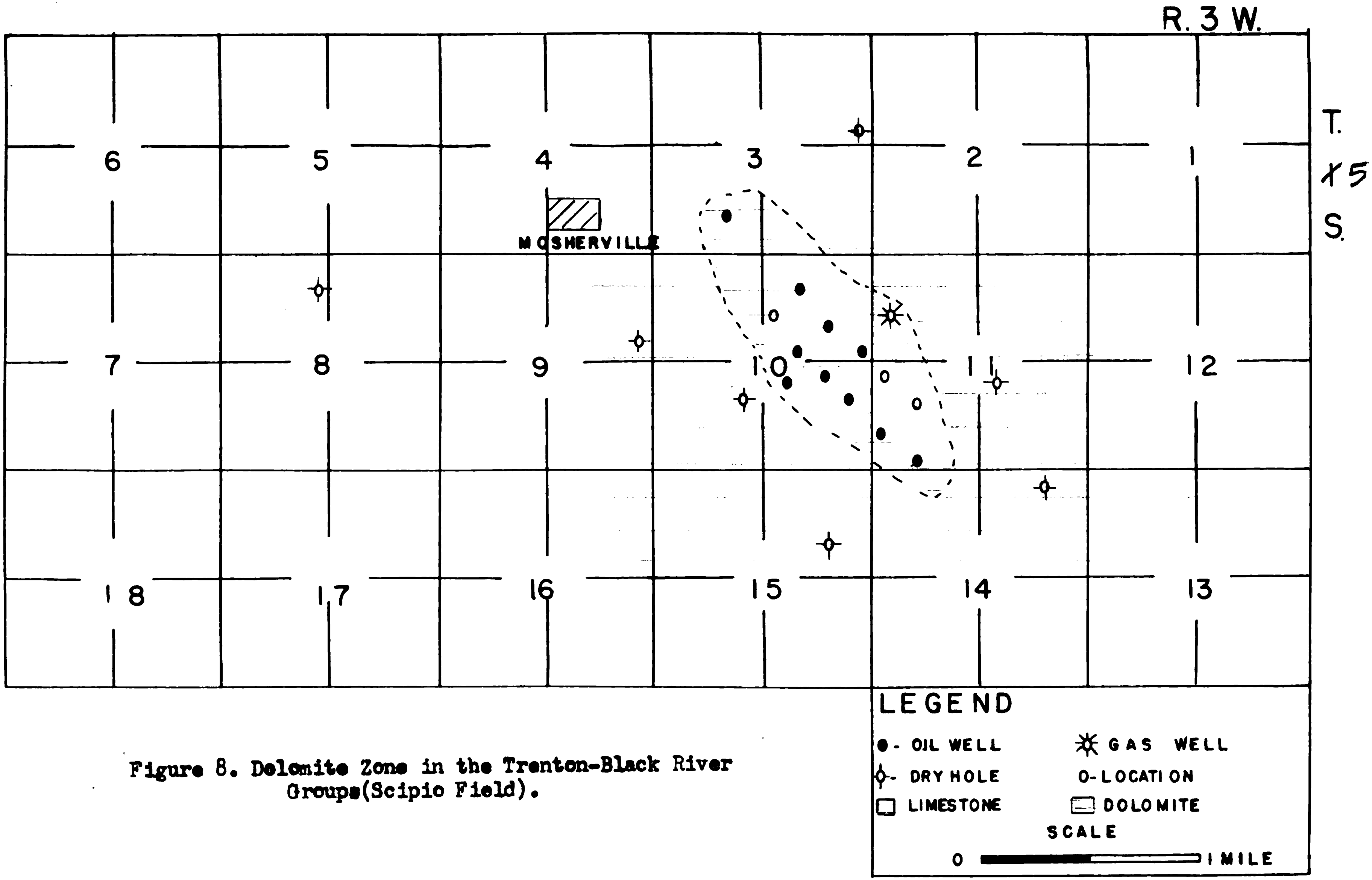

Figure 8. Dolomite Zone in the Trenton-Black River Groups(Scipio Field).

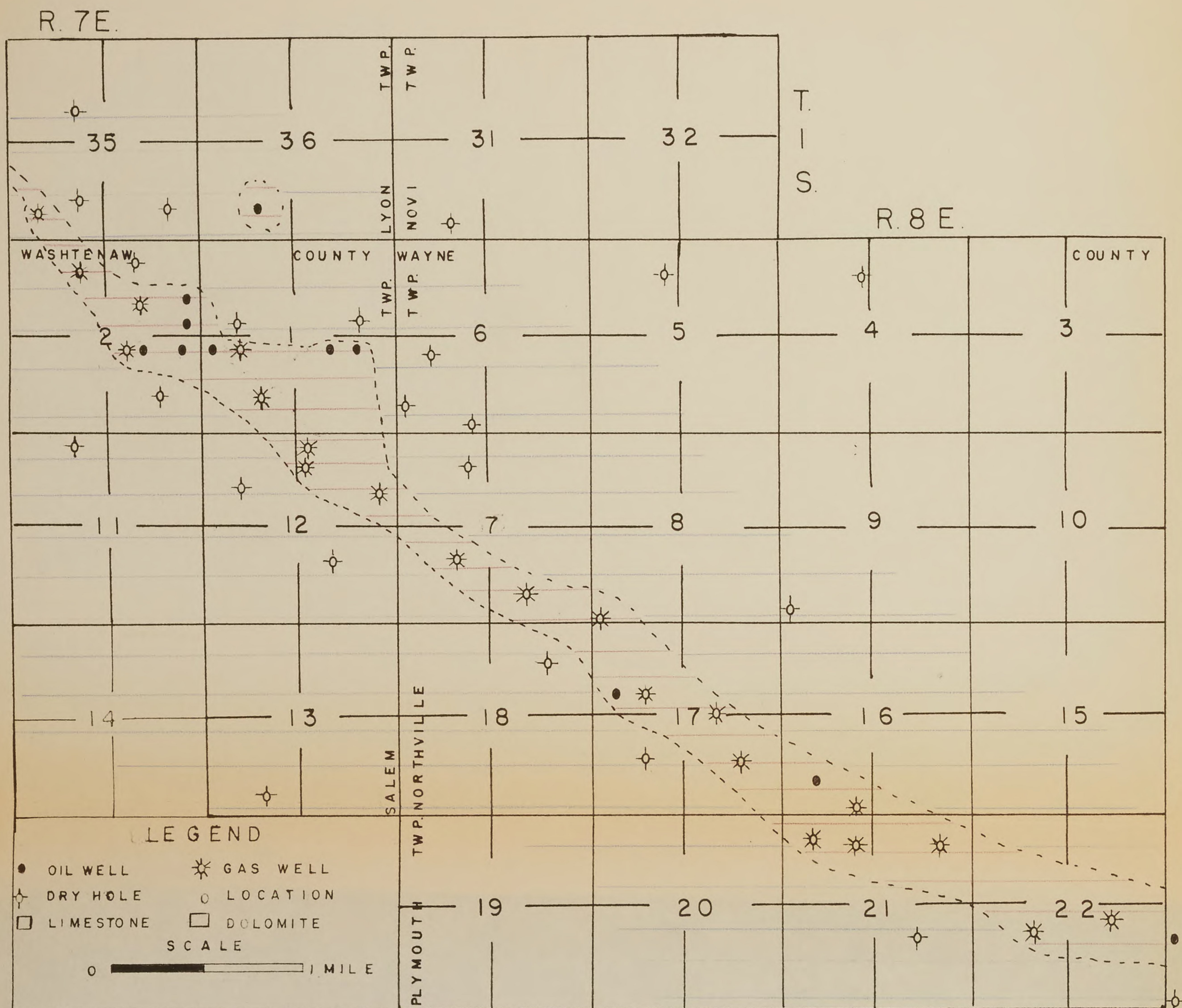

Figure 9. Dolomite Zone in the Trenton-Black River Groups (Northville Field).

field is quite well established by the dry (limestone) holes flanking the producing area. The Trenton levels decidedly both east and west of the anticline.

Figure 11 shows a cross section from Scipio to Northville, showing the change in thickness in different areas. The Middle Ordovician rocks thicken eastward within the area studied.

INTERPRETATIONS

Established Zones

During the microscopic study, separate zones were established to aid in distinguishing the older rocks in this area, as well as other sections of Michigan. Figure 13 shows these zones diagramatically. Radioactivity logs were also used in establishing these zones.

A Zone - This zone is found at the top of the Trenton group in all wells examined. It consists of a buff-brown, usually coarsely crystalline dolomite, with some shale, ranging in thickness from 10 to 20 feet. The top of this zone, which is the Trenton top, is quite distinctive on the radioactivity logs. A decided decrease in the intensity is shown on the gamma-ray side, while a decided increase is shown on the neutron curve, indicating the top of A zone.

B Zone - This zone lies beneath the A zone and consists of the remainder of the Trenton. The lithology of this zone depends upon the extent to which the limestone has been dolomitized. At the base of the B zone, the gamma-ray curve makes an abrupt increase, while the neutron curve makes an abrupt decrease. Zone B ranges in thickness from 340 to 355 feet in the Scipio Field but is thicker in the Northville Field and the intermediate area, ranging from 410 to 430 feet.

C Zone - This is a thin zone which is very difficult to pick out from the well cuttings. It is a thin shaly limestone sequence at the top of the Black River group, usually 10 feet or less thick. The shale is not usually evident in the cuttings, but the top of this thin interval makes a sharp increase on the gamma-ray curve and the neutron curve shows a sharp decrease, as stated above. The base of zone C is usually indicated by a sharp decrease on the gamma-ray curve and a sharp increase on the neutron curve.

D Zone - This zone, as in zone B, shows considerable lateral and vertical variation. In many wells the interval is a distinctive buff-brown, finely crystalline limestone. Local dolomitization has occurred at various horizons causing marked changes in certain wells, while in others the limestone is coarse crystalline. This variable limestone-dolomite sequence ranges in thickness from approximately 260 feet in the Scipio Field to 500 feet in the Northville Field.

D-1 Zone - This controversial zone is found infrequently in the area studied. The zone was established because of the oolitic dolomite found at its base, which is assumed to be the Prairie du Chien group. The infrequency of the occurrence of this impure, pyritic, dolomitic sandstone and in some instances sandy dolomite, makes it difficult to trace. The zone has not been found in the samples examined in the Northville Field. The thickness is approximately 25 feet. It is uncertain if a part of this zone is the St. Peter, immediately overlying the oolitic dolomite, which constitutes the lower portion of zone D-1. Erosion may be responsible for local occurrence of the D-1 zone. The zones established below the D-1 zone were made from information obtained from the Northville and intermediate wells, for the Hillsdale wells did not penetrate to the deeper zones. The Prairie du Chien oolitic dolomite was not included in the above thickness for the D-1 zone, but is considered part of the zone.

E Zone - This zone is directly subjacent to the D zone in the Northville Field and may have a similar position in parts of other areas. The E zone could not be examined from the Scipio samples, since the wells were not drilled to that depth. This zone is approximately 500 feet thick consisting of dolomite, glauconitic sandy dolomite and at some horizons entirely impure dolomitic sandstone. The top of this zone is a pink white crystalline dolomite. A thin shale and glauconitic sandstone sequence is also present in this part of zone E. Below this it varies from dolomitic sandstone to sandy dolomite with much glauconite present.

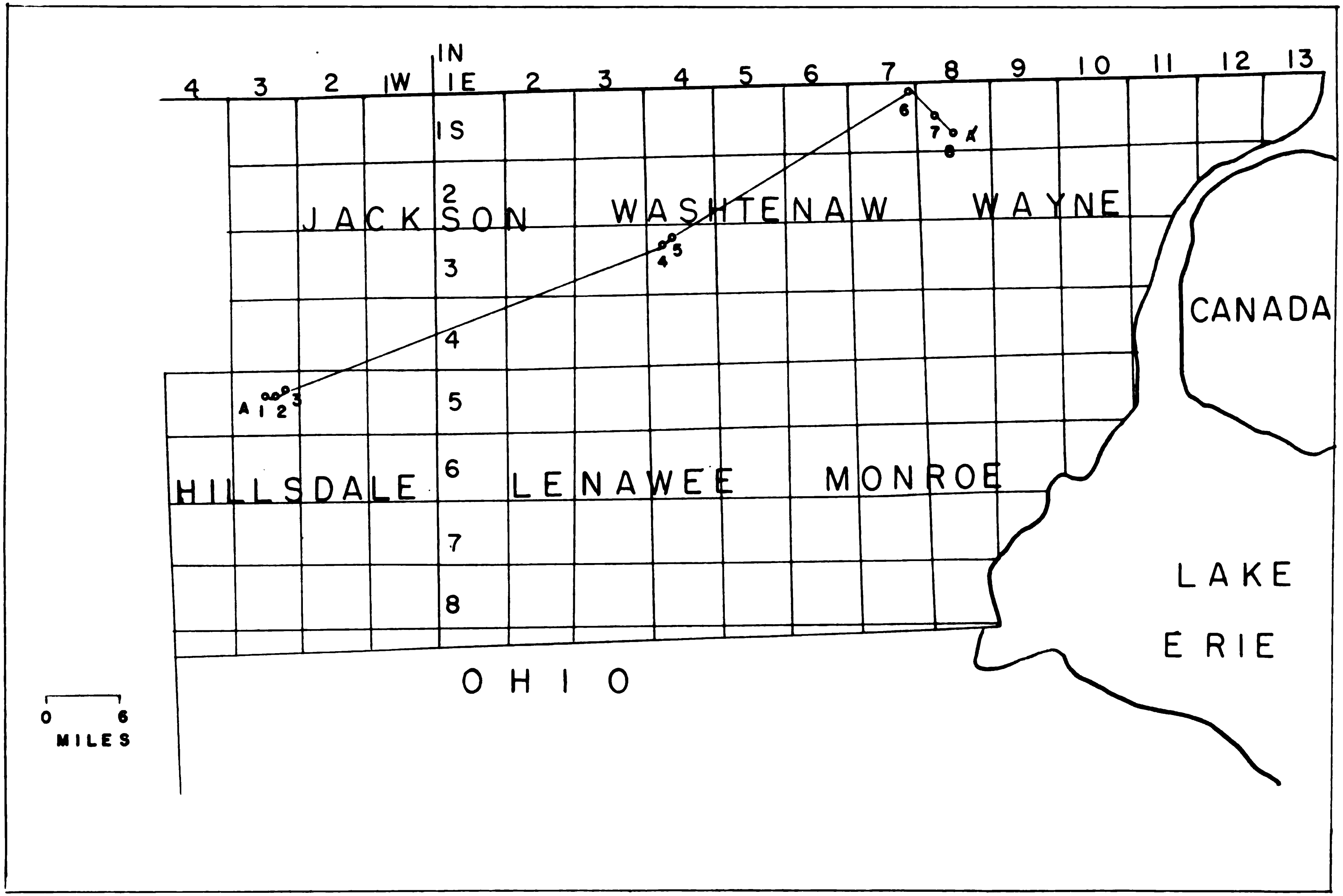

Figure 10. Locations of the Wells Used in the Cross Sections.

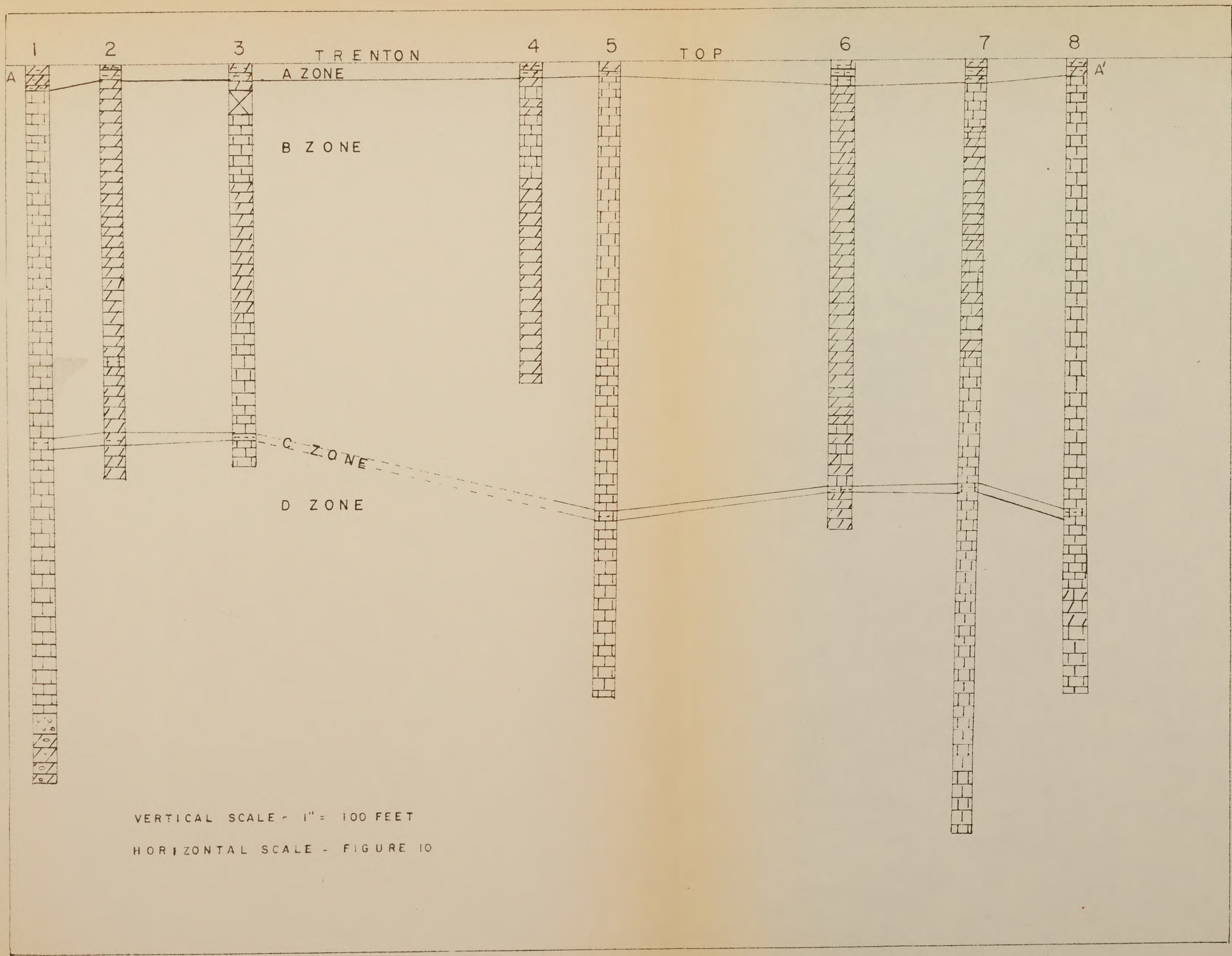

Figure 11. Lithologic Cross Section Showing the Established Zones.

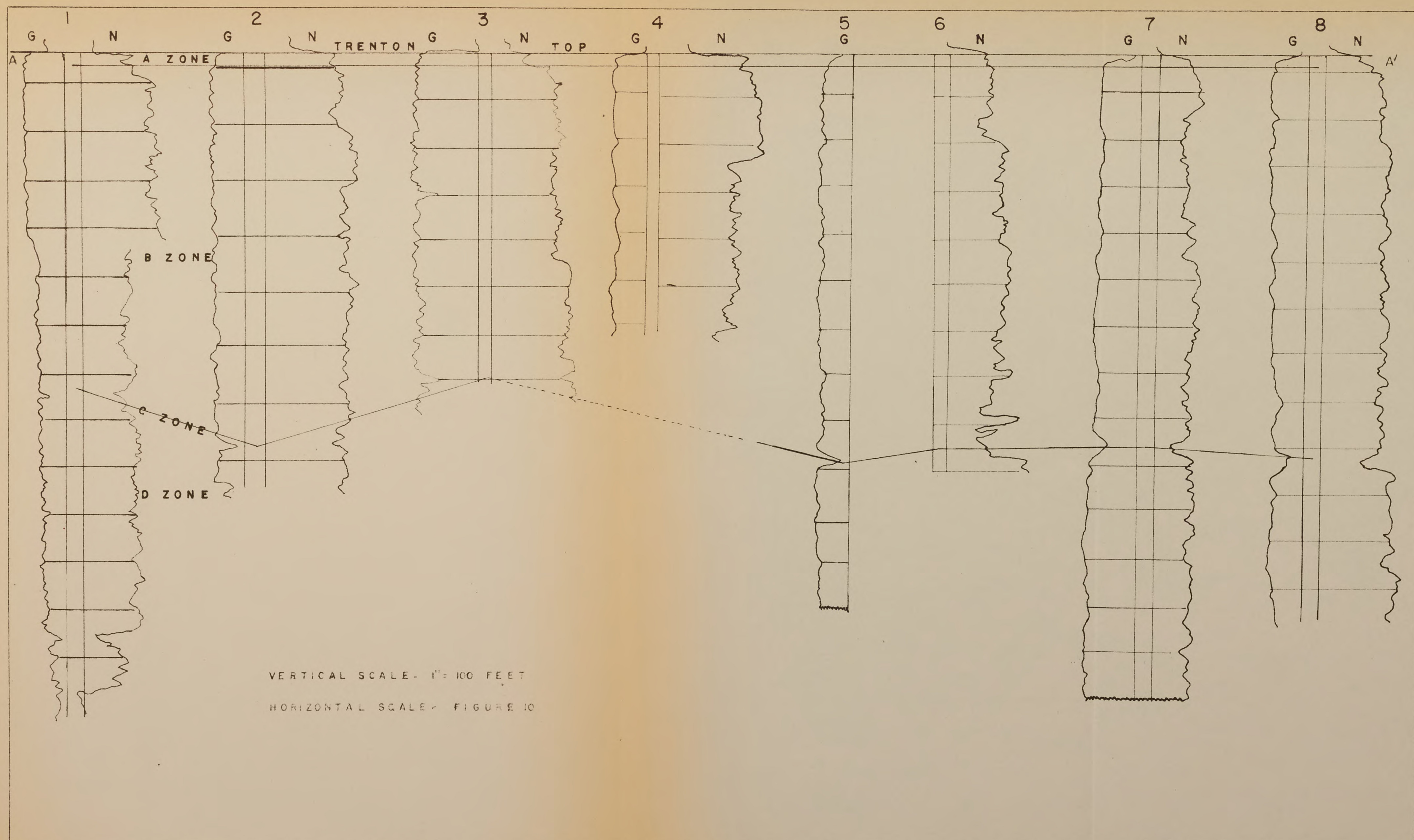

Figure 12. Cross Section With Radioactivity Logs.

The base of zone E shows a decided decrease on the gamma-ray curve.

F Zone - This zone is difficult to subdivide. It consists of dolomitic, glauconitic, and in some horizons pure sandstone. Zone F also has some glauconitic dolomite along with arkosic sands. This zone comprises the Upper Cambrian sandstones.

The established zones described above may also be traced by means of the lithologic cross section of wells shown in Figure 11. The radioactivity breaks are also shown for the same wells by Figure 12. The radioactivity logs have been reduced considerably for this diagram and show the breaks best for the upper zones.

Wells Used In the Cross Sections

1. Barnet #1 (SE¼, NE¼, SW¼, Sec. 10, T. 5S. R. 3W)
2. Hornczi & Huraczy #1 (NW¼, NW¼, SE¼, Sec. 10, T. 5S, R. 3W.)
3. Martin #1 (NW¼, SE¼, NW¼, Sec. 11, T. 5S. R. 3W)
4. Haab-Grau-Buss #1 (SW¼, NW¼, SW¼, Sec. 8, T. 3S., R. 4E.)
5. Buss-Haab #1 (SW¼, SE¼, NW¼, Sec. 8, T. 3S., R. 4E.)
6. Merritt #1 (NW¼, NW¼, sw½, Sec. 1, T. 1S., R. 7E.)
7. Detroit House of Corr. #3 (SW¼, NE¼, SE¼, Sec. 17, T. 1S., R. 8E.)
8. Unit 21-A, Forbes #1 (NE¼, NW¼, NW¼ Sec. 21, T 1S., R 8E.)

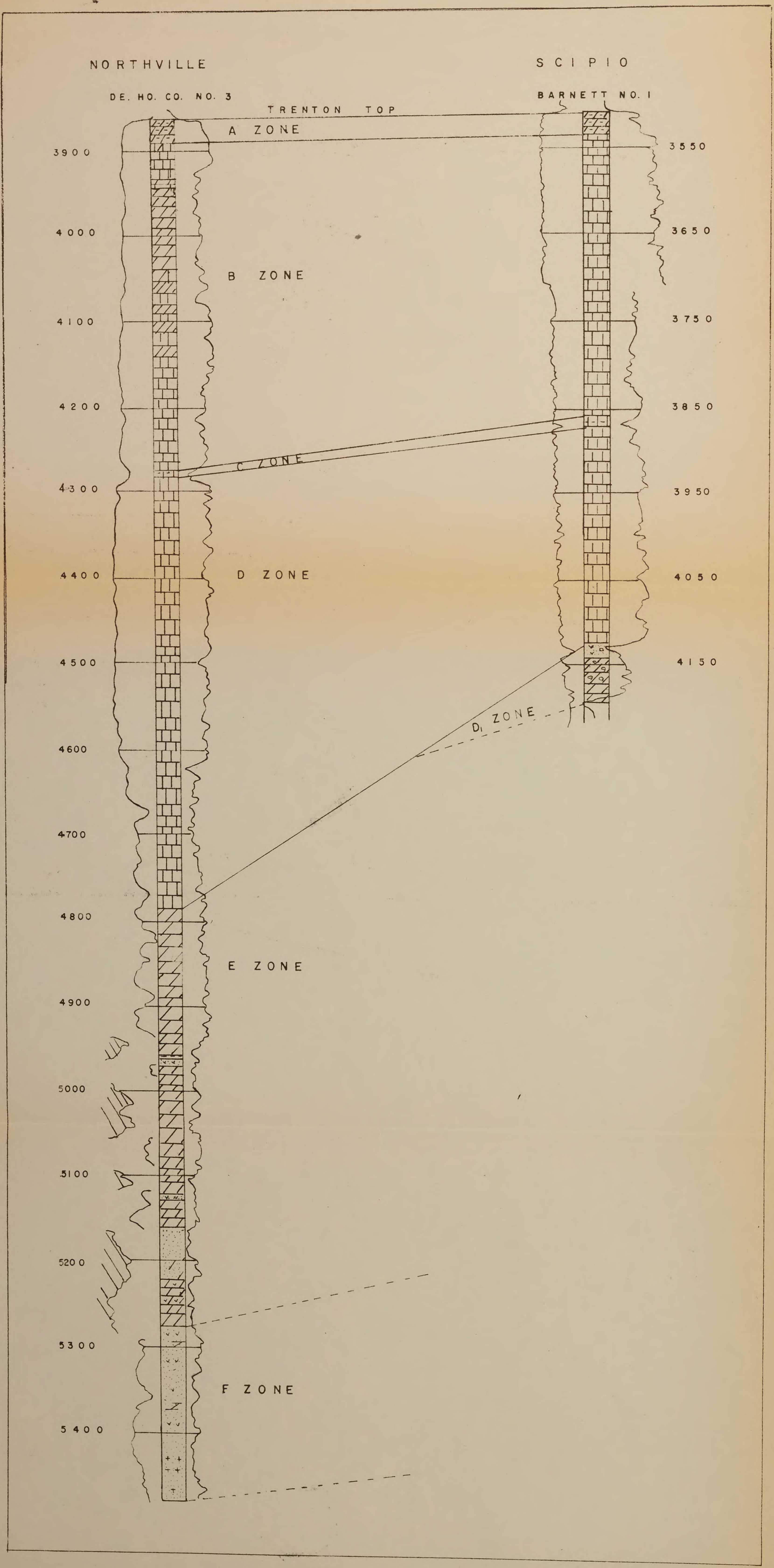

Figure 13. Zones Established Between Northville and Scipio.

SUMMARY AND CONCLUSIONS

Detailed studies of the lithology of most of the pertinent wells in the Hillsdale, Northville and intervening area together with radioactivity log studies have made possible a rather satisfactory correlation of the Middle and Lower Ordovician units throughout this area. Radioactivity logs proved especially helpful in showing compositional differences and contracts often difficult to indicate through lithology alone.

The interval from the top of the Trenton to the bottom of Upper Cambrian Sandstones was subdivided into seven units which were classified informally A to F. It is hoped these subdivisions may be of some aid to future subsurface studies. Age assignments in terms of the standard section were made indirectly through correlation into areas of outcrop where the section is better known. No identifiable fossils were observed in the well cuttings.

The Trenton lithology changes rapidly from limestone to dolomite in places. In at least a few definite instances, the dolomitized Trenton occurs along folded structures. The sharpness of the dolomite-limestone contacts infer faulting or jointing to have played a likely part in the processes, and that such breaks served as channelways for the movement of the replacing solutions.

Oil production is apparently closely tied in with the secondary dolomitization; all producing wells examined occurring within dolomite or magnesium limestone. Upon examining the dolomite facies maps, it appears that the producing wells are more dependent upon the distribution of the dolomite than on the structural highs. The dolomite is of primary importance to the production whereas the structure is of indirect significance through its control of the loci of dolomitization. This same relationship is known to exist in the Devonian producing fields in other parts of Michigan. It seems apparent that the success of future exploration for Trenton (as well as Devonian) oil possibilities will lie first in the development of better methods of locating the faulted and fractured zones beneath the glacial cover followed by detailed studies of the dolomite and limestone facies distribution concurrent with drilling operations.

In general the Trenton and Black River units (zones A-D) thicken eastward in the area studied. The Canadian equivalents (zone D-1) disappear eastward from the Hillsdale area and are represented by a disconformity in the Northville Field. On the strength of paleogeographic probabilities, it appears likely that the Chazyan equivalents are absent from southern and southeastern Michigan, through non-deposition (with the possible exception of the St. Peter sandstone, if indeed of Chazyan age). The eastward disappearance of the Canadian equivalents, however, would more likely be associated with either post Canadian (Beekmantown) erosion along a disconformity increasing eastward, or perhaps due to thinning toward the Findley arch in that direction. A resolution of this problem perhaps must wait additional drilling to the Canadian horizon in this general area.

APPENDIX

(LITHOLOGIC DESCRIPTIONS OF CERTAIN WELLS
FROM MICROSCOPIC EXAMINATIONS
MADE DURING THE STUDY)

1. Permit #20422

Aurora Gas Co. & McClure Oil Co.
Rowe #1
Sec. 10, T.5 S., R.3 W., (SE, NW, NE)
Elevation 1026.7'

	Description	Thickness	Depth
Ordovician			
Trenton Top			
A Zone			3565'
Dolomite -	gray brown crystalline shaly.	14'	3579'
B Zone			
Dolomite -	fine-coarse crystalline, brown, gray, tan with vugular porosity, dead petroleum.	96'	3676'
Dolomite -	coarse crystalline, as above with some limestone.	51'	3726'
Dolomite -	as above, with good inter-granular porosity, dead oil	126'	3852'
Dolomite -	brown-dark black, porous, some shale, pyrite, dead oil.	51'	3903'
C Zone			
Black River Top			3903'
Shale -	brown black, dolomitic, pyritic.	3'	3906'
D Zone			
Dolomite -	brown, tan, coarse to fine crystalline.	23'	3926'
Dolomite -	as above, shaly.	4'	3930'
Dolomite -	as above.	9'	3939'

Total Depth .... 3939'

2. Permit #20733

Aurora Gas Co. & McClure Oil Co.
Barnett #1
Sec. 10 T.5 S, R.3W., (SE, NE, NW)

Description	Thickness	Depth
Ordovician		
Trenton Top		3515'
<u>A Zone</u>		
Dolomite - brown-black, coarse crystalline, shaly.	20'	3535'
<u>B Zone</u>		
Limestone - brown-gray, median to coarse crystalline.	170'	3705'
Limestone - as above, buff to white, some pore openings	161'	3866'
Black River		3866'
<u>C Zone</u>		
Limestone - gray white, fine crystalline with shale.	10'	3876'
<u>D Zone</u>		
Limestone - light brown, fine crystalline.	244'	4120'
St. Peter's		4120'
<u>D-1 Zone</u>		
Limestone/sand - green brown, medium crystal-glauconite, pyrite, carbonaceous material.	14'	4134'
Sand - white-buff, some calcium, pyrite.	9'	4143'
Prairie du Chien		
Dolomite - white, tan buff, medium crystalline, glauconitic, pyritic, oolitic. Some sand	59'	4202'

3. Permit #20674

Gordon Drilling Co.
Hornczi & Huraczy #1
Sec. 10, T. 5S., R. 3W. (NW¼, NW¼, SE¼)

Description	Thickness	Depth
Ordovician		
Trenton Top		3535'
<u>Zone A</u>		
Dolomite - brown-black, fine crystalline, shaly	5'	3540'
<u>Zone B</u>		
Dolomite - brown-buff, coarse crystalline.	20'	3560'
Dolomite - brown-buff, coarse crystalline, cavernous porosity, pyrite.	30'	3590'
Dolomite - brown-buff, coarse crystalline.	15'	3605'
Dolomite - brown-buff, gray, coarse crystalline, cavernous porosity.	25'	3630'
Dolomite - brown-buff, coarse crystalline, shale particles (some cavings)	30'	3660'
Dolomite - brown-black, coarse crystalline, cavernous vugular porosity	40'	3770'
Dolomite - buff-brown, coarse crystalline, some shale little granular porosity	25'	3730'
Dolomite - black-white, calcareous shaly	10'	3740'
Dolomite - brown-tan, coarse crystalline, some white gray with shale cavings.	65'	3805'
Limestone - medium, coarse crystalline, gray.	15'	3820'
Dolomite - brown-gray, white, coarse crystalline.	10'	3820'

Permit #20674 (continued)

Dolomite -	buff-gray, coarse crystalline, calcareous, granular porosity.	50'	3880'
Black River Top			
<u>C Zone</u>			
Dolomite -	brown-gray, medium crystalline, some shale.	15'	3895'
<u>D Zone</u>			
Dolomite -	brown-gray, coarse crystalline	30'	3925'

Total Depth .... 3925'

4. Permit #20748

Clifford A. Perry
Nelligan #1
Sec. 9 T. 5S., R. 3W (SE¼, SE¼, NE¼)

Description	Thickness	Depth
Ordovician		
Trenton Top		3525'
A Zone		
Dolomite - brown to buff, fine to medium crystalline.	15'	3540'
B Zone		
Dolomite - black to brown, buff, fine to coarse crystalline, some black carbonaceous material.	20'	3560'
Limestone - black to brown, fine to coarse crystalline, black carbonaceous partings.	20'	3580'
Limestone - as above, dark brown to buff.	20'	3600'
Limestone - dark brown to buff, fine to medium crystalline, carbonaceous.	30'	3630'
Limestone - brown to gray, fine to coarse crystalline.	15'	3645'
Limestone - brown and dense, fine to coarse crystalline.	5'	3650'
Limestone - brown to buff, medium to coarse crystalline.	70'	3720'
Limestone - brown to buff, fine to coarse crystalline.	35'	3755'
Limestone - brown to buff, fine crystalline.	105'	3860'
Limestone - brown, buff, fine, petroliferous.	20'	3880'
Black River Top (Radioactivity Log)		3880'
C Zone		
Samples missing	10'	3890'
D Zone		
Limestone - brown, fine grained and very fine crystalline.	20'	3910'
Limestone - brown, fine grained and fine crystalline.	51'	3961'

Total Depth 3961'

5. Permit #19607

Clifford A. Perry
Ferne Housnecht #1
Sec. 10 T. 5S., R. 3W (NW¼, SE¼, NE¼)

Description	Thickness	Depth
Ordovician		
Trenton Top		3558'
A Zone		
Shale - with dolomite, brown and dark brown.	12'	3570'
B Zone		
Dolomite - gray brown, broken crystalline, shale as above, intermittent vugs.	23'	3593'
Dolomite - gray-brown, to light tan some white, broken crystalline, minute vugs.	13'	3606'
Dolomite - brown, coarsely crystalline, minute vugular porosity, samples appear petroliferous.	6'	3612'
Limestone - light tan to brown, dolomitic.	5'	3617'
Dolomite - brown to tan, fine to coarsely crystalline, some intercrystalline porosity.	23'	3640'
Dolomite - brown, tan fine to coarsely crystalline, vugular porosity, trace petroleum (dead), trace pyrite.	63'	3703'
Dolomite - dark brown to tan, some white, coarsely crystalline, vugular porosity (dead oil).	43'	3746'
Samples missing	17'	3763'
Samples contaminated	5'	3768'
Dolomite - tan to dark brown, some white dolomite, petroliferous.	5'	3773'
No further samples.		

Total Depth 3900'

6. Permit #19608

Sun Oil Company
Haab-Grau-Buss #1
Sec. 8, T. 3S, R. 4 E. (SW¼, NW¼, SW¼)

Description	Thickness	Depth
Ordovician		
Trenton Top		3854'
A Zone		
Dolomite - brown gray, shaly.	6'	3860'
Dolomite - brown, gray, coarse crystalline.	10'	3870'
B Zone		
Limestone & Dolomite - black, brown, crystalline.	15'	3885'
Limestone - gray, brown, crystalline	80'	3965'
Dolomite - brown, white, coarse crystalline, slight porosity.	45'	4010'
Dolomite - brown, gray, coarse crystalline, cavernous porosity.'	35'	4045'
Dolomite - white, gray, brown, coarse crystalline, some porosity.	55'	4100'
Dolomite - brown, gray, coarse crystalline.	55'	4155'

Total Depth 4155'

7. Permit #19231

Sun Oil Company
Buss and Haab #1
Sec. 8, T. 3S, R. 4 E. (SE¼, SE¼, NW¼)

Description	Thickness	Depth
Ordovician		
Trenton Top		3760'
<u>A Zone</u>		
Dolomite - brown to gray crystalline, shaly	11'	3771'
<u>B Zone</u>		
Limestone - gray-brown to black, very dense.	6'	3777'
Dolomite & Limestone - gray-brown to white, quite dense, scattered porosity	33'	3810'
Limestone - brown to gray, brown, coarsely crystalline some carbonaceous material.	200'	4010'
Limestone - light to dark gray, brown, coarsely to fine crystalline, dense, argillaceous partings.	188'	4198'
Black River Top		
<u>C Zone</u>		
Limestone - fine crystalline with dark gray to black shale partings.	4'	4202'
<u>D Zone</u>		
Limestone - light brown to gray brown, finely crystalline, very dense.	163'	4365'

8. Permit #18796

W. C. Taggart
LeMaster #1
Sec. 1, T 1S, R 7 E (NW¼, SE¼, SE¼)

Description	Thickness	Depth
Ordovician		
Trenton Top		4247'
<u>A Zone</u>		
Dolomite - gray, brown crystalline, shaly	10'	4257'
<u>B Zone</u>		
Limestone & Dolomite - white to gray, brown, porosity.	43'	4300'
Limestone - gray, buff, white, crystalline.	40'	4340'
Limestone - as above, with brown dolomite.	16'	4356'
Dolomite - brown to buff, crystalline, a little lime. Good porosity.	41'	4397'

Total Depth 4397'

9. Permit #13968

Evans Oil Company
Merritt #1
Sec. 1, T. 1S, R 7 E, (NW¼, NW¼, SW¼)

Description	Thickness	Depth
Ordovician		
Trenton Top		4050'
A Zone		
Shale - limy, gray.	10'	4060'
B Zone		
Limestone - gray, brown, dense (lithographic)	17'	4077'
Dolomite - dark gray, brown, oil oders. Medium crystal-line.	159'	4236'
Dolomite - dark brown medium crystalline.	67'	4303'
Dolomite - buff to brown, coarse to fine crystalline.	88'	4391'
Limestone - gray-brown tight, some shale and some dolomite.	77'	4468'
Black River		4468'
C Zone		
Shale - dark gray, dolomite	2'	4470'
D Zone		
Dolomite - gray-brown, medium to coarse crystalline	29'	4499'

Total Depth 4499'

10. Permit #19496

Consumer Power Co.
Detroit House of Correction #3
Sec. 17, T. 1S, R 8 E. (SW¼, NE¼, SE¼)

Description	Thickness	Depth
Ordovician		
Trenton Top		3866'
<u>A Zone</u>		
Dolomite - brown, crystalline, dense, some shale.	5'	3871'
<u>B Zone</u>		
Dolomite & Limestone - buff, brown to gray, fine crystalline, tight.	29'	3900'
Limestone - brown, gray crystalline.	55'	3955'
Dolomite - brown, buff-gray. Coarse crystalline.	80'	4035'
Limestone - gray buff to crystalline, dense.	247'	4282'
Black River		4282'
<u>C Zone</u>		
Limestone - gray to buff with shale.	10'	4292'
<u>D Zone</u>		
Limestone - gray to buff crystalline (coarse to fine)	500'	4782'
Cambrian		
Trempealeau Top		4782'
<u>E Zone</u>		
Dolomite - white, pink, gray, crystalline.	168'	4950'
Shale - gray, silty.	10'	4960'
Sandstone - white gray glauconitic.	5'	4965'
Dolomite - red, white, pink and gray. Pinpoint porosity.	154'	5115'
Dolomite - red, pink, sandy, glauconitic, pyritic; some pink and red sand.	103'	5218'

10. Permit #19496 (continued)

Dolomite - gray to dark gray shaly and very glauconitic.	53'	5271'
F Zone		
Sand - white to clear, medium to coarse, dolomitic and slightly glauconitic.	94'	5365'
Sand - white to gray, medium to fine grained, arkosic glauconitic.	25'	5390'
Sand - gray, some pink, fine to coarse grained, glauconitic.	60'	5450'
Sand - white, pink, arkosic.	33'	5483'

Total Depth 5483'

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