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DOLOMITIZATION PATTERNS
IN THE WALKER OIL FIELD,
KENT AND OTTAWA COUNTIES, MICHIGAN

presented by

Richard J. Hamrick

has been accepted towards fulfillment
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C.E. Prouty
Major professor

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DOLOMITIZATION PATTERNS
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By

Richard J. Hamrick

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ABSTRACT

DOLOMITIZATION PATTERNS
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A study of the Walker Oil Field was undertaken to achieve better understanding about the origin of dolomite in Devonian reservoir rocks and its relationship to structural configuration.

Carbonate samples from producing and nonproducing Traverse Limestone wells were analyzed by the powdered x-ray diffraction method to determine dolomite percentages from various depth intervals. It was found that the highest degree of dolomitization from the upper Traverse Limestone occurred at or near the top of the formation. The degree of epigenetic dolomitization shows a general correlation with the structural contour map developed on the top of the Traverse Limestone.

The geometry of folds and distribution of dolomite percentages suggest relationship to faulting. Folding, faulting, and solution activity are the major causes for secondary porosity in the Traverse Limestone pay zone(s).

Carbonate and evaporite facies of the Traverse

Limestone appears to be related to the hypothesized West Michigan Barrier (early diagenetic dolomite).

ACKNOWLEDGMENTS

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Foremost appreciation must go to my wife Paulette for her love and friendship throughout this time of trials and tribulation. Her patience, understanding, and encouragement made completion of this work possible.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

General Statement

Petroleum production has been actively developed in the southwestern portion of the Michigan Basin, a substantial amount of which has been developed from the dolomitized Traverse Limestone of Middle Devonian age. Porosity in this dolomitic limestone has developed because of either stratigraphically controlled, early diagenetic dolomitization or epigenetic (post consolidation) dolomite formed by fluids introduced along faults and fractures.

Many geologists contend that dolomitic limestone has a tendency to develop along bedding planes, joints, fractures, and faults within limestone formations (Landes, 1946; Powell, 1950; Jodry, 1954; Goodrich, 1957; Egleston, 1958; Jackson, 1958; Paris, 1977; Dastanpour, 1977).

A number of geologists have demonstrated that widespread dolomitic facies have developed along shallow epicontinental shelves and carbonate platform areas (Prouty, 1948; Cohee and Landes, 1958; Adams and Rhodes, 1960; Deffeyes et al., 1965; Illing et al., 1965; Bathurst, 1971). And others have proposed the development of dolomitization related to persistently emergent areas or structural highs

(Hanshaw, et al., 1971; Badiozamani, 1973; Land, 1973).

Purpose and Scope

The Walker Oil Field of Kent and Ottawa Counties, Michigan has been a prolific Traverse Limestone oil reservoir, producing over 17 million barrels of oil. This field was chosen as the area of study because the region has a well defined structure with accessible well samples.

It is the purpose of this study to: (1) establish the occurrence of dolomitization in the Traverse Limestone petroleum producing zone (implies porosity and permeability), and (2) examine the distribution of dolomite relative to the field structure. Also of importance will be a valid attempt to put forth mechanism(s) which could have produced dolomitization within the Traverse Limestone of the Walker Field.

Structural interpretations will be made from maps based on contacts established through microscopic examination of well samples. Dolomite percentages will be determined by comparative quantitative x-ray diffraction analysis of various well samples and will be vertically represented via bar graphs and laterally displayed by dolomite/limestone ratio maps representing different depth horizons below the top of the Traverse Limestone. The dolomite percentage bar graphs and maps will be compared with the structural map on the top of the Traverse Limestone to delineate relationships.

It is the hope and purpose of this writer that the results of this study will provide helpful information regarding the nature and characteristics of linear-producing fields and aid future oil and gas exploration and production programs in Michigan.

Previous Work

There have been a number of studies related to this area of research. Chemical analyses demonstrating $CaCO_3$/$MgCa(CO_3)_2$ ratios, following suggestions by Landes (1946) in regard to local dolomitization, was first done in the Michigan Basin by Powell (1950) from the Rogers City-Dundee formations. Jodry (1954) utilized the titration method for determining the Mg/Ca ratios of well samples, comparing the data with several producing oil fields in Mecosta County. In the studies of Tinklepaugh (1957), Jackson (1958), and Dastanpour (1977), a definite relationship was observed between the degree of dolomitization and structural form. Young (1955) and Egleston (1958) compared their Mg/Ca ratios with structural maps in Stony Lake and Winfield Fields, respectively, but were not impressed with such correlations in their studies.

Recent dolomitization studies from semiquantitative analyses in Michigan were made by Newhart (1976) on the Middle Ordovician, Runyon (1976) on the Traverse Group, and Syrjamaki (1977) on the Lower Ordovician. These studies, along with that of Dastanpour (1977), have established the existence of two types of dolomite: stratigraphic (diagenetic) and secondary (epigenetic).

A number of studies have been made related to the Traverse Group in Michigan. Isopach maps of the Traverse Group were first published by Newcombe (1933). Later, Cohee (1947) provided a more accurate estimate of Devonian thickness along with a structure contour map based on the available well records to 1947 which penetrated the entire Traverse Group section.

Henry (1949) studied the Traverse Group in the Pentwater Oil Field and believed the Traverse pay to be part of a Devonian reef structure. An investigation of the Traverse Group in the Lansing area was made by Gustafson (1960), who generated structural and isopach maps of this area. Fisher (1969) examined the Traverse Formation, the top unit of the Traverse Group, and developed a structure contour map on the top of the Traverse Formation. Gardener (1974) suggests the Traverse Group represents interfingering of proximal biostromal and biohermal shelf carbonates on the west with distal fossiliferous gray muds to the east.

STRATIGRAPHIC FRAMEWORK

The stratigraphic sequence of rock lithologies important to this study is Middle Devonian age. Rock units representing this geologic time span on the southwestern side of the Michigan Basin are the Traverse Group and the Rogers City and Dundee formations (Figure 1).

The Traverse Group with the Bell Shale formation at the base lies conformably on the top of the Rogers City formation (Cohee and Underwood, 1945). The Traverse Group is divided into three major units by Cohee (1944): the upper Traverse Formation, the middle Traverse Limestone, and the lower Bell Shale.

Fisher (1969) considered the Traverse Formation to be a legitimate stratigraphic formational unit and recommended its inclusion as part of the Michigan stratigraphic column. He described the Traverse Formation as a calcareous, medium gray shale and shaley limestone which is a transition zone between the Traverse Limestone of Middle Devonian age and the Antrim Shale of probable Upper Devonian age.

Cohee (1947) described the lithology of the Traverse Group in the Michigan Basin as argillaceous limestone, shales, and some pure limestone in eastern Michigan grading

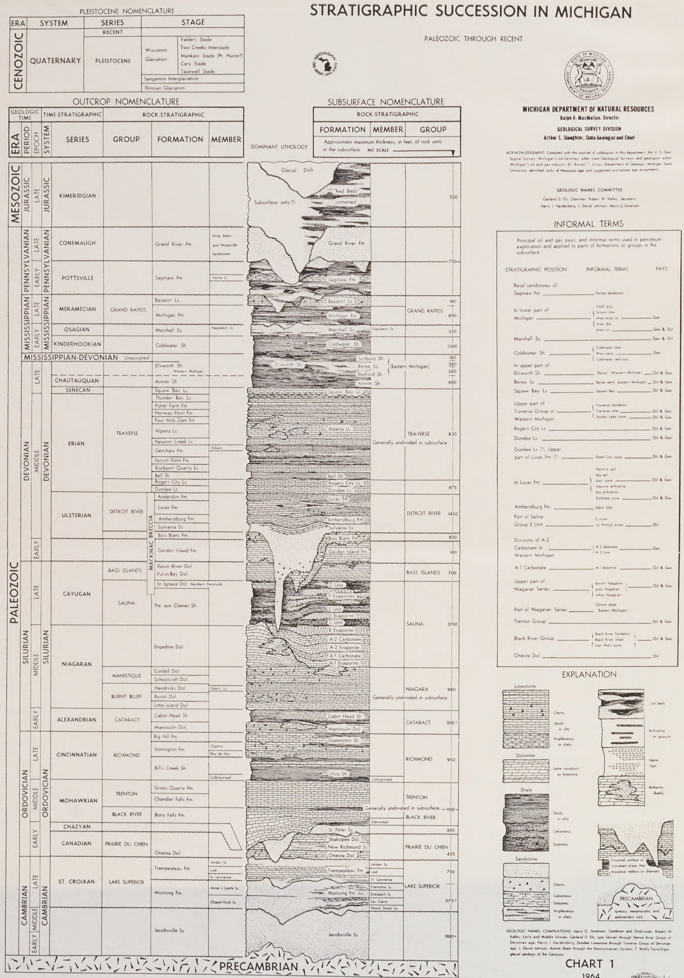


Figure 1. Stratigraphic Succession in Michigan

to the west into calcareous shales with the limestone becoming more pure until the whole group becomes relatively pure limestones in western Michigan with some dolomite and dolomitic and argillaceous limestone. Jodry (1957) recognized a lagoonal dolomitic facies in Western Michigan and open sea facies east of a line at about the position of the Walker Field today. The "barrier" bringing about this facies change was believed to reflect a high in the Precambrian basement. Runyon (1976) recognized a similar facies distribution in his semiquantitative study of the dolomite and limestone of the Traverse Group. More will be said in this regard later.

The lower Bell Shale formation of the Traverse Group thins and disappears in much of the western and southwestern portions of Michigan, so that the middle Traverse Limestones rest directly on top of the Rogers City-Dundee limestones. When present in the subsurface, the Bell Shale is typically a soft, fossiliferous, gray shale (Jodry, 1957).

Cohee and Underwood (1945) stated that the Rogers City and Dundee formations in the central part of the Michigan Basin were composed of dolomite and limestone, whereas in the far westcentral and southwestern area it is predominantly dolomite. They also went on to state that although easily recognizable on the eastern side of the Michigan Basin, the Rogers City and Dundee formations in the west-central and western side of the Basin are relatively indistinquishable in subsurface due to similar lithology.

The Traverse Limestone, for purposes of this study, is that interval between the top of the Bell Shale (if present) and the base of the Traverse Formation.

STRUCTURAL FRAMEWORK

The Michigan Basin is a roughly circular and symmetrical structural and sedimentary basin in the Central Interior platform of the United States. It encompasses the Southern Peninsula and the eastern part of the Northern Peninsula of Michigan, Eastern Wisconsin, the northeast corner of Illinois, Northern Indiana, Northwest Ohio and portions of Ontario bordering Lake Huron, Lake St. Clair, and the western end of Lake Erie (Cohee and Landes, 1958). Bordering the Basin is the Algonquin Arch to the east (Ontario), the Findlay Arch to the southeast (NW Ohio), the Kankakee Arch to the southwest (N. Indiana), the Wisconsin Arch to the west (C. Wisconsin) and the Canadian Shield to the north and northeast (Figure 2).

A number of theories have been postulated concerning the origin of the Michigan Basin. Pirtle (1932) thought the Basin probably originated in Precambrian time. He believed the Wisconsin and Kankakee Arches were the cores of Precambrian mountains that stretched from central Wisconsin to NW Indiana and that principle folds that now exist in later sedimentary rocks were controlled by trends of folding or lines of structural weakness that existed in basement rocks. Folding by compression was most intense in Mississippian

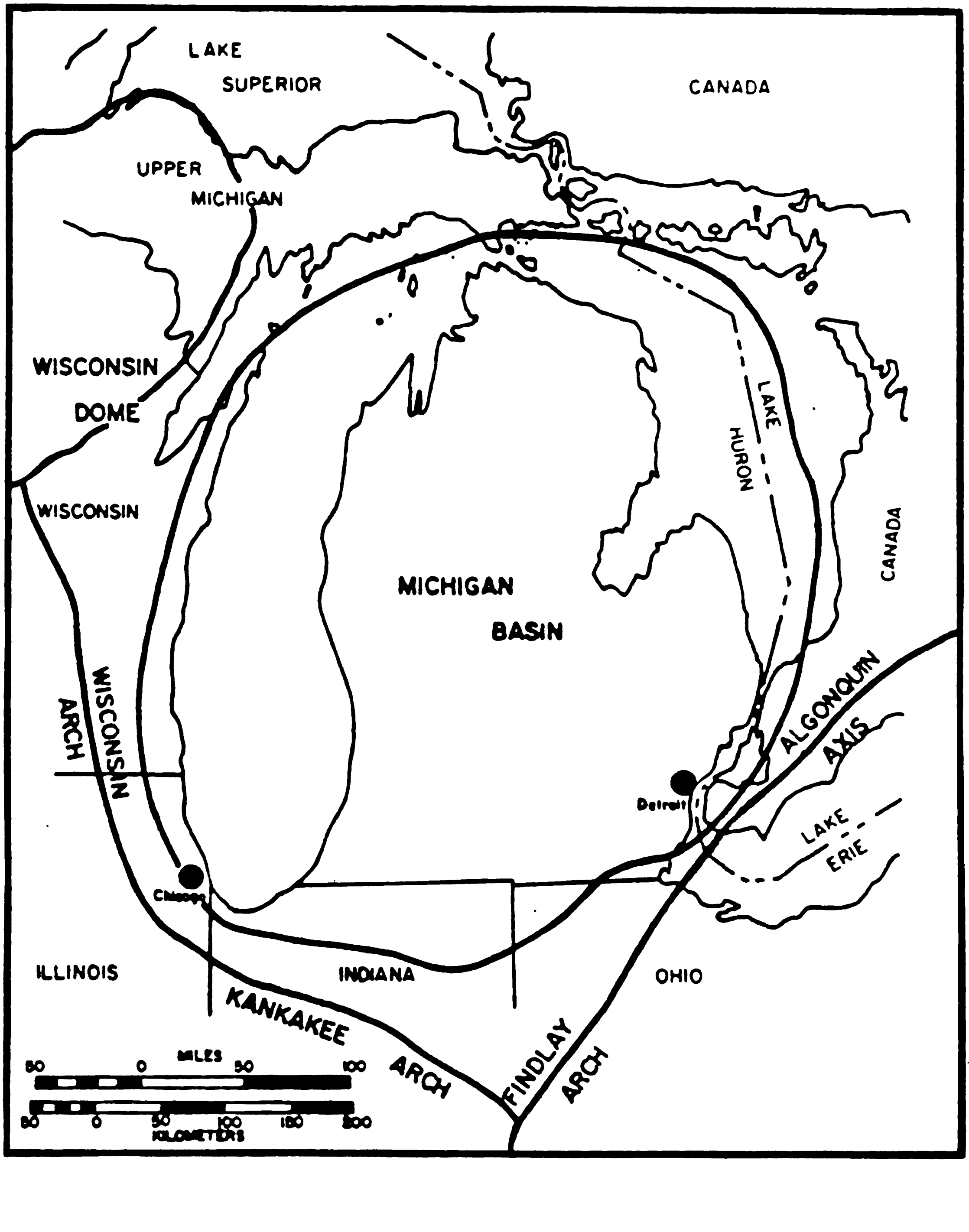


Figure 2

Regional Structure Map of Michigan and Environs time. Newcombe (1933) also believed that the inherent structure of the Michigan Basin was of Keweenawan (Precambrian) origin. He maintains that the present anticlinal trend (NW-SE) in the Basin was the result of reactions of zones of weakness developed in the basement during late Precambrian disturbances to the northeast. Lockett (1947) believed downwarping of the Basin was caused by differential sedimentary loading, causing block faulting in the basement complex. He states that the parallel pattern of structural trends in the Basin conform along basic lines of weakness in the basement rock. Cohee and Landes (1958) claim that the incipient folding (NW-SE) occurred intermittently in the Paleozoic, with the main diastrophic activity during the Lower Mississippian-pre-Pennsylvanian emergence. Green (1957) stated that the Michigan and immediately surrounding basins sank while the present bordering structures remained stable, with the age of the Michigan Basin being Niagran. Utilizing both geophysical and geological data, Hinze and Merritt (1969) believe that a major rift zone (Mid-Michigan Gravity and Magnetic High) had a dominant role in the development of the Basin. The Basin may have originated from isostatic sinking in response to the added mass of Keweenawan mafic rocks in the basement complex. Subsequent deformation within the Basin has been associated with movements along lines of basement weakness, apparently related to the rift zone.

Prouty (1970) concludes that the basic structural patterns of the Basin, including basement lineations and bordering structures, was inherited from the Upper Precambrian. Structures within the Michigan Basin (Howell Anticline, Lucas-Monroe Monocline, Albion-Scipio trend, etc.) are generally thought to be fault controlled with the faulting developing along lines of weakness in the Precambrian basement rocks, Figure 3 (Ells, 1969; Fisher, 1969; Harding, 1974). Prouty (1976) believes that lineaments gleaned from LANDSAT imagery are faults which fit a wrenching deformation model and that the folded structures of the Michigan Basin are generally related to the faults of this wrench system (Figure 4). From these lineaments, Prouty has demonstrated that many of the oil and gas fields of Michigan produce where fractures intersect (Figure 5). He indicates that it is in these cross-structures that dolomitization is apt to be most marked. Runyon (1976) states that the coincidence of the suggested faults in Ottawa and Kent Counties and Allegan County in crossing present day major structural trends and tending to fall on isolated oil fields, such as the giant Walker Field, suggest that these might also be cross-structures occurring after Traverse deposition and related to the origin of the major structural trends (Figures 4 and 5).

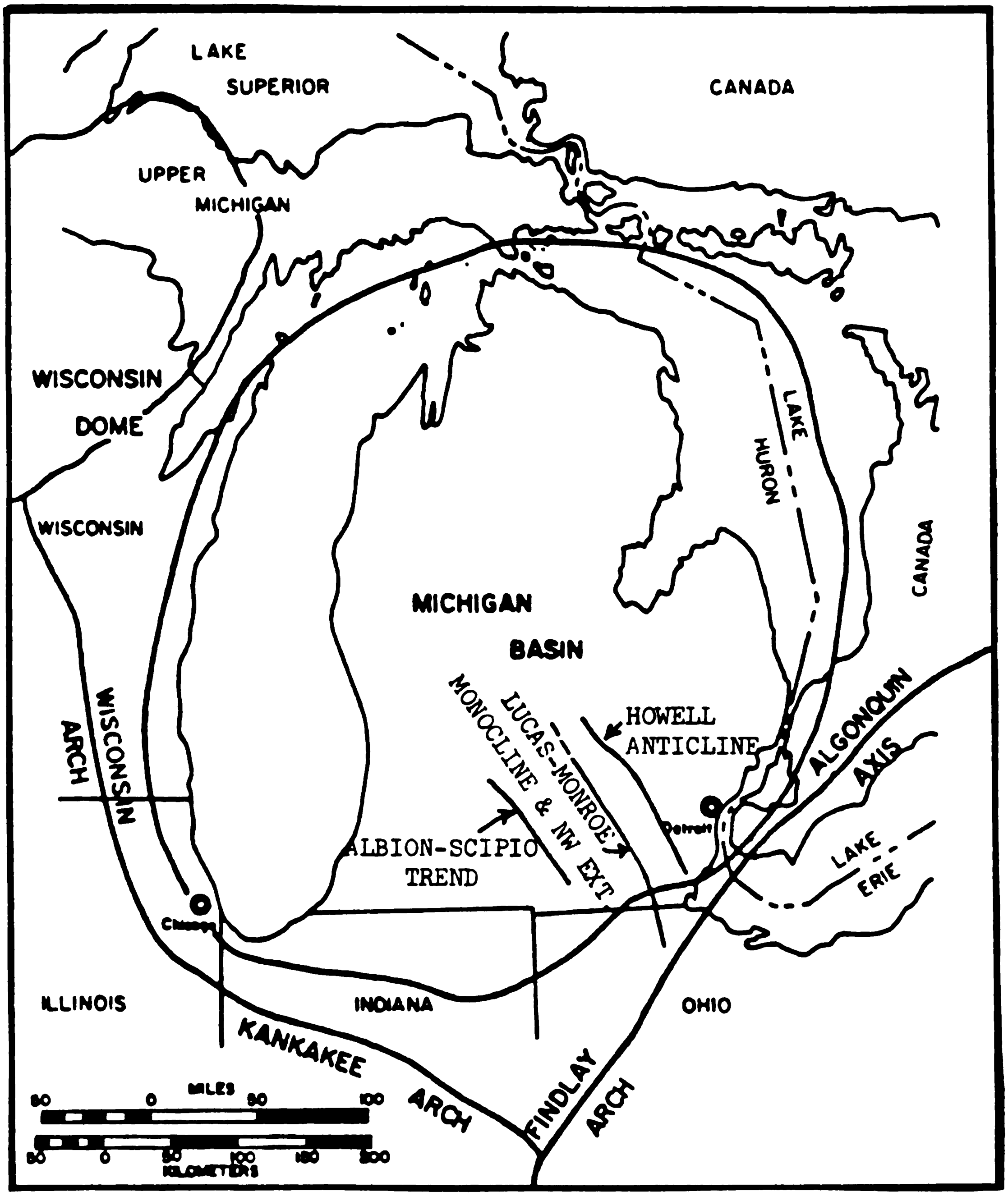


Figure 3

Regional Structure Map of Michigan
with Important Linear Structures

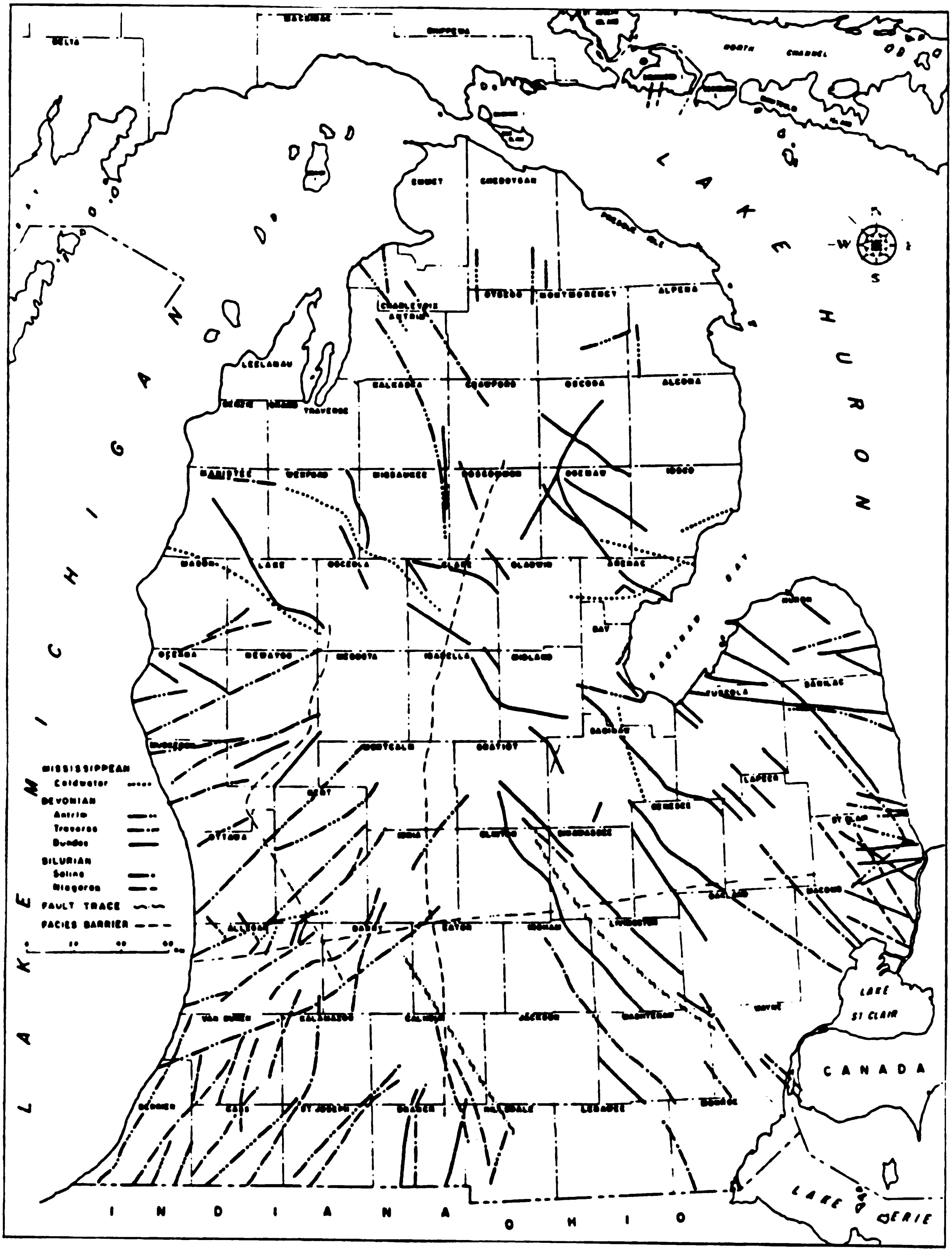


Figure 4. Major Structural Trends in the Michigan Basin (compiled by C. E. Prouty, 1971)

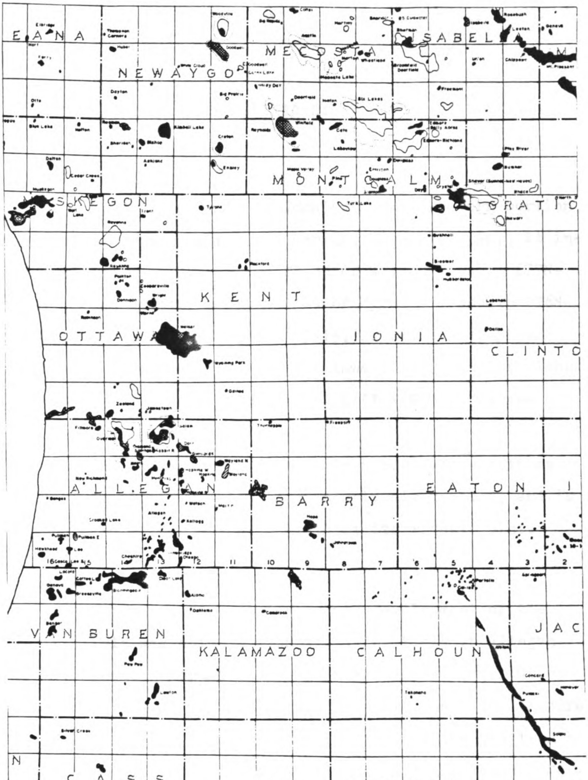


Figure 5. Southwestern Michigan Oil and Gas Fields

THE WALKER OIL FIELD

Location and Extent

The Walker Field is located in the western portion of the present greater Grand Rapids, Michigan area. It includes sections 19, 20, and 27-35 of Walker Towship (T7N-R12W), Kent County; sections 2-9 of Wyoming Township (T6N-R12W), Kent County; Sections 13-15, 22-28, and 33-36 of Tallmadge Township (T7N-R13W), Ottawa County; and sections 1, 2, and 12 of Georgetown Township (T6N-R13W), Ottawa County (Figure 6).

The Walker Field extends in a northwest-southeasterly direction for a length of nearly eight miles, and is approximately four miles in width at its widest point.

History of Development

The way to the discovery and development of the Walker Field was pointed when the Salem Field in Allegan County showed a northeast trend in the direction of Grand Rapids. The area which ultimately became the field (Figure 5) was approximately at the intersection of the two trends determined by extending the main axes of the Salem and Muskegon Fields (Newcombe, 1939). The Grand River takes a broad southward meander around the area in which doming was

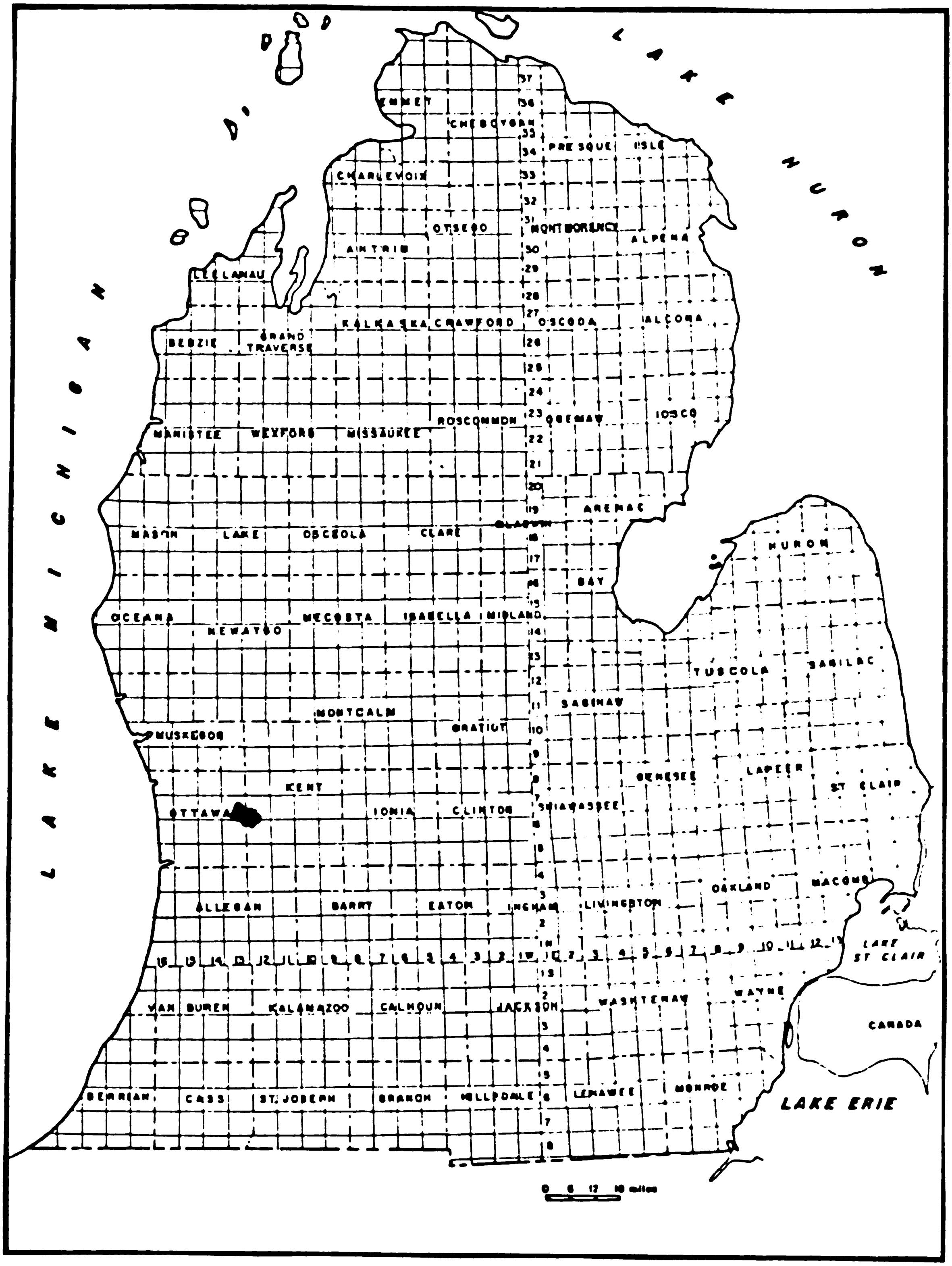


Figure 6. Location of Walker Oil Field in Michigan

thought to exist, and shallow bedrock of the Michigan formation quarried and mined near Grandville suggested comparatively strong off-structure dip and reversal. The shallow bedrock was thought to be under a region of abnormal dip because this condition had been characteristic of several Michigan producing structures (Newcombe, 1939). A structure contour map, based on data from 35 water wells and core holes and the subsurface topography of three gypsum mines, was developed on the Marshall sandstone to delineate the structure. The discovery well in the Walker Field was located in an area encircled by the highest closing Marshall contour.

The Walker Oil Field came into being with the discovery of oil on September 24, 1938, by MacCallum and Herr's L. M. Story No. 1 located in section 32 of Walker Township (T7N-R12W), Kent County. Field development started slowly until Spring, 1939, when larger producing wells were brought in approximately one-half mile east of the discovery well. Then a drilling boom began which took on major proportions by June, 1939. Because of this frenzied activity, the Walker Field was known as the "field of the year" in Michigan in 1939.

Production

The Walker Field produces from the Traverse Limestone at approximately 1,140-1,205 feet depth below sea level. The limestone section in which porosity has developed is 30-50 feet thick, but the actual pay section is much less than this. It may total 3-12 feet in thickness.

In 1940, the Walker Field was the most active field in the state with 170 producing wells completed. With drilling based on a ten acre spacing pattern, production in the field reached its peak in January, 1940, with 566,665 barrels of oil and steadily declined to 162,940 barrels of oil in December, 1940 (Grant, 1941). At the end of that year, recovery had been approximately 1,500 barrels of oil per acre.

The Walker Field is still an active field with 342 Traverse Limestone wells producing. As of the end of 1976, 784 Traverse wells had been drilled in the Walker Field, covering and area of 8,560 acres (Mich. Geol. Survey, 1977). Total production in 1976 was 112,081 barrels of oil, and the cumulative oil production for the field through 1976 was 17,042,228 barrels of oil (Mich. Geol. Survey, 1977).

Lithology

The lower twenty feet of the Traverse Formation in the Walker Field is typically a light gray to gray, shaley, slightly pyritic, fine crystalline limestone. In numerous wells throughout the field's extent and at various depth horizons in the lower twenty feet of the Traverse Formation are thin units of gypsum. These evaporite units are massive and earthy to fibrous, with some random speckling of insoluble residue materials.

The Traverse Limestone interval from the Walker Field, as examined under the binocular microscope (Appendix I), ranges from limestone to dolomite, with dolomitic limestone and calcic dolomite most prevalent. Color is gray to buff to tan brown. This fine to medium crystalline carbonate rock has associated beds of gypsum, which are typically white to buff color, massive-earthy, randomly speckled with very fine grain insoluble residues, and often slightly pyritic.

In the majority of well sample suites examined, a 5-6 feet thick bed of gypsum occurs approximately 10-15 feet below the top of the Traverse Limestone interval. This evaporite unit is usually overlain by fine to medium crystalline dolomitic limestone or calcic dolomite. More well data from the area of study is necessary to attempt successfully the generation of cross-sections through the field depicting possible facies relationships between dolomites, limestones, and evaporites.

Structure

Structural interpretation of the Walker Field was based upon a cuttings study from 133 wells and selected driller's logs. Well locations are shown in Figure 7 and well locations and depths are recorded in Appendix II.

A general structural contour map of the field on the top of the Traverse Limestone is shown in Figure 8. This map reveals a large regional anticlinal structure with a

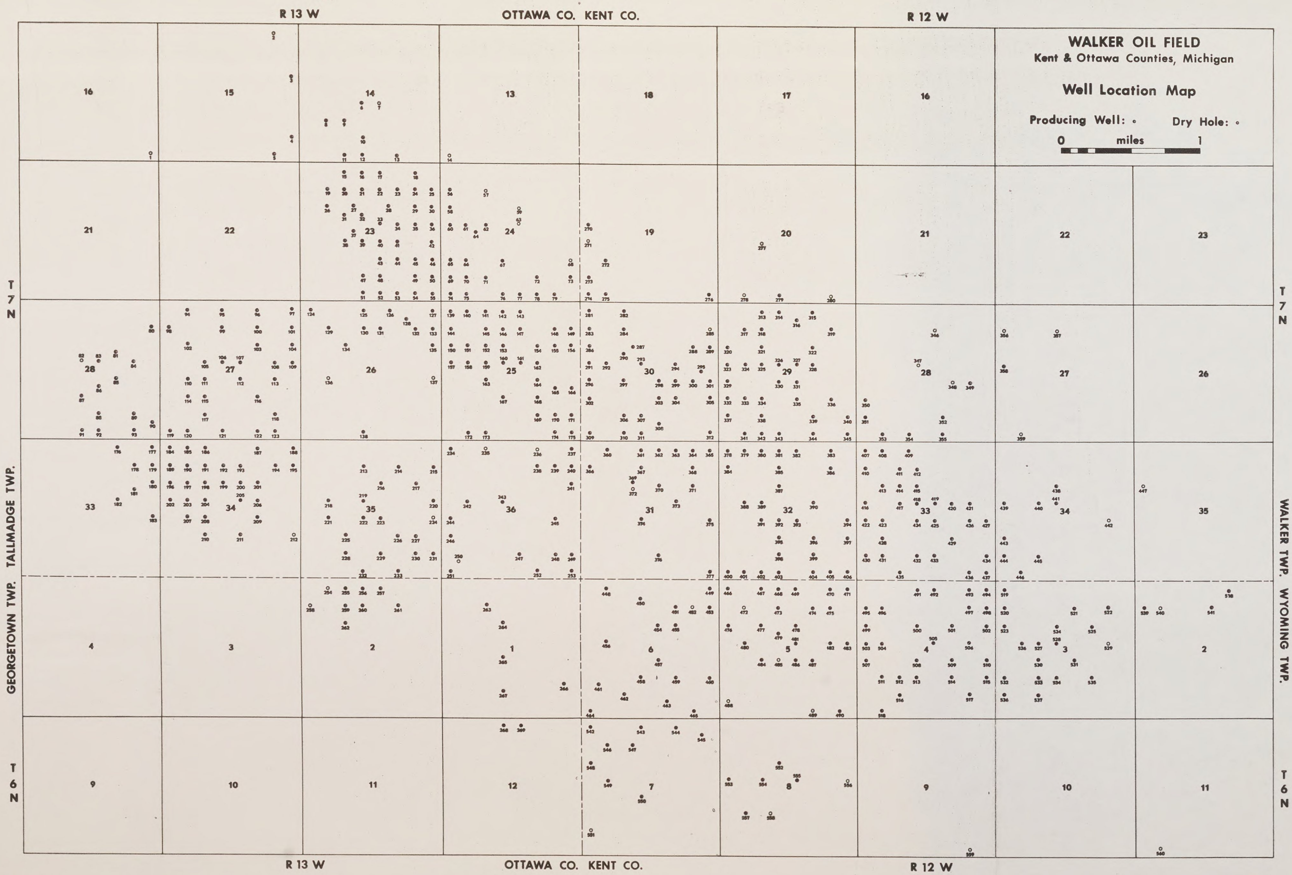


FIGURE 7. WELL LOCATION MAP

Figure 8

Structure Map on the Top of the Traverse Limestone

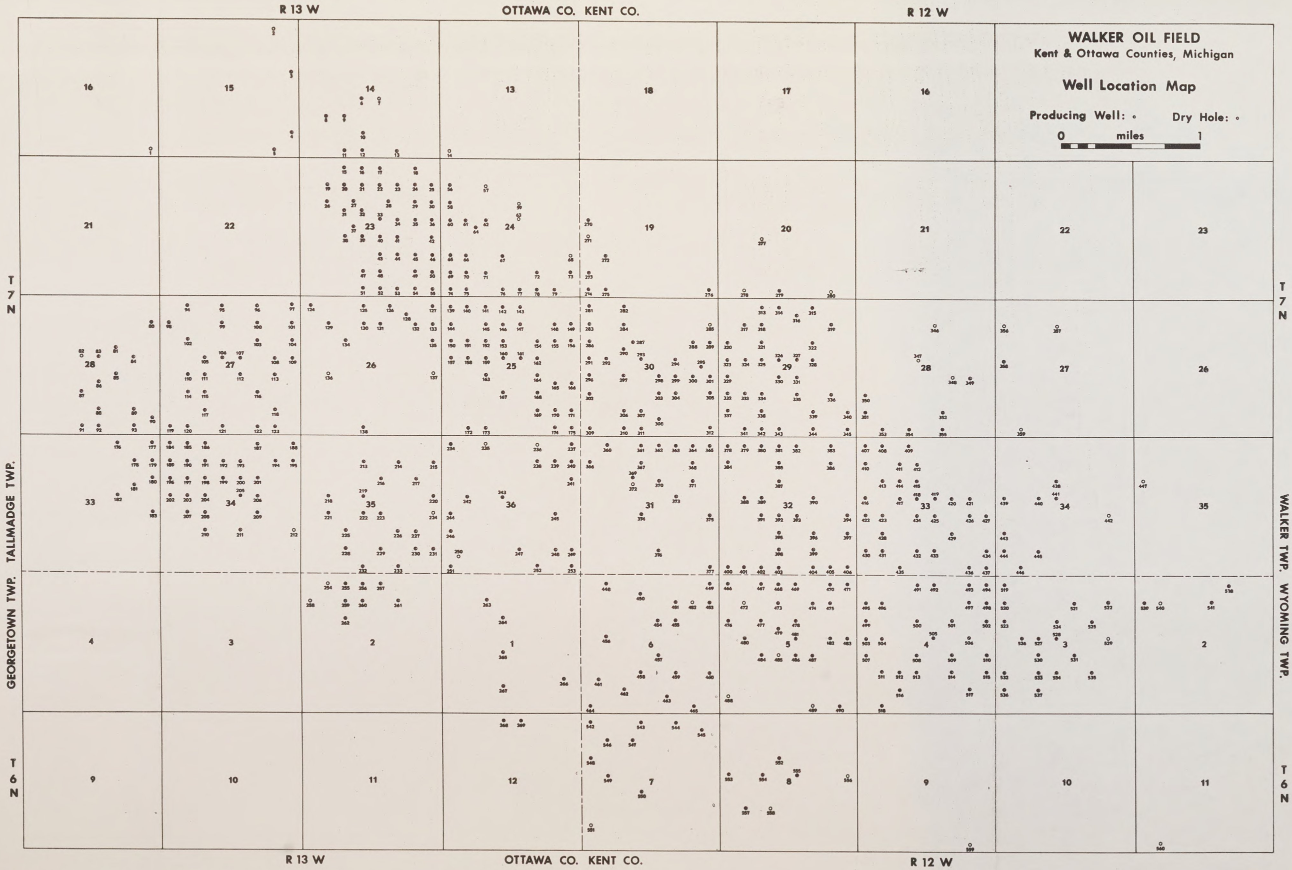
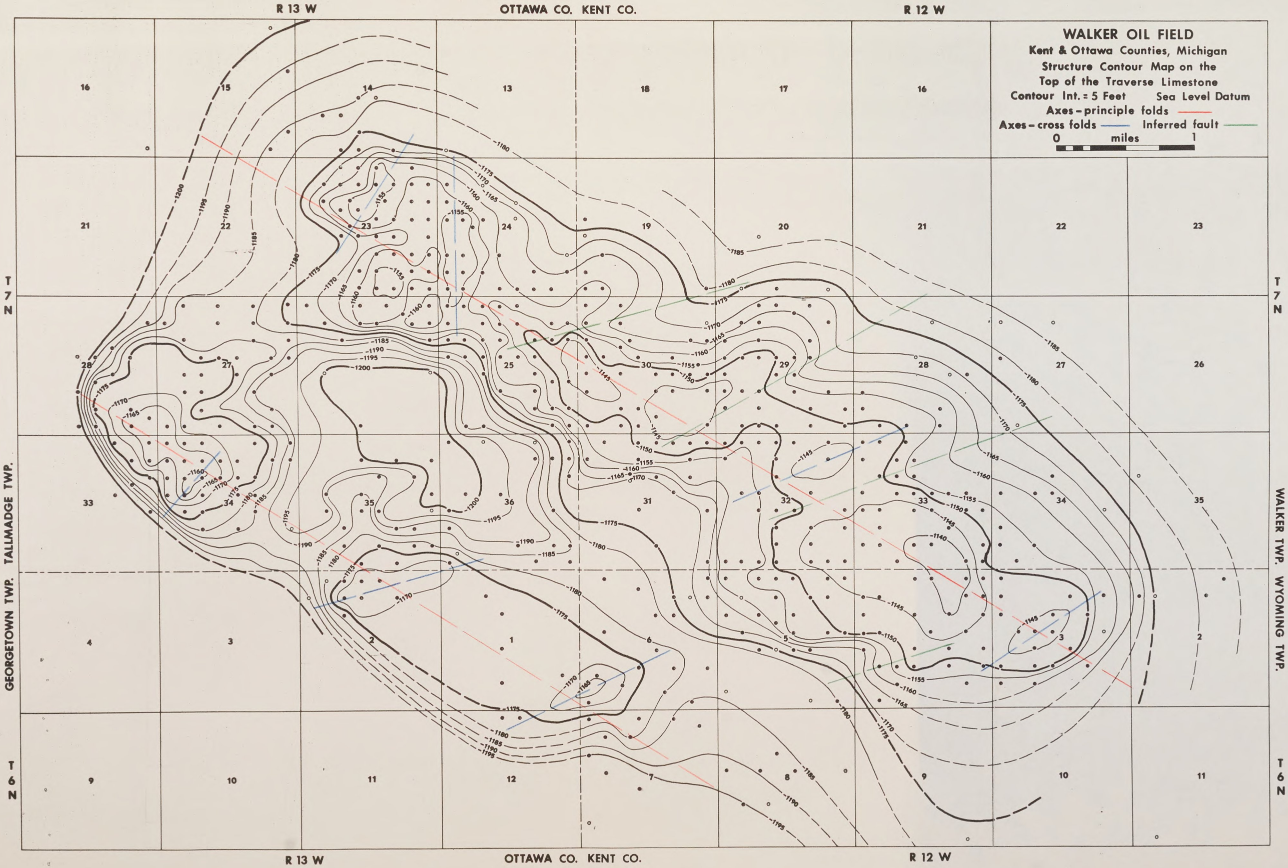


FIGURE 7. WELL LOCATION MAP

Figure 8

Structure Map on the Top of the Traverse Limestone


WALKER OIL FIELD
Kent & Ottawa Counties, Michigan
Structure Contour Map on the
Top of the Traverse Limestone
Contour Int. = 5 Feet
Sea Level Datum
Axes - principle folds
Axes - cross folds
Inferred fault
0 miles 1
R 13 W
OTTAWA CO. KENT CO.
R 12 W
T 7 N
T 6 N
GEORGETOWN TWP. TALLMADGE TWP.
WALKER TWP. WYOMING TWP.

smaller doubly-plunging anticlinal structure to the southwest and trending parallel to it. A small synclinal structure separates these two anticlinal structures. The major axes of these larger structural trends is in a northwest-southeast direction. This structural alignment is in agreement with the general structural trends of the Traverse Group in the southwestern portion of the Michigan Basin as described by Runyon (1976).

Cross-structure trends within the Traverse Limestone appear to be oriented in a general southwest-northeast direction. These trends are especially discernable on the northeast flank of the field where drag folding is observed between the -1150 to -1175 feet contour intervals. Also, a number of structural highs are oriented in a northeast-southwest direction. In a summary of structural trends within the Basin, Prouty (1970) states that there is prominent NW-SE and NE-SW folding with evident lateral faults (Figure 4). The geometry of the Traverse Limestone structure highly suggests fault-related folding in the Walker Field. On the basis of LANDSAT imagery studies, Prouty (1976) has concluded that lineaments gleaned from these studies are shear faults, that most basin folds are fault related, that the principal faulting and folding was in pre-Marshall-Mississippian time, and that the causative shearing stresses are related to structural activity in the east (Appalachian Orogeny).

LIMESTONE AND DOLOMITE ANALYSES

Experimental Procedures

Source of Samples

In subsurface geological research, the best type of sample materials for analysis are well core samples, because of known depth and lack of contamination. Rotary drill samples usually are unsatisfactory to work with because of difficultly in locating sample depth (due to down-hole contamination), whereas cable tool samples are comparatively pure and are satisfactory for depth location (Krumbein and Sloss, 1963).

The well samples utilized in this study were from cable tool sample suites from the Walker Oil Field which, among other samples, the Gulf Refining Company donated to the Department of Geology, Michigan State University.

Sample Study

Because of the lack of electric and mechanical logs from the Walker Oil Field, the top of the Traverse Limestone was picked from cuttings from 133 cable tool sample suites and selected driller's logs. The sample suites represent both producing and nonproducing wells and display a good geographical spacing throughout the field.

To check the validity of certain driller's logs for their designation of the top of the Traverse Limestone, the writer contacted two drillers who heavily participated in the field's development (John Mackey of Marne, Michigan and Orville Palmer of Allegan, Michigan). It was established that the Traverse Limestone top is an important drilling marker throughout much of the Michigan Basin and this particular top is very distinctive and is an easy call to make. Two-thirds of the sample suites examined microscopically were from wells drilled by one or the other of these two drillers. Comparison of the Traverse Limestone tops as picked by these drillers and my own interpretation varied no more than two feet in each well, with one exception.

The Traverse Limestone interval lies between the top of the Bell Shale and the base of the Traverse Formation. The top of this limestone interval was placed at the 90-100 percent level of carbonate concentration, as suggested by Runyon in his study of the Traverse Group of Michigan (1976). All well cuttings were examined under an Olympus Binocular Microscope under a 10X combination of lenses, with a maximum magnification of up to 40X. A fluorescent lamp was used as the light source. For identifying and differentiating carbonates, a mixture of 7 parts water to 1 part concentrated hydrochloric acid was utilized. Differentiation of carbonate samples followed the procedure discussed by Low (1951).

Well Sample Preparation

The well samples to be used for x-ray diffraction analyses were throughly washed with distilled water and dried. Samples representing each five foot interval below the top of the Traverse Limestone were selected and weighed to approximately 2.0 grams. Most of the well sample suites used penetrated only up to 30 feet into the Traverse Limestone upon reaching the pay zone.

X-Ray Diffraction Procedure

Conventional chemical methods utilized in the determination of limestone and dolomite percentages in particular rock specimens usually are very tedious and time consuming. The x-ray diffraction method is a newer technique that offers speed without sacrificing the accuracy and precision found in wet chemical procedures (Kutsykovich, 1971; Gunatilaka and Till, 1971). In the x-ray method, which is based on the crystal phases of dolomite and calcite, the ratio of calcite-to-dolomite is determined independently of other Mg, Ca, and other carbonate-bearing materials (Tennant and Berger, 1956). The x-ray diffraction technique is being applied by workers in various areas of geological research (Tennant and Berger, 1956; Weber, 1967; Otálora and Hess, 1969; Gunatilaka and Till, 1971; Badiozamani, 1973; Folk and Land, 1975; Supko, 1977).

The Method

The determination of the relative quantities of a multicomponent mixture by x-ray diffraction is based on the relationship between the absorptive properties of minerals and their peak intensities (Jenkins and DeVries, 1968).

The method utilized in this study consists of the measurement of the relative peak intensities of the strongest powder x-ray diffraction line for calcite and for dolomite in a series of mixtures of known proportions. A calibration curve is then constructed from these standards of known quantities or proportions, and samples of unknown composition are then compared with the calcite/dolomite standardization curve (Tennant and Berger, 1956). This procedure is primarily reliable for the determination of a quantitative ratio for the minerals present in a rock specimen. When an accurate and precise quantitative measurement of a single mineral is required, a spiking system (use of an internal standard) becomes necessary (Gunatilaka and Till, 1971).

Diffraction peak intensities are influenced by grain size, sample packing, and mineral orientation (Jenkins and DeVries, 1968). To minimize peak intensity variability, all samples x-rayed (calibration standard samples and well samples) were crushed and placed in a tungsten carbide grinding vial and ground for approximately ten minutes in a Spex 8000 Ball Mill Grinder to achieve grain size uniformity. All powdered samples were packed tightly with consistency into specially crafted sample holders of Bakelite. Sample surfaces were then smoothed off and covered with a thin Mylar strip.

Standardization Sample Preparation

In this study, previously prepared dolomite calibration standards were used. These standards were prepared by M. Dastanpour for a recently completed investigation (1977). The following two paragraphs and Table 1 are a summation describing the procedure Dastanpour followed in preparing the calibration standards.

The dolomite and calcium carbonate used in preparing the calibration standards were purchased specimens of analytical quality. The dolomite grains were soaked in 5 percent hydrochloric acid for several hours to dissolve any fine calcite crystals that might have grown between the dolomite crystals. The dolomite grains were then throughly washed with distilled water and dried.

Different proportions of dolomite and calcite were weighed to an accuracy of one tenth of one milligram. Each component was then completely mixed with another weighed component to produce the desired dolomite mixture. Table 1 illustrates the different mixtures which were prepared for use as calibration standards.

Table 1. Different Components Used for Standardization.

Weight percent dolomite	Grams Mass dolomite	Grams Mass calcite
15	0.3000	1.7000
25	0.5000	1.5000
30	0.6000	1.4000
50	1.0000	1.0000
60	1.2000	0.8000
75	1.5000	0.5000
90	1.8000	0.2000
100	2.0000	0.0000

Procedure

Once packed into sample holders, the powdered carbonate samples were placed into the x-ray diffraction goniometer and irradiated using Iron Kα radiation with Manganese filtration at 50 kilovolts and 10 milliamperes. A General Electric X-Ray Diffraction Goniometer (Model XRD-6) was utilized for the irradiation of the carbonate samples. The x-ray diffraction peaks were recorded by a strip-chart recorder (type HF, DC millivolt) with an event marker pen and multispeed chart-drive unit. A range of 200 counts per second and a time constant of 1 were used with a scan rate of 0.5° 2θ/minute and a chart speed of 75 inches per hour. All scans of $^\circ 2\theta$ were made using a 1°, 0.1° slit system.

Each calibration standard sample and each well sample was scanned twice (sample was rotated 180° in goniometer holder before second scan) and the average intensity for both calcite and dolomite was determined.

The following x-ray diffraction data was utilized in the x-ray procedure (Berry, 1974; Fang and Bloss, 1974). The interplanar spacing (d) corresponds to °2θ for various wavelengths where $°2\theta < 90°$:

	Dolomite $MgCa(CO_3)_2$	Calcite $CaCO_3$
d spacing	2.88 Å	3.03 Å
°2θ	39.14°	37.13°
File No.	11-78	5-586
Fiche No.	1-38-D10	1-18-E4

Calibration Curve

The meaning of the percentage of dolomite, as used in this study, is the percent of the total carbonate, dolomite ($MgCa(CO_3)_2$) plus calcite ($CaCO_3$), which is present as dolomite in a rock specimen. Also, the dolomite described in this study is considered an ideal dolomite. The ideal mineral dolomite is described by Goldsmith and Graf (1958) as a rhombohedral carbonate containing equal molar proportions of calcium carbonate and magnesium carbonate.

A calibration curve was constructed by plotting the dolomite/(dolomite+calcite) x 100 intensity ratio as measured versus the weight percent dolomite in the mixture

(Figure 9). Points plotted on the calibration curve were obtained by preparing three samples of each weight percent dolomite concentration and scanning each one twice (sample rotation of 180°). Each point on the curve represents the average result of six separate intensity peaks for each dolomite standard concentration.

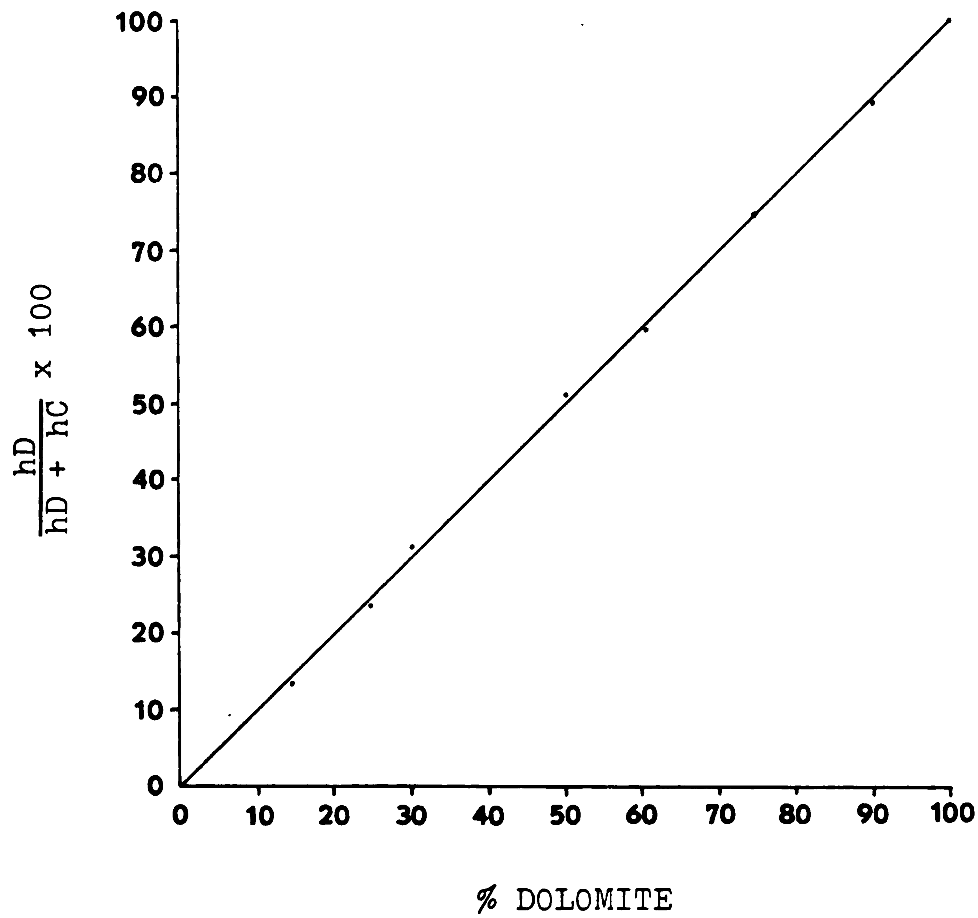
Data Calculation

The correlation coefficient between the peak intensities and the mass of dolomite percents from the calibration standard samples is 0.996 (r = 0.996). This value indicates that there is a high correlation or "good fit" between these two sets of variables. The calibration curve (Figure 9) demonstrates that the calculated peak intensity value, $\frac{hD}{hD + hC} \times 100$, represents the dolomite percent concentrated in that sample. Expressed in another way:

$$\text{Dolomite percent} = \frac{\text{Dolomite mass} \times 100}{(\text{Dolomite + Calcite}) \text{ mass}} = \frac{\text{Dolomite peak} \times 100}{(\text{Dolomite + Calcite}) \text{ peak}}$$

Each of the 315 powdered samples from 58 wells in the study area were scanned twice and the average intensity peaks for calcite and dolomite were determined. The dolomite percentage of each well sample was calculated using the following expression:

$$\text{Dolomite percent} = \frac{\text{Dolomite average peak} \times 100}{(\text{Dolomite + Calcite}) \text{ average peak}}$$



hD = Height of Dolomite Peak at 2.88 Å
hC = Height of Dolomite Peak at 3.03 Å

Figure 9. Calibration Curve of Dolomite Percent

Data Interpretation

The Traverse Limestone in the area of study was divided into intervals of 0-5, 5-10, 10-20, 20-30, and 30-40 feet below the top of the Traverse Limestone in each well that was x-rayed. Some wells do not have the lower depth intervals because these wells had reached the pay zone. Dolomite percentage for each of these depth intervals was calculated from the result of the x-ray diffraction analysis (Appendix III). Vertical and lateral variation of dolomite percent is discussed below.

Vertical Dolomite Variation

Dolomite percent values were plotted against their depth below the top of the Traverse Limestone. Typical vertical dolomitization patterns within the upper Traverse Limestone in the area of study is shown in Figure 10. Two of the wells show the highest dolomite ratios in the 0-5 feet interval, and the other two wells show the highest ratios in the 5-10 feet interval. All these wells display a distinct decrease in dolomite percentage downward from higher dolomite percentages at or near the top of the Traverse Limestone.

Bar graphs were constructed depicting the field average of dolomite percent values versus depth interval and the average percent values versus depth interval from the northwest portion and the southeast portion of the field's main structural trend (Figure 11). The bar graphs of the

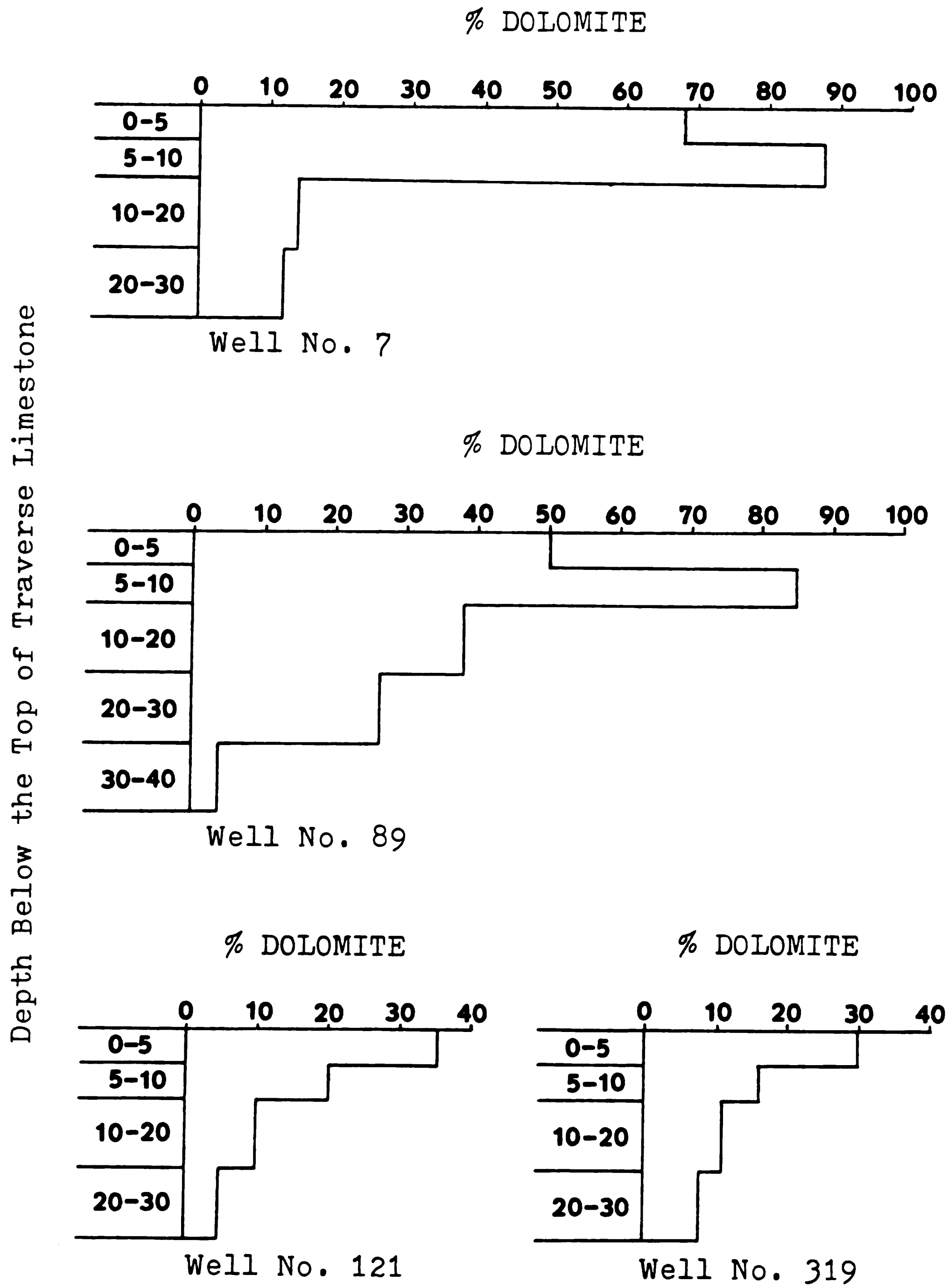


Figure 10

Typical Vertical Dolomitization Patterns
in the Traverse Limestone

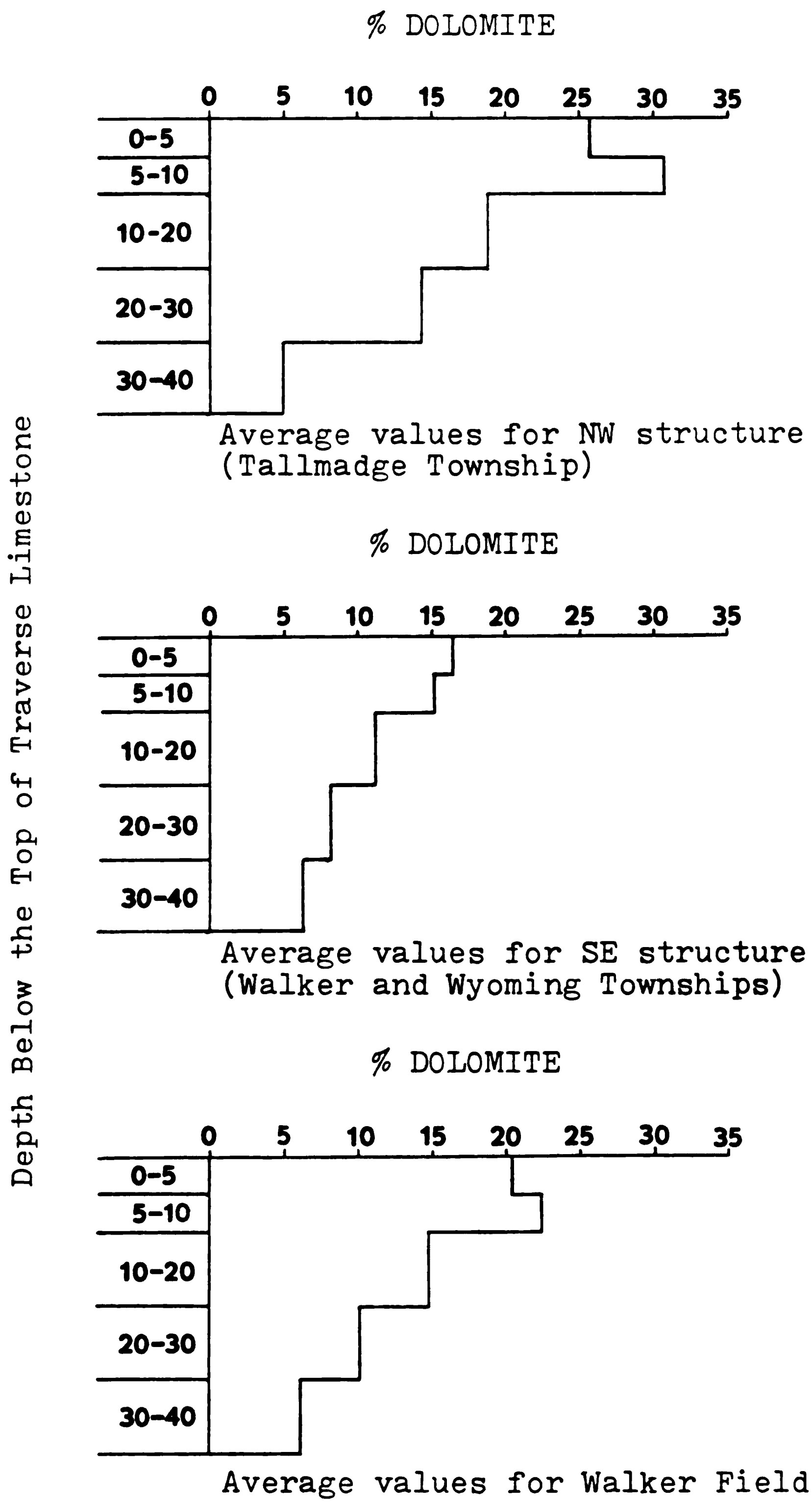


Figure 11

Average Vertical Dolomitization Patterns
in the Traverse Limestone

field average and that of the NW portion of the structural trend show the highest dolomite percent values in the 5-10 feet depth interval. The SE portion of the main structural trend shows the highest dolomite percent value in the 0-5 feet depth interval. As demonstrated in the bar graphs of individual wells, the bar graphs illustrating average dolomite percent values show a decrease in dolomite percent downward from higher dolomite percent values at or near the top of the Traverse Limestone.

Lateral Dolomite Variation

The dolomite analyses provided data for dolomite ratio maps, which indicate the relative degree of dolomitization to the Traverse Limestone structure. Dolomite percent values were plotted on the base map of the area for each of the top four depth intervals (0-5 feet, 5-10 feet, 10-20 feet, and 20-30 feet) and lines of equal dolomite percent (isodolic) were constructed. A similar map of the 30-40 feet depth interval was not constructed because of the small lateral variation demonstrated in this section.

The dolomitization patterns of each isodolic map (Figures 12, 13, 14, and 15) roughly correlate with the structural alignment of the area. With each of the isodolic maps, high dolomitization values coincide closely with a structural high located in the most westerly portion of the field. In the north-northwesterly portion of the field structure, the highest dolomitization values do not

Figure 12

Dolomite Ratio Map
0-5 Feet Below the Top of the Traverse Limestone

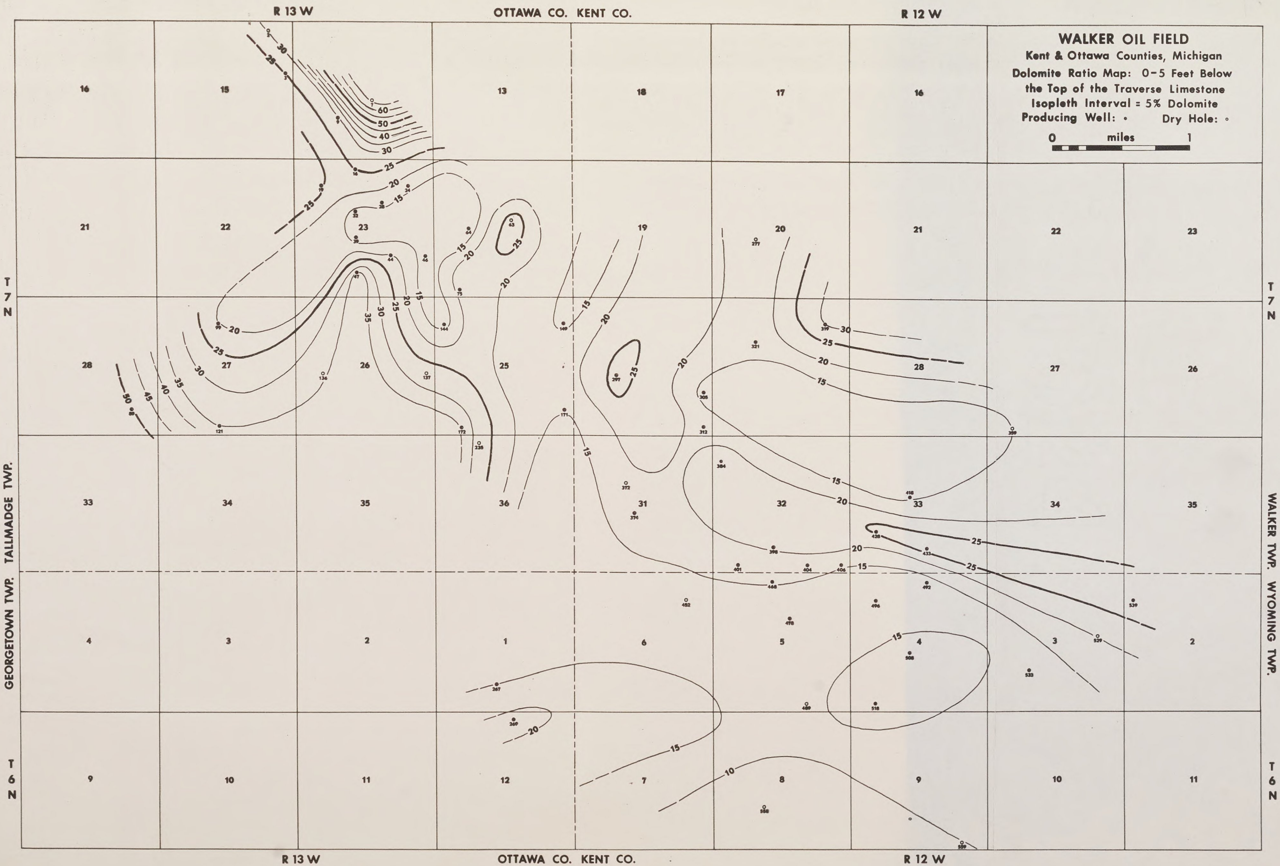

R 13 W
OTTAWA CO. KENT CO.
R 12 W
WALKER OIL FIELD
Kent & Ottawa Counties, Michigan
Dolomite Ratio Map: 0-5 Feet Below the Top of the Traverse Limestone
Isopleth Interval = 5% Dolomite
Producing Well: • Dry Hole: ◦
0 miles 1
T 7 N
T 6 N
GEORGETOWN TWP. TALLMADGE TWP.
WALKER TWP. WYOMING TWP.
R 13 W
OTTAWA CO. KENT CO.
R 12 W

Figure 13

Dolomite Ratio Map
5-10 Feet Below the Top of the Traverse Limestone

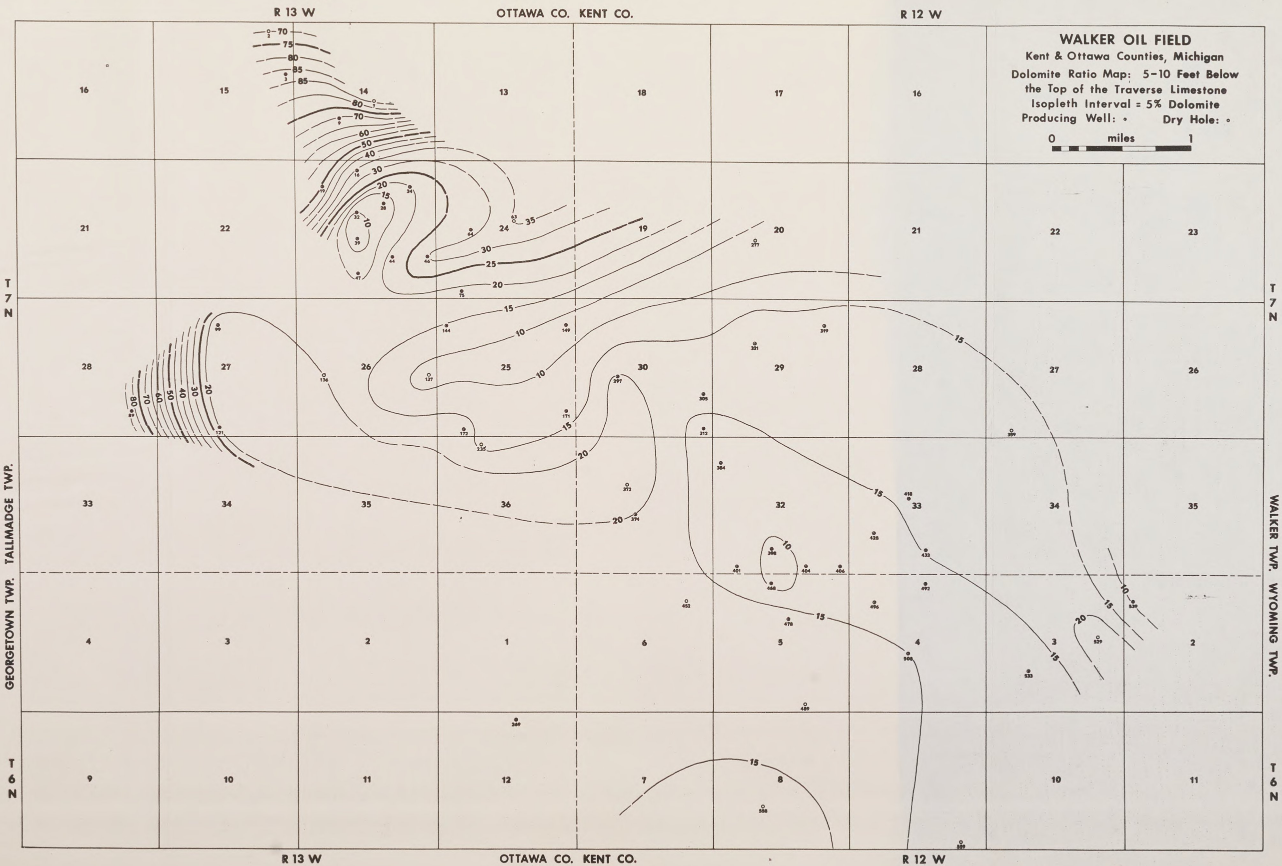

WALKER OIL FIELD
Kent & Ottawa Counties, Michigan
Dolomite Ratio Map: 5-10 Feet Below
the Top of the Traverse Limestone
Isopleth Interval = 5% Dolomite
Producing Well: •
Dry Hole: ○
0 miles 1
R 13 W
OTTAWA CO. KENT CO.
R 12 W
T 7 N
T 6 N
GEORGETOWN TWP. TALLMADGE TWP.
WALKER TWP. WYOMING TWP.
R 13 W
OTTAWA CO. KENT CO.
R 12 W

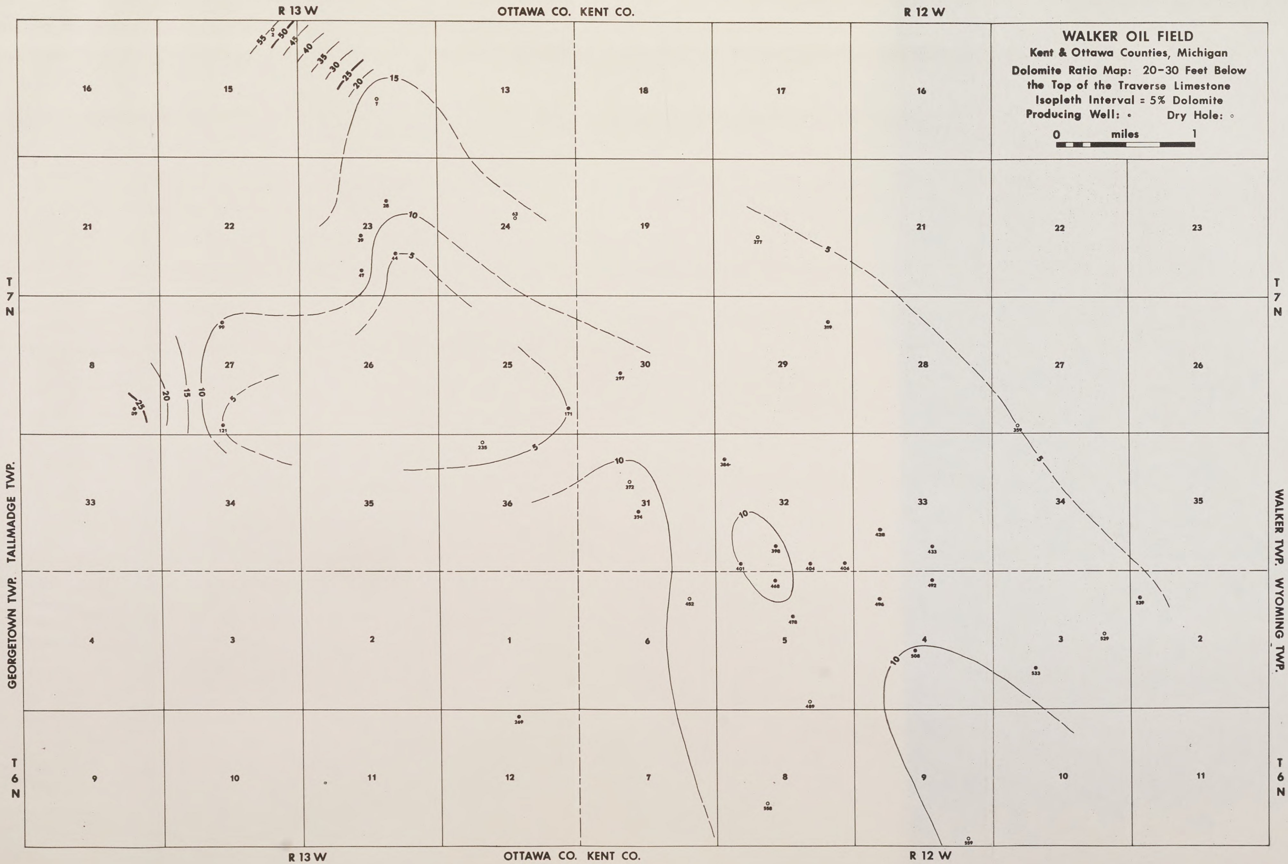
Figure 14

Dolomite Ratio Map
10-20 Feet Below the Top of the Traverse Limestone


R 13 W
OTTAWA CO. KENT CO.
R 12 W
WALKER OIL FIELD
Kent & Ottawa Counties, Michigan
Dolomite Ratio Map: 10-20 Feet Below the Top of the Traverse Limestone
Isopleth Interval = 5% Dolomite
Producing Well: •
Dry Hole: ○
0 miles 1
T 7 N
T 6 N
GEORGETOWN TWP. TALLMADGE TWP.
WALKER TWP. WYOMING TWP.
R 13 W
OTTAWA CO. KENT CO.
R 12 W

Figure 15

Dolomite Ratio Map
20-30 Feet Below the Top of the Traverse Limestone


WALKER OIL FIELD
Kent & Ottawa Counties, Michigan
Dolomite Ratio Map: 20-30 Feet Below the Top of the Traverse Limestone
Isopleth Interval = 5% Dolomite
Producing Well: •
Dry Hole: ○
0 miles 1
R 13 W
OTTAWA CO. KENT CO.
R 12 W
T 7 N
T 6 N
GEORGETOWN TWP. TALLMADGE TWP.
WALKER TWP. WYOMING TWP.
R 13 W
OTTAWA CO. KENT CO.
R 12 W

correlate with the structural high, but increase in value downdip off structure.

Isodolic maps representing the top three depth intervals (Figures 12, 13, and 14) display a number of NE-SW trends, which in some instances, closely correlate with cross-structures observed in the structure contour map. The isodolic maps of the 0-5 and 5-10 feet intervals display a N-S trend of certain isodolic contour intervals in the NW portion of the field.

Of the four isodolic maps constructed depicting lateral dolomite variation in the upper Traverse Limestone, the isodolic map representing the 0-5 feet depth interval below the top of the Traverse Limestone most closely correlates with the field's diverse structure.

Where the degree of dolomitization increases along the structural trend and the apices of folds, the inference can be made that channelways along which dolomitization occurred are related in some way to the axes (and origin) of these folds. This implies faulting and fracturing. Where dolomitization patterns do not correlate with the structural trends or folding, the dolomitization patterns might be identifying the traces of faults and fractures not expressed by folding.

Walker Field Dolomitization Models

Dolomite percent in the upper portion of the Traverse Limestone throughout the Walker Field displays a wide variation over a short distance, both vertically and laterally. Much of this limestone interval is composed of very fine to finely crystalline dolomitic limestone and calcic dolomite with associated evaporite units (gypsum). In only 7 of the 315 well samples x-rayed were the dolomite percent values over 70 percent. This dolomite was typically fine to medium crystalline. In the majority of well samples x-rayed, dolomitization values ranging from 10 percent up to 70 percent within limestone and gypsum units indicates the presence of dolomite, even though dolomite itself was not observed under the binocular microscope.

Criteria exist which point to two separate dolomitization processes which developed at different times within the upper Traverse Limestone of the Walker Field. One dolomitization process is an early diagenetic dolomitization, where Mg replacement of Ca occurs before cementation of the calcite matrix, probably penecontemporaneous with sediment deposition. The second dolomitization process is post-diagenetic in nature where a secondary, clearly epigenetic dolomite replaces calcite after cementation of the original calcite matrix.

Certain conditions are necessary for dolomitization to occur (Wilson, 1975): (1) a sufficiently porous and permeable calcareous sediment to act as host for the Mg replacement; (2) a fluid of the correct chemical composition to react, capable of dissolving $CaCO_3$ releasing Mg; (3) a long-enduring supply fo Mg; and (4) a hydrodynamic head to force great volumes of water through the sediment.

Secondary, post diagenetic dolomite is believed to exist in a number of wells in the Walker Field based on crystalline dolomite, high x-ray dolomite percent values, and a general correlation between dolomite values and the field's structure. This secondary replacement dolomite is probably brought about by ground water percolation through existing fractures in brittle carbonate rocks. Ground water in this zone percolating along joints, fractures, seams, and other post-consolidation channelways could selectively dissolve the relatively soluble calcite and precipitate dolomite.

In their study of dolomitization by ground water, Hanshaw, et al. (1971) state that the Mg/Ca ratio in aquifer water has low magnitude, where the water is undersaturated with respect to both calcite and dolomite. With time and length of travel path in the system, the water increases systematically in Mg/Ca ratio, then dolomite crystals will form. Because of the limited amount of magnesium available from the solution of magnesium calcite and dolomite in the zone of active fluid circulation, they maintain that only localized dolomitization can occur.

The source of these dolomitizing fluids necessary to produce secondary, post diagenetic dolomite could be of artesian origin from outcrops off of the Wisconsin Arch (Figure 2). The high magnesium concentration in the groundwater develops by its movement along the bedding planes of Lower Ordovician (i.e. Pairie du Chien Group) and Upper Cambrian dolomitic formations and may have migrated upwards through fault and fracture systems, dolomitizing the Traverse Limestone, among other susceptible formations.

Hydrocarbon production in stratigraphic sections of the Middle Ordovician and the Middle Devonian are primarily located in the south and southwest areas of Michigan (Figure 5). Newhart (1976) and earlier workers have postulated for Ordovician fields, and Runyon (1976) for Traverse fields, that magnesium-rich waters ascended fracture systems and were dammed by an impervious seal above, the Utica Shale in the former and the shale-rich Traverse Formation and/or the Antrim Shale in the latter. The fact that the percent dolomite in the Traverse Limestone of the Walker Field has a relatively higher at or near the top of the limestone interval beneath the limy shale of the Traverse Formation (Figures 10 and 11), indicates these shaley beds might have acted as dams to the upward percolating water.

Another possible explanation for the vertical dolomitization patterns observed in the upper portion of the Traverse Limestone could be an environmental buildup that allowed increasing dolomitization of the carbonate sediments to occur. The slow development of a shallow lagoonal or sabkha environment, for example, could be reflected in the vertical dolomitization patterns, which demonstrate an increase from low dolomite percent values in the lower depth intervals within the Traverse Limestone to significantly higher dolomite percent values at or near the top of the Traverse Limestone. These higher dolomitization values at or near the top of the Traverse Limestone might indicate the presence of a carbonate depositional environment that was more susceptible to early diagenetic dolomite replacement than earlier environmental conditions represented by dolomite percent values of the lower depth intervals within the Traverse Limestone.

A high amount of dolomite along the west side of Michigan in the Traverse Group has been noted by Gardener (1974). Others, such as Hake and Maebius (1938) indicate that various counties on the west side of Michigan contain a higher amount of dolomite than usual. Regional dolomitization of carbonate facies in western Michigan is suggested in the studies by Syrjamaki, 1977, Lower Ordovician; Newhart, 1976, Middle Ordovician; and Runyon, 1976, Middle Devonian. Some interesting parallels can be drawn between their respective studies. Stratigraphic sections from each of these studies demonstrate the same high regional dolomite trend in a north-south orientation, along western Michigan, indicating a possible close relationship to the Wisconsin Arch during Ordovician and possibly Devonian time. As regional dolomite content may indicate a shallow, near-shore environment (Prouty, 1946), the presence of a high amount of dolomite in this north-south trend in western Michigan suggests the possibility that the Wisconsin Arch might have been high and broad enough to cause shallowing of the Traverse seas along it.

Much of the upper Traverse Limestone interval of the Walker Field is composed of crystalline dolomitized limestones and calcic dolomites with associated evaporites (gypsum). The occurrence of crystalline dolomitized carbonate rock, the general lack of correlation between dolomite values of these carbonate rocks and the field structure, the the significant presence of evaporites in this stratigraphic interval, and the regional dolomite trends through the area of study tend to support the idea of early diagenetic dolomitization of some of the Traverse carbonate sediments.

Some of the dolomitization patterns observed from isodolic maps of the field could possibly be related to an early diagenetic dolomitization process, probably penecontemporaneous with sedimentation.

Adams and Rhodes (1960), Deffeyes, et al. (1965), and Illing, et al. (1965) have provided a dolomitization theory to explain early diagenetic replacement based on the development of Mg-rich brines through evaporation. These authors have proposed that dense saline brines, whose Mg/Ca ratios have been raised by the loss of Ca through evaporative precipitation of gypsum and anhydrite in tidal flats, ponds, and supratidal areas (sabkhas), have migrated regularly down through lime sediment, dolomitizing it (evaporative reflux).

Folk and Land (1975) state that an important way to precipitate dolomite is to dilute sea water or sabkha-evaporitic water with fresh water. Dilution allows the Mg/Ca ratio to remain very high, but slows the crystallization rate and reduces the concentration of competing ions. There are two ideal sites where such a mixing mechanism can take place. One site is floodable sabkhas or inundatable shallow lagoons where the salinity undergoes rapid fluctuation between hypersaline and nearly fresh water conditions. Another important site is the subsurface zone where sea water or evaporitic waters come into contact with a wedge or lens of meteoric water and salinity reduction occurs. In both of the above cases Mg is supplied by saline waters, but precipitation is permitted only by dilution with fresh water. Studies by Land (1973), Badiozamani (1973), and Land, et al. (1975) indicate that the freshwater phreatic (water table) zone, in places where some slight mixing with sea water occurs, may be an important zone of dolomitization.

The Dorag dolomitization model (Ordovician of Wisconsin) of Badiozamani (1973) illustrates the concept that saturation with respect to dolomite increases continuously with increasing sea water added to phreatic water. He calculated that in brackish water "in the range of 5-30% sea water, the solution is undersaturated with respect to calcite and many times supersaturated with respect to dolomite." His proposed model necessitates a continuous supply of Mg derived from sea water and mixing with meteoric water during constant fluctuations of sea level. During emergence, the interface where the phreatic lens of fresh water impinges on underlying marine or saline connate water would be a dolomitizing zone; this front could pass through a considerable thickness of sediment as sea level drops. The same conditions would occur during marine transgression.

In support of the idea of regional dolomitization of Traverse Group sediments in western Michigan, several writers have noted the existence of a structural barrier in the western Michigan area. In postulating the barrier's existence during Traverse Group time, Jodry (1957) cites as evidence the presence of Traverse structural contour highs, high dolomite and evaporite content to the west of it, reef development abreast of it (Paris Oil Field), and a lithofacies change from a lagoonal environment on the west side of the barrier to an open sea environment east of the barrier. As additional evidence to delineate this barrier, Jodry utilized a regional gravity map of Michigan by Logue (Tulsa Geological Society Digest, volume 18, 1950). The map shows the major regional gravity anamoly in Michigan to lie along the axis of the postulated West Michigan "Barrier" (Figure 16). Jodry further states that by projecting the barrier from areas of better control, it appears to pass directly through the Walker-Wyoming Park fields. Gardener (1974), in his Middle Devonian study of the Michigan Basin,

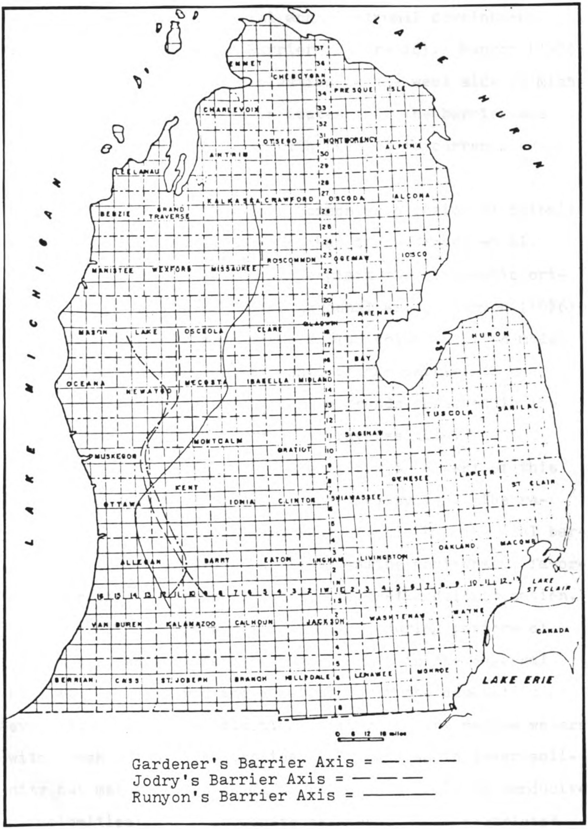


Figure 16. West Michigan Barrier Axes

indicates a linear biohermal and biostromal development along this West Michigan Barrier (Figure 16). Runyon (1976) suggests that the lack of clastics on the west side of Michigan during Traverse time indicates that the barrier was probably a physical barrier with respect to currents (Figure 16).

Gardener (1974), on a common association of dolomite below anhydrite beds, suggests that the Deffeyes et al. evaporative reflux model could explain the diagenetic origin of these sediments in the lagoonal area. Runyon (1976) believes a evaporative-seepage reflux dolomitization model helps to explain the relationship of the barrier to the limestone, dolomite, and evaporite trends observed in the western part of the Basin during Traverse time.

The Walker Field could possibly be a part of this hypothetical barrier-backwater lagoonal system. The restricted nature of the waters west of this hypothetical barrier could have developed a highly saline environment favorable for the occurrence of early diagenetic dolomitization. High salinity levels would be enhanced during periods of slight regression, where the water level in the lagoonal area would be lowered and possibly favor the deposition of evaporites. Periodic flushing of these marine saline waters with fresh water (i.e. tropical rainfall) would lower salinity but maintain a high Mg/Ca ratio that would be conducive to dolomitization of carbonate sediments. The restricted nature of this lagoonal area could have been augmented by the presence of the Wisconsin Arch to the west (Figure 2).

Due to the absence of core samples from the upper Traverse Limestone of the Walker Oil Field, there was no direct petrographic evidence available with which to postulate which dolomitization process (early diagenetic or epigenetic) was primarily responsible for the development of porosity and permeability in the Traverse Limestone pay zone(s). Petrographic analysis of the total carbonate rock fabric is necessary to successfully attempt the determination of the timing of dolomite replacement and its timing relative to other diagenetic events that could have occurred, such as anhydrite replacement, silicification, and calcite cementation(s).

Utilizing evidence compiled during this study, it appears that early diagenetic dolomitization occurred penecontemporaneously with the deposition of the Traverse Limestone. Secondary, post-diagenetic dolomitization of portions of the Traverse Limestone could possibly have occurred contemporaneously with or after Basin faulting during post-Osagean-Mississippian time caused by shearing stresses from the east.

CONCLUSIONS

From the analytical data obtained from the Middle Devonian Traverse Limestone rocks, certain conclusions can be drawn:

(1) The highest values of dolomite percent were found at or near the top of the Traverse Limestone.

(2) There is a general correlation between the dolomitization patterns and the structural configuration of the Traverse Limestone interval in the Walker Field.

(3) A few high dolomite percentage value locations occur outside of the fold closure area of the Walker Field and therefore are likely located on faults or fractures where epigenetic dolomitization has occurred.

(4) Widespread, crystalline dolomitic limestone is associated with significant amounts of gypsum. This type of dolomite is probably the result of early diagenetic dolomitization and is likely penecontemporaneous with sedimentation.

(5) Folding, fracturing, and solution activity are the major causes for the secondary porosity in the pay zone(s) of the Traverse Limestone of the Walker

Field.

(6) Dolomite percentage determinations can be helpful in detecting fault traces in folded structures in the Traverse Limestone that may otherwise go undetected.

(7) There appears to be a good correlation between faults and folds in the Traverse Limestone of the Walker Oil Field, and the relationship is probably a "cause and effect" relationship.

(8) The carbonate and evaporitic facies of the upper Traverse Limestone in the Walker Field appear to be related in some way to the hypothesized West Michigan Barrier.

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APPENDICES

APPENDIX I

SAMPLE WELL DESCRIPTIONS

APPENDIX I

SAMPLE WELL DESCRIPTIONS

Well Name: R. Terpstra No. 1

Location: NW-NE-NE Sec. 15, T7N-R13W

Permit No. 8418

Elevation: 665 feet above sea level

Traverse Formation

1842-50	Ls, shy, gy, vf-f xll, fos (90%); gyp, brn, fib, pyr (9%); tr sh, bl gn; tr bent.
1850-55	Ls, shy, lt gy-gy, vf xll, fos (95%); gyp, gy brn, fib (5%); tr pyr.
1855-62	Ls, shy, gy, vf xll, sl pyr.
1862-67	Ls, dol, gy, vf-f xll, fos (85%); gyp, wh-brn, rthy-fib, tr cht, wh-lt gy, porcel; tr pyr.

Top of Traverse Limestone

1867-70	Dol, calc, buff-gy, f-m xll (85%); gyp, wh, rthy-mas, spec; tr pyr; tr cht, wh, porcel.
1870-77	Dol, calc, buff-tan brn, f-m xll (60%); gyp, wh-buff, mot, rthy-fib; tr sh, gy.
1877-82	Dol, gy, f-m xll (90%); gyp, wh, rthy-mas, spec (10%); tr cht, wh, porcel.
1882-86	Dol, gy-tan brn, f-m xll (50%); gyp, wh, rthy-mas (50%).

Appendix I - Continued.

Well Name: S. Kuiper No. 1

Location: SE-SW-SW Sec. 25, T7N-R13W

Permit No. 6617

Elevation: 686 feet above sea level

Traverse Formation

1838-52	Ls, shy, gy, vf xll (70%); gyp, gy-brn, mas-fib, sft (30%).
1852-57	Ls, shy, lt gy-gy, vf xll (80%); gyp, lt gy, mas, sft (20%).
1857-64	Ls, shy, lt gy, vf xll (99%); tr pyr.
1864-72	Ls, shy, lt gy, vf xll (100%).

Top of Traverse Limestone

1873-79	Dol, buff, f-m xll (45%); gyp, dol, m-dk gy, mas, spec (35%); sh, lmy, gy (20%), tr pyr.
1879-85	Gyp, wh-gy, spec (80%); ls, coralline, wh-buff, f xll; tr pyr; tr cht, wh; tr qtz; clr, f gr, subang; tr bent, gn gy.
1885-92	Gyp, lmy, wh-buff, mas-fib, spec (95%); sh, gn gy-dk gy (5%); tr ls, coralline, wh.

APPENDIX II

LIST OF WELLS USED IN STUDY

APPENDIX II

LIST OF WELLS USED IN STUDY

Well No.	Permit No.	Section Location	Ground Elev.	Traverse Ls Top	Traverse Ls Top S.L. Datum
Ottawa County, Tallmadge Township, T7N, R13W					
Section 16					
1	6801	SE-SE-SE	729	-1996	-1267
Section 15					
2	8418	NW-NE-NE	665	-1867	-1202
3	9542	CE/2-SE-NE	677	-1871	-1194
4	9851	NE-SE-SE	683	-1867	-1184
5	7887	SW-SE-SE	667	-1850	-1183
Section 14					
6	7699	NE-NE-SW	691	-1877	-1186
7	8287	NW-NW-SE	695	-1875	-1180
8	7695	SE-NW-SW	677	-1861	-1184
9	7318	SW-NE-SW	665	-1848	-1183
10	7825	NE-SE-SW	688	-1863	-1175
11	8424	SW-SE-SW	693	-1870	-1177
12	7768	SE-SE-SW	692	-1865	-1173
13	7995	SE-SW-SE	691	-1861	-1170
Section 13					
14	7533	SW-SW-SW	692	-1867	-1175
Section 23					
15	8211	NW-NE-NW	695	-1864	-1169
16	7720	NE-NE-NW	691	-1856	-1165
17	7745	NW-NW-NE	694	-1850	-1156
18	7858	NW-NE-NE	684	-1835	-1151
19	7717	SE-NW-NW	695	-1866	-1171

Well No.	Permit No.	Section Location	Ground Elev.	Traverse Ls Top	Traverse Ls Top S.L. Datum

Ottawa County, Tallmadge Township, T7N, R13W

Section 23

20	7605	SW-NE-NW	694	-1858	-1164
21	7637	SE-NE-NW	693	-1855	-1162
22	7681	SW-NW-NE	694	-1846	-1152
23	7578	SE-NW-NE	699	-1854	-1155
24	7263	SW-NE-NE	693	-1856	-1163
25	7378	SE-NE-NE	692	-1854	-1162
26	7600	NE-SW-NW	695	-1853	-1158
27	7570	CN/2-SE-NW	697	-1850	-1153
28	7447	CN/2-SW-NE	695	-1854	-1159
29	7418	NW-SE-NE	694	-1858	-1164
30	7412	NE-SE-SE	699	-1862	-1163
31	7752	CW/2-SE-NW	697	-1853	-1156
32	7411	CE/2-SE-NW	694	-1844	-1150
33	7630	SW-SW-NE	692	-1850	-1158
34	7631	SE-SW-NE	690	-1850	-1160
35	7569	SW-SE-NE	688	-1852	-1164
36	7518	SE-SE-NE	702	-1863	-1161
37	7581	S/2-S/2-SE-NW	695	-1850	-1155
38	7649	NW-NE-SW	688	-1863	-1175
39	7579	NE-NE-SW	694	-1858	-1164
40	7650	NW-NW-SE	694	-1862	-1168
41	7552	NE-NW-SE	691	-1853	-1162
42	7329	NE-NE-SE	709	-1870	-1161
43	8348	SW-NW-SE	693	-1852	-1159
44	7469	SE-NW-SE	691	-1849	-1158
45	7422	SW-NE-SE	697	-1861	-1164
46	7328	SE-NE-SE	711	-1870	-1159
47	8522	NE-SE-SW	689	-1850	-1161
48	7932	NW-SW-SE	693	-1845	-1153
49	7367	NW-SE-SE	703	-1862	-1159
50	7241	NE-SE-SE	714	-1871	-1157
51	8131	SE-SE-SW	687	-1846	-1159
52	7764	SW-SW-SE	691	-1845	-1154
53	7677	SE-SW-SE	690	-1843	-1153
54	7239	SW-SE-SE	699	-1863	-1164
55	7240	SE-SE-SE	716	-1877	-1161

Section 24

56	7601	SW-NW-NW	714	-1873	-1159
57	7265	SW-NE-NW	746	-1919	-1173
58	7452	NW-SW-NW	719	-1881	-1162
59	7214	NW-SW-NE	752	-1923	-1171
60	7532	SW-SW-NW	717	-1885	-1168

Well No.	Permit No.	Section Location	Ground Elev.	Traverse Ls Top	Traverse Ls Top S.L. Datum

Ottawa County, Tallmadge Township, T7N, R13W

Section 24

61	7291	SE-SW-NW	733	-1901	-1168
62	7051	SW-SE-NW	754	-1913	-1159
63	7285	SW-SW-NE	754	-1918	-1164
64	7215	CW/2	757	-1916	-1159
65	7203	SW-NW-SW	717	-1884	-1167
66	7204	SE-NW-SW	720	-1891	-1171
67	7302	SE-NE-SW	720	-1881	-1161
68	8151	SE-NE-SE	739	-1909	-1170
69	7202	NW-SW-SW	712	-1880	-1168
70	7170	NE-SW-SW	705	-1873	-1168
71	7266	NW-SE-SW	705	-1863	-1158
72	7423	NE-SW-SE	754	-1916	-1162
73	7762	NE-SE-SE	740	-1905	-1165
74	7206	SW-SW-SW	710	-1875	-1165
75	7151	SE-SW-SW	698	-1862	-1164
76	7183	SE-SE-SW	711	-1868	-1157
77	7252	SW-SW-SE	726	-1885	-1159
78	7074	SE-SW-SE	748	-1908	-1160
79	7150	SW-SE-SE	748	-1910	-1162

Section 28

80	22008	SE-NE-NE	718	-1910	-1192
81	22020	CE/2-SW-NE	712	-1901	-1189
82	23963	SE-SE-NW	701	-1904	-1203
83	22202	SW-SW-NE	706	-1901	-1195
84	6317	SW-SE-NE	736	-1910	-1174
85	19562	NE-NW-SE	724	-1904	-1180
86	22829	CW/2-NW-SE	710	-1888	-1178
87	23042	SE-NE-SW	671	-1869	-1198
88	22612	NW-SW-SE	715	-1887	-1172
89	7331	NW-SE-SE	686	-1852	-1166
90	22389	CE/2-SE-SE	673	-1836	-1163
91	24122	SE-SE-SW	641	-1842	-1201
92	7730	SW-SW-SE	688	-1866	-1178
93	8581	SW-SE-SE	673	-1833	-1160

Section 27

94	23028	NE-NW-NW	622	-1806	-1184
95	22947	NE-NE-NW	648	-1832	-1184
96	2187	NE-NW-NE	679	-1860	-1181
97	20161	NE-NE-NE	672	-1846	-1174
98	22105	SW-NW-NW	699	-1887	-1188

Well No.	Permit No.	Section Location	Ground Elev.	Traverse Ls Top	Traverse Ls Top S.L. Datum

Ottawa County, Tallmadge Township, T7N, R13W

Section 27

99	6675	SE-NE-NW	612	-1796	-1184
100	22120	SE-NW-NE	663	-1843	-1180
101	20350	SE-NE-NE	677	-1850	-1173
102	22091	NE-SW-NW	670	-1853	-1183
103	20218	NE-SW-NE	677	-1859	-1182
104	20432	NE-SE-NE	666	-1849	-1183
105	22572	SW-SE-NW	617	-1794	-1177
106	22689	SE-SE-NW	639	-1815	-1176
107	19852	SW-SW-NE	612	-1789	-1177
108	22979	SW-SE-NE	669	-1848	-1179
109	23014	SE-SE-NE	655	-1842	-1187
110	19668	NE-NW-SW	682	-1854	-1172
111	19449	NW-NE-SW	628	-1799	-1171
112	19970	NW-NW-SE	610	-1787	-1177
113	23055	NW-NE-SE	624	-1813	-1189
114	19559	SE-NW-SW	619	-1792	-1173
115	19492	SW-NE-SW	605	-1776	-1171
116	21937	SE-NW-SE	679	-1869	-1190
117	21212	NW-SE-SW	649	-1828	-1179
118	21361	NW-SE-SE	672	-1862	-1190
119	8140	SW-SW-SW	606	-1766	-1160
120	8677	SE-SW-SW	636	-1809	-1173
121	6293	SE-SE-SW	661	-1834	-1173
122	7165	SE-SW-SE	717	-1897	-1180
123	21263	SW-SE-SE	682	-1866	-1184

Section 26

124	20280	NW-NW-NW	676	-1849	-1173
125	8409	NE-NE-NW	685	-1842	-1157
126	7535	CN/2-NW-NE	688	-1847	-1159
127	7171	NE-NE-NE	699	-1857	-1158
128	7292	CN/2-CN/2-NE	689	-1848	-1159
129	20489	SE-NW-NW	676	-1846	-1170
130	8629	SE-NE-NW	682	-1840	-1158
131	15831	SW-NW-NE	685	-1845	-1160
132	7262	SW-NE-NE	685	-1841	-1156
133	7172	SE-NE-NE	689	-1845	-1156
134	22262	NW-SE-NW	680	-1860	-1180
135	15532	NE-SE-NE	682	-1850	-1168
136	6998	NE-NW-SW	643	-1845	-1202
137	7175	NE-NE-SE	665	-1870	-1205
138	20567	SE-SE-SW	671	-1872	-1201

Well No.	Permit No.	Section Location	Ground Elev.	Traverse Ls Top	Traverse Ls Top S.L. Datum

Ottawa County, Tallmadge Township, T7N, R13W

Section 25

139	7142	NW-NW-NW	702	-1867	-1165
140	7235	NE-NW-NW	701	-1861	-1160
141	7277	NW-NE-NW	697	-1852	-1155
142	7859	NE-NW-NW	702	-1860	-1158
143	7181	NW-NW-NE	710	-1863	-1153
144	7078	SW-NW-NW	688	-1851	-1163
145	7207	SW-NE-NW	680	-1842	-1162
146	7155	SE-NE-NW	697	-1852	-1155
147	7140	SW-NW-NE	682	-1837	-1155
148	6937	SW-NE-NE	734	-1892	-1158
149	6938	SE-NE-NE	735	-1890	-1155
150	7143	NW-SW-NW	687	-1862	-1175
151	7236	NE-SW-NW	672	-1846	-1174
152	7276	NW-SE-NW	681	-1845	-1164
153	7085	NE-SE-NW	685	-1848	-1163
154	6979	NE-SW-NE	709	-1858	-1149
155	6861	NW-SE-NE	717	-1869	-1152
156	6860	NE-SE-NE	731	-1876	-1145
157	7397	SW-SW-NW	666	-1850	-1184
158	7237	SE-SW-NW	666	-1844	-1178
159	7121	SW-SE-NW	668	-1840	-1172
160	6895	SE-SE-NW	689	-1848	-1159
161	6981	SW-SW-NE	676	-1833	-1157
162	6845	SE-SW-NE	701	-1851	-1150
163	7157	NW-NE-SW	680	-1855	-1175
164	6741	NE-NW-SE	692	-1849	-1157
165	6953	CW/2-NE-SE	694	-1845	-1151
166	6106	CE/2-NE-SE	711	-1854	-1143
167	6942	SE-NE-SW	682	-1845	-1163
168	6795	SE-NW-SE	688	-1851	-1163
169	6949	NE-SW-SE	686	-1846	-1160
170	6781	NW-SE-SE	680	-1835	-1155
171	6654	NE-SE-SE	699	-1848	-1149
172	6617	SE-SW-SW	686	-1873	-1187
173	7238	SW-SE-SW	670	-1860	-1190
174	6657	SW-SE-SE	680	-1853	-1173
175	6525	SE-SE-SE	674	-1833	-1159

Section 33

176	22063	NE-NW-NE	681	-1854	-1173
177	8232	NE-NE-NE	657	-1820	-1163
178	8360	SW-NE-NE	656	-1828	-1172
179	8340	SE-NE-NE	643	-1806	-1163

Well No.	Permit No.	Section Location	Ground Elev.	Traverse Ls Top	Traverse Ls Top S.L. Datum
Ottawa County, Tallmadge Township, T7N, R13W					
Section 33					
180	8342	NE-SE-NE	635	-1810	-1175
181	22989	W/2-SE-NE	621	-1802	-1181
182	22827	SE-SW-NE	617	-1820	-1203
183	21891	NE-NE-SE	618	-1815	-1197
Section 34					
184	8209	NW-NW-NW	602	-1764	-1162
185	8313	NE-NW-NW	632	-1800	-1168
186	8139	NW-NE-NW	638	-1806	-1168
187	21187	NE-NW-NE	678	-1848	-1170
188	22102	NE-NE-NE	663	-1849	-1186
189	8189	SW-NW-NW	597	-1763	-1166
190	8201	SE-NW-NW	630	-1793	-1163
191	8071	SW-NE-NW	663	-1825	-1162
192	8391	SE-NE-NW	679	-1846	-1167
193	8458	SW-NW-NE	672	-1844	-1172
194	20864	SW-NE-NE	696	-1876	-1180
195	20780	SE-NE-NE	679	-1870	-1191
196	8273	NW-SW-NW	622	-1789	-1167
197	8093	NE-SW-NW	625	-1785	-1160
198	8002	NW-SE-NW	647	-1807	-1160
199	7854	NE-SE-NW	675	-1840	-1165
200	7694	NW-SW-NE	686	-1857	-1171
201	21238	NE-SW-NE	713	-1888	-1175
202	8338	SW-SW-NW	604	-1772	-1168
203	8374	SE-SW-NW	635	-1795	-1160
204	8339	SW-SE-NW	650	-1817	-1167
205	7933	SW-SW-NE	710	-1888	-1178
206	21375	SE-SW-NE	689	-1871	-1182
207	8481	NE-NW-SW	639	-1811	-1172
208	8676	NW-NE-SW	676	-1852	-1176
209	23515	NE-NW-SE	674	-1860	-1186
210	21814	SW-NE-SW	617	-1796	-1179
211	21569	SW-NW-SE	609	-1793	-1184
212	8425	SE-NE-SE	610	-1806	-1196
Section 35					
213	21314	SE-NE-NW	665	-1870	-1205
214	21152	SE-NW-NE	703	-1910	-1207
215	21399	SE-NE-NE	702	-1905	-1203
216	21084	NW-SW-NE	680	-1867	-1187
217	21335	NW-SE-NE	732	-1927	-1195

Well No.	Permit No.	Section Location	Ground Elev.	Traverse Ls Top	Traverse Ls Top S.L. Datum

Ottawa County, Tallmadge Township, T7N, R13W

Section 35

218	14981	SE-SW-NW	719	-1906	-1187
219	13537	SE-SE-NW	675	-1860	-1185
220	22701	SE-SE-NE	728	-1930	-1202
221	14990	NE-NW-SW	710	-1906	-1196
222	14826	NE-NE-SW	704	-1887	-1183
223	15096	NW-NW-SE	715	-1910	-1195
224	6625	NE-SE-SE	726	-1923	-1197
225	16289	SW-NE-SW	624	-1812	-1188
226	19268	SE-NW-SE	645	-1835	-1190
227	19469	SW-NE-SE	612	-1800	-1188
228	15581	NW-SE-SW	592	-1772	-1180
229	15567	NW-SW-SE	596	-1771	-1175
230	18083	NW-SE-SE	590	-1767	-1177
231	17949	NE-SE-SE	608	-1788	-1180
232	15642	SE-SE-SW	592	-1767	-1175
233	16969	SE-SW-SE	598	-1771	-1173

Section 36

234	20614	NW-NW-NW	702	-1903	-1201
235	6624	NW-NE-NW	672	-1869	-1197
236	6016	NE-NW-NE	674	-1860	-1186
237	7062	NE-NE-NE	679	-1845	-1166
238	21324	SE-NW-NE	682	-1874	-1192
239	21515	SW-NE-NE	683	-1861	-1178
240	21182	SE-NE-NE	682	-1855	-1173
241	6647	NE-SE-NE	680	-1848	-1168
242	21795	SE-SW-NW	734	-1937	-1203
243	23131	SE-SE-NW	714	-1910	-1196
244	21981	NW-NW-SW	719	-1919	-1200
245	22976	NW-NE-SE	681	-1861	-1180
246	18038	SW-NW-SW	723	-1908	-1185
247	21358	NW-SW-SE	703	-1892	-1189
248	21179	NW-SE-SE	689	-1878	-1189
249	22943	NE-SE-SE	685	-1871	-1186
250	22860	C/SE-SW	720	-1896	-1176
251	18468	SW-SW-SW	619	-1789	-1170
252	21248	SE-SW-SE	703	-1886	-1183
253	21092	SE-SE-SE	687	-1869	-1182

Well No.	Permit No.	Section Location	Ground Elev.	Traverse Ls Top	Traverse Ls Top S.L. Datum
Ottawa County, Georgetown Township, T6N, R13W					
Section 2					
254	7959	NE-NW-NW	603	-1777	-1174
255	7871	NW-NE-NW	596	-1771	-1175
256	8018	NE-NE-NW	606	-1772	-1166
257	8329	NW-NW-NE	595	-1761	-1166
258	8683	SW-NW-NW	600	-1794	-1195
259	8400	SW-NE-NW	607	-1774	-1167
260	8164	SE-NE-NW	597	-1763	-1166
261	8465	SE-NW-NE	607	-1776	-1169
262	8617	NW-SE-NW	595	-1774	-1179
Section 1					
263	8639	SW-NE-NW	711	-1884	-1173
264	8369	NE-SE-NW	689	-1861	-1172
265	8430	NE-NE-SW	708	-1881	-1173
266	9901	CE/2-SE	677	-1853	-1176
267	8304	NE-SE-SW	695	-1868	-1173
Section 12					
268	8542	NE-NE-NW	671	-1848	-1177
269	8447	NW-NW-NE	663	-1839	-1176
Kent County, Walker Township, T7N, R12W					
Section 19					
270	6282	SW-SW-NW	727	-1903	-1176
271	8419	NW-NW-SW	726	-1899	-1173
272	8535	SE-NW-SW	749	-1914	-1165
273	7930	NW-SW-SW	742	-1905	-1163
274	7327	SW-SW-SW	737	-1894	-1157
275	7662	SE-SW-SW	742	-1900	-1158
276	6549	SE-SE-SE	727	-1908	-1181
Section 20					
277	7268	NW-NE-SW	730	-1920	-1190
278	7565	SE-SW-SW	740	-1915	-1175
279	6841	SE-SE-SW	734	-1906	-1172
280	6894	SW-SE-SE	722	-1895	-1173

Well No.	Permit No.	Section Location	Ground Elev.	Traverse Ls Top	Traverse Ls Top S.L. Datum

Kent County, Walker Township, T7N, R12W

Section 30

281	6976	NW-NW-NW	739	-1895	-1156
282	6821	NW-NE-NW	739	-1903	-1164
283	6975	SW-NW-NW	736	-1899	-1163
284	7242	SW-NE-NW	741	-1909	-1168
285	7527	SE-NE-NE	722	-1894	-1172
286	6974	NW-SW-NW	737	-1890	-1153
287	6961	CN/2-SE-NW	736	-1898	-1162
288	6674	NW-SE-NE	730	-1895	-1165
289	7257	NE-SE-NE	735	-1901	-1166
290	6604	CW/2-SE-NW	737	-1892	-1155
291	6522	SW-SW-NW	732	-1874	-1142
292	6825	SE-SW-NW	722	-1873	-1151
293	6808	SE-SE-NW	725	-1883	-1158
294	6664	SE-SW-NE	732	-1890	-1158
295	6514	S/2-S/2-SE-NE	736	-1892	-1156
296	6780	NW-NW-SW	717	-1858	-1141
297	6820	NW-NE-SW	732	-1880	-1148
298	6667	NW-NW-SE	728	-1877	-1149
299	6753	NE-NW-SE	736	-1885	-1149
300	6694	NW-NE-SE	733	-1885	-1152
301	6703	NE-NE-SE	707	-1857	-1150
302	6663	SW-NW-SW	703	-1845	-1142
303	6598	SW-NW-SE	740	-1885	-1145
304	6497	SE-NW-SE	728	-1872	-1144
305	6671	SE-NE-SE	726	-1867	-1141
306	6590	NW-SE-SW	702	-1850	-1148
307	6477	NE-SE-SW	704	-1846	-1142
308	6480	W/2-SW-SE	729	-1872	-1143
309	6917	SW-SW-SW	676	-1829	-1153
310	6698	SW-SE-SW	693	-1846	-1153
311	6593	SE-SE-SW	704	-1852	-1148
312	6496	SE-SE-SE	738	-1883	-1145

Section 29

313	7061	NW-NE-NW	731	-1899	-1168
314	7058	NE-NE-NW	722	-1888	-1166
315	7025	NE-NW-NE	742	-1910	-1168
316	6923	CW/2-NW-NE	727	-1892	-1165
317	8190	SE-NW-NW	739	-1906	-1167
318	7060	SW-NE-NW	716	-1878	-1162
319	6915	SW-NE-NE	726	-1897	-1171
320	7101	NW-SW-NW	727	-1885	-1158
321	7059	NW-SE-NW	707	-1863	-1156

Well No.	Permit No.	Section Location	Ground Elev.	Traverse Ls Top	Traverse Ls Top S.L. Datum

Kent County, Walker Township, T7N, R12W

Section 29

322	7023	NE-SW-NE	748	-1913	-1165
323	6888	SW-SW-NW	710	-1865	-1155
324	6930	SE-SW-NW	732	-1880	-1148
325	6765	SW-SE-NW	708	-1855	-1147
326	7021	SE-SE-NW	712	-1864	-1152
327	7264	SW-SW-NE	715	-1868	-1153
328	6967	SE-SW-NE	743	-1905	-1162
329	6834	NW-NW-SW	705	-1853	-1148
330	7127	NE-NE-SW	713	-1865	-1152
331	6929	NW-NW-SE	724	-1882	-1158
332	6735	SW-NW-SW	689	-1833	-1144
333	7091	SE-NW-SW	728	-1874	-1146
334	6914	SW-NE-SW	733	-1881	-1148
335	7146	SW-NW-SE	741	-1896	-1154
336	8116	SW-NE-SE	746	-1904	-1158
337	6746	NW-SW-SW	687	-1835	-1148
338	6833	NW-SE-SW	730	-1878	-1148
339	6851	NE-SW-SE	747	-1898	-1151
340	7219	NE-SE-SE	753	-1905	-1152
341	6759	SE-SW-SW	691	-1839	-1148
342	7182	SW-SE-SW	729	-1876	-1150
343	7336	SE-SE-SW	707	-1856	-1149
344	6600	SE-SW-SE	742	-1891	-1149
345	6843	SE-SE-SE	759	-1909	-1150

Section 28

346	6971	SW-NW-NE	743	-1923	-1180
347	7445	SE-SE-NW	750	-1920	-1170
348	16114	NE-NW-SE	733	-1902	-1169
349	7330	NW-NE-SE	731	-1902	-1171
350	6873	SW-NW-SW	747	-1905	-1158
351	7413	NW-SW-SW	746	-1899	-1153
352	7249	CN/2-SW-SE	749	-1905	-1156
353	7065	SE-SW-SW	739	-1888	-1149
354	7064	CS/2-SE-SW	754	-1905	-1151
355	8162	CS/2-SW-SE	735	-1892	-1157

Section 27

356	7459	SW-NW-NW	702	-1886	-1184
357	7456	SE-NE-NW	758	-1946	-1188
358	7451	SW-SW-NW	699	-1879	-1180
359	5936	SE-SW-SW	704	-1876	-1172

Well No.	Permit No.	Section Location	Ground Elev.	Traverse Ls Top	Traverse Ls Top S.L. Datum

Kent County, Walker Township, T7N, R12W

Section 31

360	6523	NE-NW-NW	675	-1828	-1153
361	6459	NE-NE-NW	690	-1838	-1148
362	6506	NW-NW-NE	714	-1860	-1146
363	6488	NE-NW-NE	712	-1857	-1145
364	6476	NW-NE-NE	714	-1860	-1146
365	6850	NE-NE-NE	732	-1881	-1149
366	7243	SW-NW-NW	679	-1838	-1159
367	6589	SE-NE-NW	704	-1857	-1153
368	7588	SW-NE-NE	676	-1830	-1154
369	6995	CN/2-SE-NW	681	-1841	-1160
370	6731	NW-SW-NE	679	-1847	-1168
371	6479	NW-SE-NE	675	-1833	-1158
372	6773	S/2-N/2-SE-NW	685	-1857	-1172
373	6513	SE-SW-NE	701	-1873	-1172
374	6137	NE-NE-SW	675	-1863	-1173
375	8459	NE-NE-SE	720	-1887	-1167
376	6788	NW-SW-SE	695	-1870	-1175
377	7352	SE-SE-SE	672	-1837	-1165

Section 32

378	6789	NW-NW-NW	730	-1879	-1149
379	6997	NE-NW-NW	711	-1866	-1155
380	6475	NW-NE-NW	713	-1865	-1152
381	6886	NE-NE-NW	727	-1879	-1152
382	7553	NW-NW-NE	721	-1869	-1148
383	7689	NW-NE-NE	735	-1880	-1145
384	6483	SW-NW-NW	700	-1855	-1155
385	7160	SE-NE-NW	727	-1876	-1149
386	7159	SW-NE-NE	756	-1898	-1142
387	7033	NE-SE-NW	725	-1873	-1148
388	7037	SE-SW-SW	663	-1821	-1158
389	6056	SW-SE-NW	680	-1835	-1155
390	6478	SE-SW-NE	690	-1838	-1148
391	7426	NW-NE-SW	700	-1855	-1155
392	7295	NE-NE-SW	706	-1860	-1154
393	7057	NW-NW-SE	715	-1868	-1153
394	7810	NE-NE-SE	703	-1853	-1150
395	7145	SE-NE-SW	669	-1817	-1148
396	7820	SE-NW-SE	659	-1804	-1145
397	7763	SE-NE-SE	626	-1769	-1143
398	5937	NE-SW-SW	644	-1794	-1150
399	5858	NE-SW-SE	653	-1796	-1143
400	7316	SW-SW-SW	716	-1874	-1158

Well No.	Permit No.	Section Location	Ground Elev.	Traverse Ls Top	Traverse Ls Top S.L. Datum

Kent County, Walker Township, T7N, R12W

Section 32

401	5207	SE-SW-SW	702	-1860	-1158
402	5725	SW-SE-SW	658	-1814	-1156
403	5785	SE-SE-SW	647	-1793	-1146
404	6069	SE-SW-SE	619	-1763	-1144
405	5998	SW-SE-SE	607	-1750	-1143
406	6097	SE-SE-SE	610	-1752	-1142

Section 33

407	7020	NW-NW-NW	738	-1886	-1148
408	7141	NE-NW-NW	702	-1850	-1148
409	7807	CN/2-NE-NW	756	-1906	-1150
410	6940	SW-NW-NW	721	-1870	-1149
411	6987	SW-NE-NW	703	-1855	-1152
412	7003	SE-NE-NW	744	-1902	-1158
413	6166	NE-SW-NW	633	-1782	-1149
414	7144	NW-SE-NW	662	-1815	-1153
415	7004	NE-SE-NW	710	-1868	-1158
416	6495	SW-SW-NW	711	-1860	-1149
417	7335	SW-SE-NW	720	-1866	-1146
418	6842	SE-SE-NW	676	-1820	-1144
419	6386	SW-SW-NE	754	-1910	-1156
420	7558	SE-SW-NE	764	-1920	-1156
421	7218	SW-SE-NE	693	-1856	-1163
422	7290	NW-NW-SW	686	-1829	-1143
423	7153	NE-NW-SW	672	-1819	-1147
424	6554	NE-NE-SW	724	-1868	-1144
425	6760	NW-NW-SE	741	-1886	-1145
426	7571	NW-NE-SE	682	-1833	-1151
427	7480	NE-NE-SE	688	-1842	-1154
428	6292	SE-NW-SW	617	-1764	-1147
429	7317	SE-NW-SE	695	-1840	-1145
430	7960	NW-SW-SE	609	-1753	-1144
431	6177	NE-SW-SW	608	-1750	-1142
432	6190	NE-NE-SW	600	-1738	-1138
433	6052	NW-SW-SE	606	-1744	-1138
434	7479	NE-SE-SE	725	-1874	-1149
435	7323	SW-SE-SW	607	-1748	-1141
436	6468	SW-SE-SE	603	-1743	-1140
437	7478	SE-SE-SE	602	-1752	-1150

Well No.	Permit No.	Section Location	Ground Elev.	Traverse Ls Top	Traverse Ls Top S.L. Datum
Kent County, Walker Township, T7N, R12W					
Section 34					
438	12899	NE-SE-NW	762	-1924	-1162
439	6973	SW-SW-NW	655	-1813	-1158
440	7072	SW-SE-NW	696	-1856	-1160
441	6807	SE-SE-NW	741	-1904	-1163
442	7269	NW-NE-SE	595	-1771	-1176
443	7658	SW-NW-SW	622	-1775	-1153
444	7404	NW-SW-SW	603	-1755	-1152
445	6939	NW-SE-SW	598	-1753	-1155
446	7659	SE-SW-SW	605	-1757	-1152
Section 35					
447	7015	NW-SW-NW	597	-1781	-1152
Kent County, Wyoming Township, T6N, R12W					
Section 6					
448	21386	NE-NW-NW	682	-1866	-1184
449	22479	N/2-NE-NW	667	-1849	-1182
450	6339	NE-NE-NE	697	-1863	-1166
451	21741	SE-NW-NE	662	-1837	-1162
452	6053	SW-NE-NE	663	-1825	-1162
453	7580	SE-SE-NE	697	-1865	-1168
454	13042	NW-SW-NE	662	-1842	-1180
455	19890	NE-SW-NE	658	-1834	-1176
456	13040	SE-SW-NW	672	-1850	-1178
457	12560	NW-NW-SE	661	-1840	-1179
458	13157	SE-NE-SW	669	-1845	-1176
459	12805	SE-NW-SE	712	-1889	-1177
460	21658	SE-NE-SE	700	-1884	-1184
461	9611	CW/2-SW	672	-1831	-1159
462	13231	NW-SE-SW	666	-1831	-1165
463	21542	CSW/4-SE	715	-1899	-1184
464	21584	SW-SW-SW	659	-1820	-1161
465	21538	SW-SE-SE	729	-1914	-1185
Section 5					
466	7035	NW-NW-NW	721	-1880	-1159
467	6033	NW-NE-NW	630	-1782	-1152
468	5433	NE-NE-NW	707	-1861	-1154
469	6062	NW-NW-NE	614	-1765	-1151
470	5880	NW-NE-NE	602	-1748	-1146

Well No.	Permit No.	Section Location	Ground Elev.	Traverse Ls Top	Traverse Ls Top S.L. Datum

Kent County, Wyoming Township, T6N, R12W

Section 5

471	6425	NE-NE-NE	603	-1745	-1142
472	6018	SE-NW-NW	665	-1825	-1160
473	6188	SE-NE-NW	612	-1770	-1158
474	6187	SE-NW-NE	605	-1753	-1148
475	6122	SW-NE-NE	605	-1752	-1147
476	22030	NW-SW-NW	702	-1870	-1168
477	6450	NW-SE-NW	626	-1787	-1161
478	6211	NW-SW-NE	605	-1759	-1154
479	5933	E/2-SE-NW	611	-1768	-1157
480	21876	SE-SW-NW	660	-1830	-1170
481	22357	SW-SW-NE	604	-1758	-1154
482	6315	SW-SE-NE	614	-1768	-1154
483	6316	SE-SE-NE	617	-1767	-1150
484	21819	NW-NE-SW	622	-1799	-1177
485	8593	NE-NE-SW	603	-1777	-1174
486	7178	NW-NW-SE	600	-1771	-1171
487	5923	NE-NW-SE	618	-1788	-1170
488	13698	CW/2-SW-SW	636	-1820	-1184
489	23988	SE-SW-SE	598	-1780	-1182
490	23192	CS/2-SE-SE	597	-1777	-1180

Section 4

491	6170	NE-NE-NW	599	-1741	-1142
492	6530	NW-NW-NE	598	-1738	-1140
493	6920	NW-NE-NE	597	-1735	-1138
494	7247	NE-NE-NE	595	-1744	-1149
495	6309	SW-NW-NW	608	-1754	-1146
496	6341	SE-NW-NW	608	-1752	-1144
497	6696	SW-NE-NE	596	-1738	-1142
498	7135	SE-NE-NE	595	-1737	-1142
499	6138	NW-SW-NW	611	-1758	-1147
500	6368	NE-SE-NW	615	-1760	-1145
501	6583	NE-SW-NE	600	-1740	-1140
502	6695	NE-SE-NE	598	-1743	-1145
503	6449	SW-SW-NW	623	-1772	-1149
504	6376	SE-SW-NW	620	-1770	-1150
505	6702	SW-SW-NE	597	-1741	-1144
506	6562	SW-SE-NE	593	-1738	-1145
507	6673	NW-NW-SW	625	-1790	-1165
508	6885	NE-NE-SW	594	-1740	-1146
509	6524	NE-NW-SE	601	-1748	-1147
510	6216	NE-NE-SE	595	-1743	-1148
511	6819	SE-NW-SW	596	-1754	-1158

Well No.	Permit No.	Section Location	Ground Elev.	Traverse Ls Top	Traverse Ls Top S.L. Datum

Kent County, Wyoming Township, T6N, R12W

Section 4

512	6378	SW-NE-SW	593	-1748	-1155
513	6806	SE-NE-SW	597	-1746	-1149
514	6736	SE-NW-SE	598	-1750	-1152
515	6620	SE-NE-SE	602	-1753	-1151
516	6552	NW-SE-SW	593	-1753	-1160
517	6784	NW-SE-SE	599	-1757	-1158
518	6528	SE-SW-SW	595	-1764	-1169

Section 3

519	7437	NW-NW-NW	595	-1740	-1145
520	7347	SW-NW-NW	594	-1741	-1147
521	6630	SW-NW-NE	598	-1746	-1148
522	7546	SW-NE-NE	605	-1763	-1158
523	6717	NW-SW-NW	595	-1744	-1149
524	6582	NE-SE-NW	594	-1738	-1144
525	7537	NE-SW-NE	598	-1748	-1150
526	6631	SE-SW-NW	603	-1747	-1144
527	6466	SW-SE-NW	598	-1740	-1142
528	7484	SE-SE-NW	599	-1741	-1142
529	7005	SW-SE-NE	607	-1764	-1157
530	6912	NW-NE-SW	594	-1738	-1144
531	7197	NW-NW-SE	606	-1755	-1149
532	6714	SW-NW-SW	595	-1745	-1150
533	5004	SW-NE-SW	607	-1754	-1147
534	6494	SE-NE-SW	603	-1753	-1150
535	7425	SE-NW-SE	619	-1784	-1165
536	6924	NW-SW-SW	602	-1758	-1156
537	8854	NW-SE-SW	613	-1775	-1162

Section 2

538	6536	NE-NW-NE	604	-1786	-1162
539	6670	SW-NW-NW	614	-1780	-1166
540	7087	SE-NW-NW	608	-1784	-1176
541	8261	SW-NW-NE	607	-1788	-1181

Section 7

542	21425	NW-NW-NW	646	-1821	-1175
543	21237	NE-NE-NW	692	-1869	-1177
544	21407	NE-NW-NE	729	-1912	-1183
545	22502	CNE/4-NE	680	-1867	-1187
546	21781	SE-NW-NW	675	-1863	-1188

Well No.	Permit No.	Section Location	Ground Elev.	Traverse Ls Top	Traverse Ls Top S.L. Datum
Kent County, Wyoming Township, T6N, R12W					
Section 7					
547	22299	CS/2-NE-NW	700	-1879	-1179
548	24170	NW-SW-SW	680	-1875	-1195
549	24870	SE-SW-NW	640	-1840	-1200
550	25364	NE-NE-SW	678	-1876	-1198
551	8675	NW-SW-SW	602	-1885	-1283
Section 8					
552	21669	NE-SE-NW	596	-1783	-1187
553	25314	SW-SW-NW	595	-1787	-1192
554	21840	SW-SE-NW	596	-1786	-1190
555	6943	SW-SW-NE	600	-1786	-1186
556	7036	SE-SE-NE	608	-1791	-1183
557	13858	SE-NW-SW	596	-1791	-1195
558	5946	CS/2-NE-SW	601	-1794	-1193
Section 9					
559	6653	SW-SE-SE	633	-1810	-1177
Section 11					
560	6424	SE-SW-SW	675	-1866	-1191

APPENDIX III

DOLOMITE PERCENT FROM TRAVERSE LIMESTONE

APPENDIX III

DOLOMITE PERCENT FROM TRAVERSE LIMESTONE

Well No.	Well Name - Operator	Depth Below Top of Traverse Ls 0-5 feet	5-10 feet	10-20 feet	20-30 feet	30-40 feet
2	R. Terpstra No. 1 - Perry, Gould, & Cross	30	70	85	55	X
3	Cross No. 2 - Oil Producers	25	85	92	X	X
7	R. Bronkema No. 1 - Sprenger Brothers	68	88	14	12	X
9	A. Lipski No. 1 - Mesel & Spielberg	30	70	X	X	X
16	F. T. White No. 3 - Turner Petroleum Corp.	25	34	14	X	X
19	R. Bronkema No. 2 - Gulf Refining Company	26	50	16	X	X
24	F. Cook No. 1 - George Kernodle	16	20	6	X	X
28	F. T. White - Turner Petroleum Corp.	16	12	11	10	X
32	C. Den Boer No. 1 - M. H. Bauman	10	10	6	X	X
39	A. E. Raup No. 3 - Gulf Refining Company	12	8	15	12	X
44	A. E. Raup No. 1 - Gulf Refining Company	20	22	16	5	X
46	J. Masterson No. 1 - J. C. Newell, Tr.	14	30	8	X	X
47	A. E. Raup No. 3 - J. C. Newell, Tr.	35	14	9	13	X
63	Daverman No. 1 - Columbia Oil & Gas Co.	28	35	30	14	6

Well No.	Well Name - Operator	Depth Below Top of Traverse Ls 0-5 feet	5-10 feet	10-20 feet	20-30 feet	30-40 feet
64	J. Zokoe No. 1 - American Drilling Co.	10	28	7	X	X
75	McKay No. B-1 - Twin Drilling Company	22	18	15	X	X
89	Sutter, et al No. 1 - Swanson Consol. Oil Co.	50	85	38	26	4
99	R. H. Lauer No. 1 - Lenoran Petroleum Co.	20	8	20	10	X
121	M. Wisniswski No. 1 - Smith Petroleum Co.	35	20	10	5	X
136	W. H. Clarke No. 1 - Smith Petroleum Co.	32	20	12	X	X
137	W. & A. Bergman No. 1 - R. W. Atha	26	8	5	X	X
144	F. McKay No. 1 - Twin Drilling Company	12	15	9	X	X
149	Park No. 4 - Twin Drilling Company	14	8	4	X	X
171	F. Sund No. 1 - Turner Petroleum Corp.	16	12	8	5	X
172	S. Kuiper No. 1 - Welsh Oil Company	35	20	11	X	X
235	J. Kuiper No. 1 - North American Drilling & Production Company	28	12	10	4	X
267	L. S. Wells No. 1 - Fisher-McCall Oil & Gas Company	15	X	X	X	X
269	Doyle No. 1 - Fisher-McCall Oil & Gas Co.	22	12	16	14	X
277	Lincoln Country Club No. 1 - Twin Drilling Company	16	7	6	6	X
297	Handley & O'Sullivan No. 4 - Smith Petroleum Company	26	20	22	8	X
305	G. Riddering No. 3 - Smith Petroleum Co.	14	18	8	X	X

Well No.	Well Name - Operator	Depth Below Top of Traverse Ls 0-5 feet	5-10 feet	10-20 feet	20-30 feet	30-40 feet
312	G. Riddering No. 1 - Smith Petroleum Co.	18	14	12	X	X
319	Synder-McGrath No. 1 - Michigan Devonian Petroleum Company	30	16	11	8	X
321	Newhouse No. 3 - Fisher-McCall Oil & Gas Company	16	18	11	X	X
359	Grand Rapids Plaster Co. No. 1 - Smith Petroleum Company	15	18	9	5	X
372	Smith-Burrows No. 1 - Cryden Petroleum Corp.	18	25	19	11	5
374	Powers No. 1 - Voorhees Drilling Company	18	20	10	12	9
384	G. & C. Engelsma No. 1 - Smith Petroleum Company	22	15	12	5	X
398	Whalen No. 3 - Smith Petroleum Company	14	10	13	12	X
401	Story No. 1 - MacCallum & Herr	18	20	10	10	X
404	Laquae-Fletcher No. 1 - Swanson Consol. Oil Co.	18	12	10	6	8
406	Zeeff No. 1 - Smith Petroleum Company	12	15	5	5	X
418	Cudahy et al No. 2 - Smith Petroleum Company	14	16	10	X	X
428	Van Euwen No. 1 - Smith Petroleum Company	26	18	8	8	4
433	Renihan No. 2 - Ide & Glavin	28	16	11	9	14
452	Sagman No. 1 - R. W. Atha	12	10	19	9	4
468	Orlik No. 1 - Wolverine Natural Gas Company	14	8	9	13	X
478	Van Dyke No. 1 - Swanson Consolidated Oil Company	12	16	10	7	X
489	A. Heald No. 1 - R. Wright	14	20	14	9	4

Well No.	Well Name - Operator	Depth Below Top of Traverse Ls 0-5 feet	5-10 feet	10-20 feet	20-30 feet	30-40 feet
492	Gilbert Estate No. 7 - Smith Petroleum Company	11	16	13	8	3
496	Johnson No. 6 - Wolverine Natural Gas Company	10	12	9	6	3
508	W. Gilbert No. 10 - Smith Petroleum Company	18	15	14	7	10
518	Grand Rapids Trust Co. No. 1 - H. C. Williams	16	X	X	X	X
529	Grand Rapids Gravel No. 1 - Twin Drilling Co.	20	24	7	8	4
533	Grand Rapids Gravel No. 1 - Cryden Petroleum Corp.	12	10	9	9	5
539	Alabastine Co. No. 1 - Hogan Brothers	12	8	11	6	4
558	H. A. Chapin No. 1 - Charles Harrison	8	12	11	8	10
559	Tanglefoot No. 1 - R. W. Atha	10	10	10	7	8