

STRUCTURE AND STRATIGRAPHY OF THE
TRAVERSE GROUP IN THE LANSING AREA,
MICHIGAN

Thesis for the Degree of M. S.
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Lewis Allan Gustafson

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STRUCTURE AND STRATIGRAPHY OF THE TRAVERSE
GROUP IN THE LANSING AREA, MICHIGAN

by
Lewis Allan Gustafson

AN ABSTRACT

Submitted to the College of Science and Arts of Michigan
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LEWIS ALLAN GUSTAFSON

ABSTRACT

The Lansing area includes Ingham County, Eaton County, Clinton County, the east half of Ionia County and the west half of Shiawassee County. This area has seen little drilling activity in the last two decades. Yet, the Traverse group which underlies the Lansing area, at relatively shallow depths, has been productive in other parts of the state.

The purpose of this investigation was to survey the Traverse group in the Lansing area to determine its petroleum possibilities, and describe the structural and stratigraphic conditions.

Due to the absence of Traverse outcrops in the Lansing area it was necessary to gather information from lithologic logs and well samples of the 163 wells which have reached the Traverse group.

The Traverse group underlies most of the Lower Peninsula of Michigan. It is composed of limestone, calcareous shale, dolomite, and chert. In the Lansing area the Traverse group is at depths ranging from 420 feet to 1840 feet below sea level, with a thickness which varies from 300 feet in the south part to 450 feet in the north part of the area. It dips generally to the north at less than one-half of one degree.

Traverse stratigraphy in the Lansing area can be described best by dividing the Traverse group into

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ABSTRACT

lithologic units. From bottom to top these are: basal shale zone, gray-brown limestone, buff limestone, gray-cherty limestone, and "Traverse formation." "Traverse formation" is a term which refers to the transition zone between the Traverse limestone and the Antrim shale above.

Three large structures are present in the Traverse rocks of the Lansing area. These are the northwest trending Howell anticline, a high structure trending northeast across Eaton County, and a northwest trending trough across Clinton County.

No structural or stratigraphic traps were discovered by this investigation. However, porous horizons which could serve as reservoir rocks exist within the upper part of the Traverse group. Also, high structures are present in the Lansing area and should closure be found on these structures there is a fair chance that they would contain petroleum.

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INTRODUCTION

General Information

Lansing, Michigan, is located eighty-five miles west-northwest of Detroit in the south central portion of the Lower Peninsula. The Lansing area, as defined in this investigation, includes Ingham County, Eaton County, Clinton County, the east half of Ionia County, and the west half of Shiawassee County (Figure 1).

This area is well developed and populated. Lansing with a population of 110,000 people is the largest industrial city in the area. Farm lands occupy almost all of the area. The average farm is about 60 acres. Michigan was surveyed into townships, ranges, and sections, with the state retaining the right to place roads on all section lines. Consequently, there are secondary roads, gravel or macadam, on most section lines. A very good highway net covers the area.

Average elevation is approximately 800 feet above sea level and ranges from 650 feet to 950 feet. Low gently rolling hills with intervening flat lands dominate the landscape. Maximum relief at any particular location does not exceed 200 feet. The Lansing area was glaciated during the Pleistocene and displays moraines, eskers, and outwash

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SCALE OF MILES

Figure 1.

Index map of Michigan showing location of the Lansing area.



plains. Drainage is fair, although there are some small swamps located throughout the area. Soil trafficability is usually good.

Rainfall in Michigan averages about 30 inches per year. The climate is moderate for Michigan's latitude due to the proximity of the Great Lakes. Yearly temperature averages about 45 degrees. Trees are confined to woodlots, along rivers, and on unmanageable soil.

Purpose of Investigation

The purpose of this investigation is to survey the Traverse group in the Lansing area with the intent of examining the structure and stratigraphy, and defining any possible structure which may have accumulated petroleum.

Drilling Activity

Drilling activity started in this area before the turn of the century and progressed very slowly until the oil boom of the 1930's. At that time the area received a great increase in drilling which subsequently declined to what it is today, practically nothing. Approximately 163 wells have reached or penetrated the Traverse group in the Lansing area up to the time of this investigation (Plate 1). Some production has been gained from the Traverse within this area. Most of the wells in the Lansing area were drilled by the cable tool method.

Rock Exposures

Rock exposures are practically non-existent and Traverse rocks are not exposed within the Lansing area. The Traverse group is exposed in three outcrop areas and several quarries in the northern Lower Peninsula. Outcrop areas are in the Alpena, Grand Traverse Bay, and Little Traverse Bay regions (Figure 1).

Conduct of Investigation

Due to the absence of exposures in the Lansing area this investigation was conducted entirely from subsurface records and samples. Sample logs of 163 wells which penetrated or reached any part of the Traverse were examined and correlated on the basis of lithologic similarity, continuity, and stratigraphic position.

In addition, samples from 30 wells were examined megascopically and samples from 6 wells were examined with the binocular microscope. Correlation proved difficult between many wells due to poor sampling, recording, and extreme variation in the Traverse rocks over short distances. The maps accompanying this study were drawn with a contour interval of 25 feet. This allowed for inaccuracies arising from depth measurements, correlation, poor sampling, and poor recording.

REGIONAL STRATIGRAPHY

General

The distinction between Traverse rocks and other Michigan strata was recognized as early as 1841. C. C. Douglass (Geological Reports of Douglass Houghton, 1928, p. 579) named these beds, in their northwestern occurrences, "Little Traverse Bay limestones." Winchell (1871, p. 28) renamed them "Little Traverse group." Still later the name was simplified by Dr. Lane (1895, p. 24) to "Traverse group." The latter nomenclature remains today.

The name Traverse group is assigned to a series of limestones, shales, and shaly limestones, with dolomite, dolomitic limestone, and chert, of secondary importance. The texture of the limestone varies from lithographic to coarse crystalline to fragmental.

Traverse rocks are exposed on the western shoreline of the northern Lower Peninsula in the Grand Traverse Bay and the Little Traverse Bay region (Figure 1). They are also exposed on the eastern side of the northern Lower Peninsula, in the Alpena and Thunder Bay region (Figure 1). In addition to these natural outcrops the Traverse group has been exposed by quarry operations in the same general area.

"Saucer shaped" is a term which has been used to describe rock units in the Michigan basin. This description also applies to the general aspect of the Traverse group. The rim of the Traverse saucer forms a circle of bedrock within the basin. This rim passes through the Michigan outcrop area, southwestern Ontario, northwestern Ohio, northern Indiana, Lake Michigan, and eastern Wisconsin. In the southeast, the Traverse group is mainly shale and relatively thin, 60 feet in Ontario, and 50 feet in Ohio (Pohl, 1929, pp. 30-31). In the northwest, it is mainly limestone, 500 to 800 feet thick.

Pohl (1929, p. 33) has placed the Traverse group of Ontario between the Onondaga and the Hamilton. Actually, post-Onondaga pre-Moscow, with Ludlowville and Skaneateles times represented by an unconformity. This unconformity is directly above the Thunder Bay formation (Figure 2). Warthin and Cooper (1943, pp. 578-595) believe the formations of the Traverse group below the Norway Point to be equivalent to Hamilton strata in New York, and those above to be in the upper Devonian (Figure 2).

Numerous workers have described and divided the Traverse group of Michigan. Three generally accepted divisions are shown in Figure 2. Shown also is the strictly lithologic subsurface division of Traverse rocks in the Central Michigan area by Hake and Maebius (1938, pp. 451-457). The units and descriptions below in ascending order,

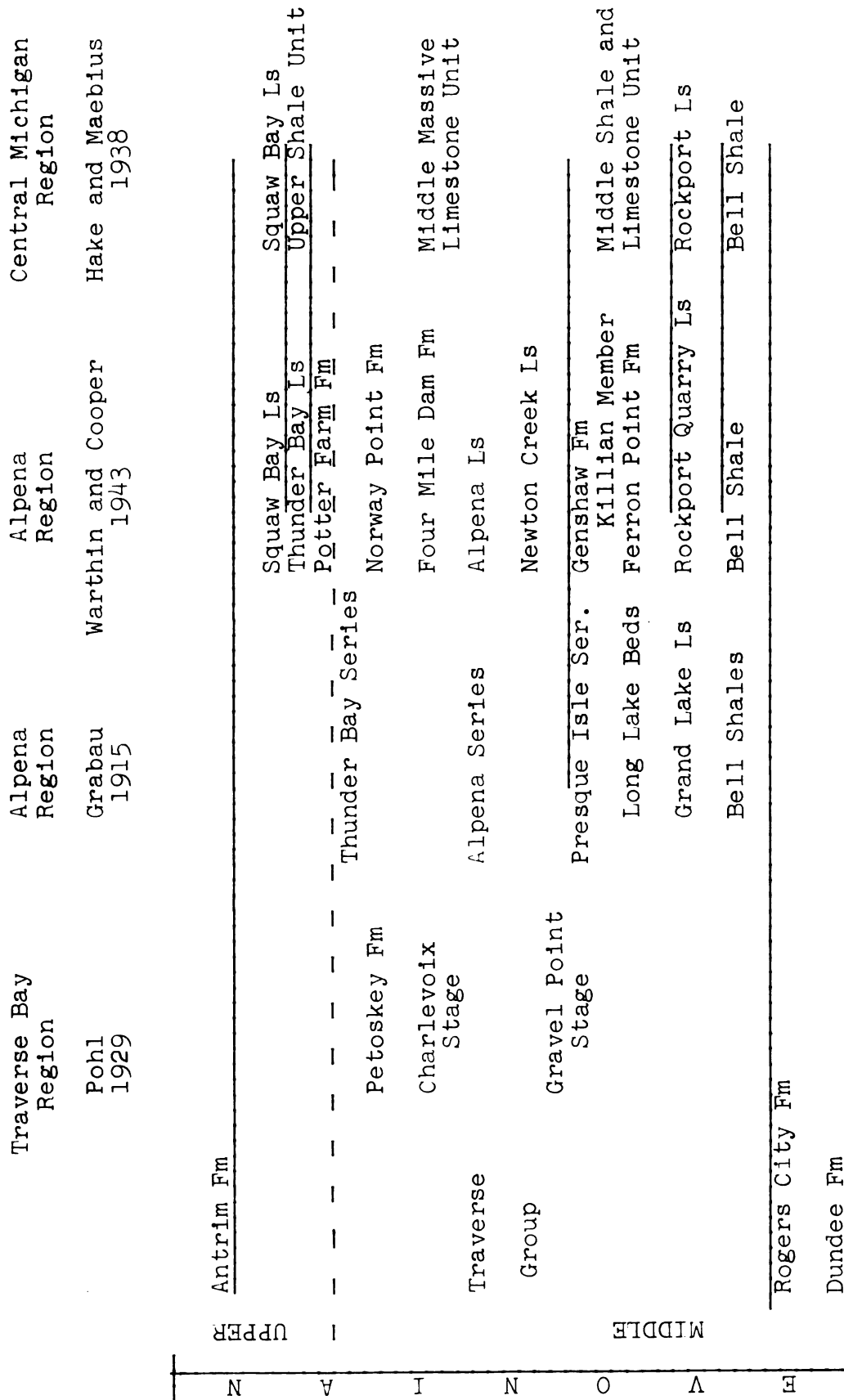


Figure 2. Traverse Nomenclature

from the Alpena type locality, are mainly those of Warthin and Cooper (1943, pp. 578-595).

Bell Shale

The Bell shale is the lowest unit of the Traverse group. It is separated from the Rogers City and Dundee formations below by an unconformity (Newcombe, 1930). The Bell has a thickness of 60 to 80 feet in the northern Lower Peninsula, over 200 feet in the central Michigan area, and thins to the south and west (Newcombe, 1933, p. 45). It is absent in the extreme southwestern counties.

The Bell is a blue-gray calcareous shale. When it forms a thick deposit the Bell becomes dark and non-calcareous at its base. It is correlated with the middle of the Skaneateles formation.

Rockport Quarry Limestone

This unit is represented, in its type locality, by 50 feet of gray and brown limestone. The Rockport Quarry becomes limy shale in central Michigan and dolomitic gray limestone in northwestern Michigan (Hake and Maebius, 1938, p. 452).

Ferron Point Formation

Gray calcareous shale and argillaceous limestone occupy the position above the Rockport Quarry. The Ferron Point totals 37 feet in exposure. Possibly, the Silica shale of Ohio corresponds to this formation.

Genshaw Formation

The Genshaw is gray shale and argillaceous limestone totaling 116 feet. At its top it contains the Killian member which is a 23 foot layer of black to dark gray limestone with thin black shale partings.

Equivalence of the Ferron Point and Genshaw formations to the "middle shale and limestone unit" of Hake and Maebius is suggested (Hake and Maebius, 1938, p. 452). To the west the Ferron Point and Genshaw formations become massive limestone and dolomite (Hake and Maebius, 1938, p. 453).

Newton Creek Limestone

This limestone is dark brown, crystalline, and has a thickness in its type locality of 25 feet. It was distinguished from the limestone above and below on faunal evidence alone.

Alpena Limestone

The Alpena is 79 feet thick in the type locality. It is a pure limestone, usually white, light brown, or light gray, and contains bioherms and biostromes. Porosity is greater in this limestone than the other units. This fact is due to the fossil material and lime sands associated with the organic structures.

Four Mile Dam Formation

This is a variable bed of brownish gray limestone or shale from 8 to 14 feet thick. It is believed to correspond to the Centerfield of New York.

Norway Point Formation

The Norway Point is the youngest Michigan formation with "definite Hamilton affinities" (Warthin and Cooper, 1943, p. 589). It is represented by 45 feet of bluish gray shale and gray limestone.

Potter Farm Formation

The Potter Farm Formation is 68 to 74 feet of gray or brown limestone with some thin shale layers, in the type locality.

Thunder Bay Limestone

The Thunder Bay is 13 feet of gray shale and limestone. This formation and the Potter Farm are probably equivalent to the Petoskey (Pohl, 1929, p. 5) of western Michigan.

Squaw Bay

This is considered the upper-most bed of the Traverse group. It is probably equivalent to the Genundewa limestone of New York. The Squaw Bay is traceable over much of Michigan and in the type locality shows 8 feet of brown crystalline limestone or dolomitic limestone.

Above the Squaw Bay is a transition zone of gray calcareous shale. This zone varies greatly over small distances. The relationship between this shale and the overlying beds is not well understood. Kirkham (1932, pp. 136-137) has suggested the possibility of an unconformity at the top of the Traverse.

LOCAL STRATIGRAPHY

General

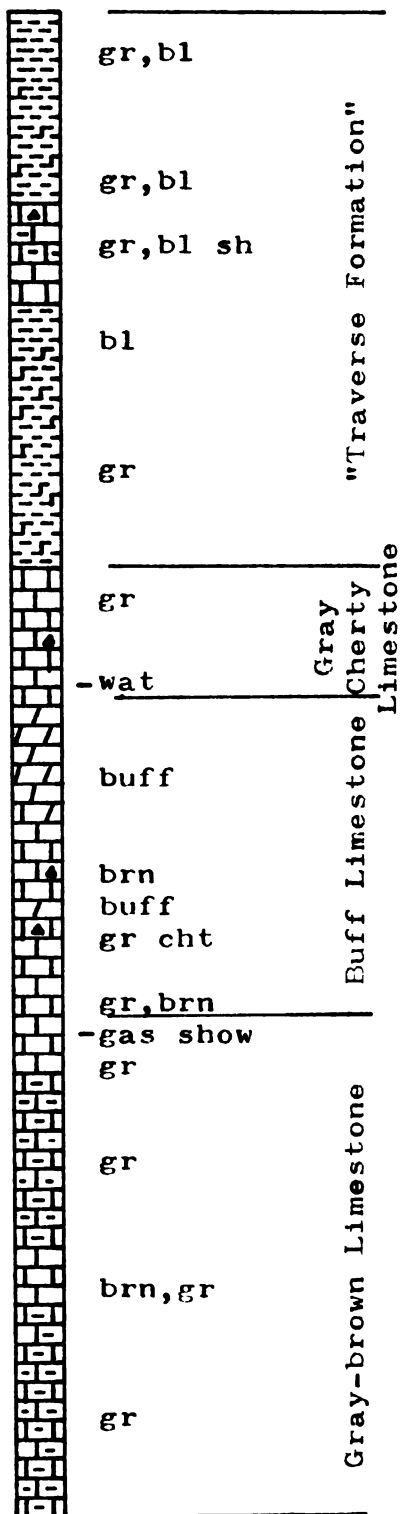
The Traverse group in the Lansing area is composed of limestone, shale, chert, and dolomite (Figures 3, 4, and Plate 2). Minor amounts of pyrite and gypsum also have been encountered. In general, the Traverse dips to the north at a rate of less than one-half of one degree and thins to the south by about 150 feet (Plates 2, 3, 4, and 5). Total accumulation of Traverse sediments in the extreme north of the area are in the order of 450 feet and in the south, 300 feet. This thinning seems to be distributed among the various lithologic units which are described below, with the exception of the "Traverse formation." "Traverse formation" is a term which does not necessarily follow the scheme of geologic nomenclature, but has been usefully applied to the transition zone between the Traverse limestone and the overlying Antrim shale (Plate 2).

Division of the Traverse group into units can be accomplished by examination of samples and well logs. However, the boundaries between some units are indistinct due to the type of information used. Necessarily, these divisions are apparent as observed in samples and not absolute, as would be observed in outcrops. No attempt has been made in this investigation to correlate the individual

Figure 3.

Scale: 1 in. = 40 feet.
 Chert: ▲

#157 Typical Well Record of Eaton County.



#146 Typical Well Record of Ingham County.

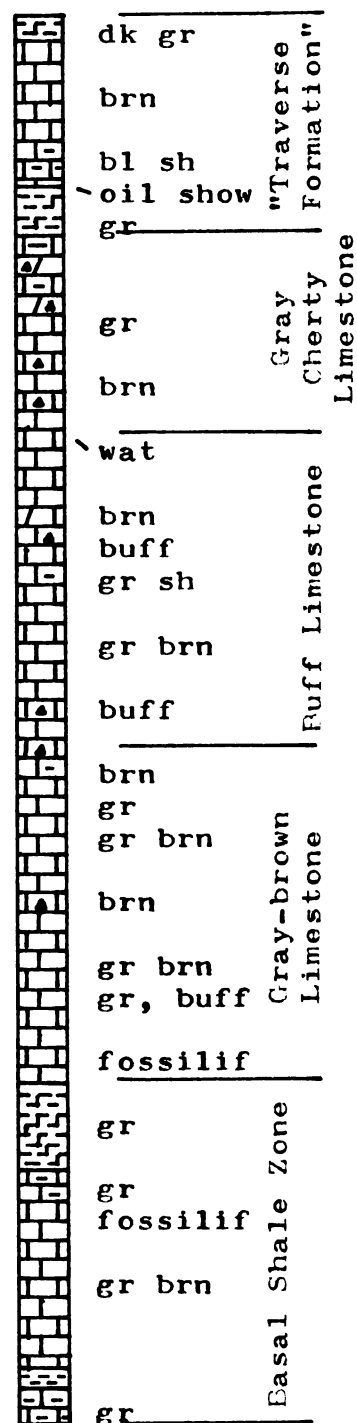
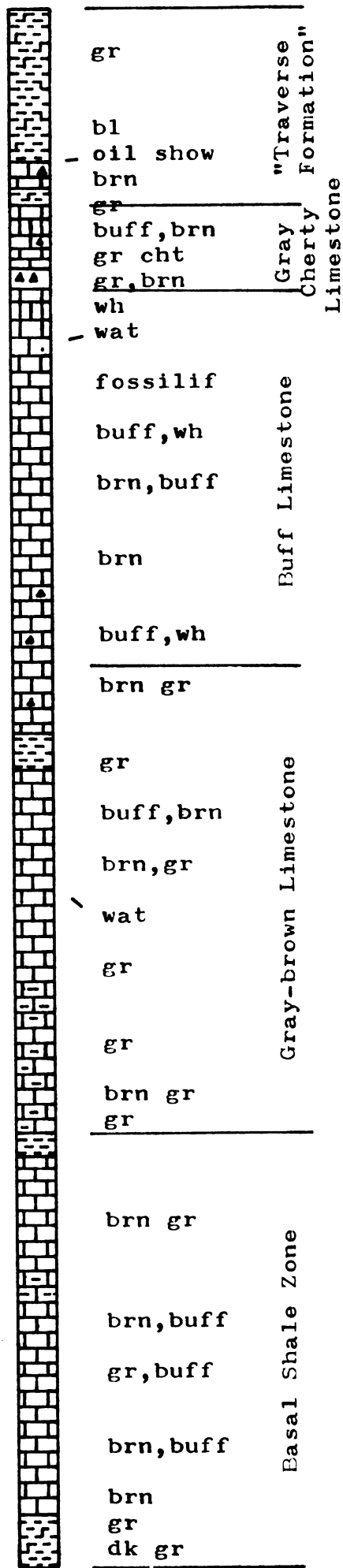
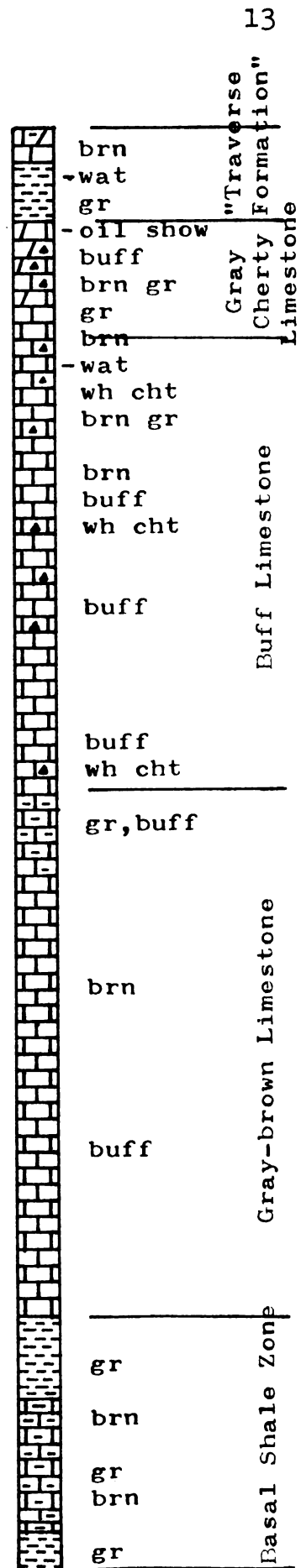


Figure 4. Scale: 1 inch = 40 feet.

#50 Typical Well Record of Ionia County



#100 Typical Well Record of Clinton County



lithologic units of the Traverse group in the Lansing area to the described units in the outcrop area since it was not deemed critical to the study.

Dundee-Traverse Unconformity

The stratigraphy of the Traverse group begins with what appears to be an unconformity (Newcombe, 1930). This unconformity is between the base of the Traverse group and the underlying Dundee and Rogers City (Plate 6). How far it extends into the Lansing area is not known. However, it probably is present throughout the entire area.

No direct evidence has been discovered to prove the existence of this unconformity in the Lansing area. However, some facts tend to point toward this assumption. Primary among these is the fact that the water horizons of the Dundee are not always at the same interval below the basal Traverse shale zone. Some water horizons are at times missing completely (Newcombe, 1933, p. 195). Indicative also is the fact that different lithology is sometimes encountered directly below the basal shale zone. There seems to be no transition zone or interfingering between the Traverse and Dundee. These conditions would not be likely to occur in a conformable series of strata. The time span represented by this unconformity has not been determined.

Basal Shale Zone

Cohee (1947) believes that the Bell shale is absent southwest of a northwest-southeast line across Clinton

County. However, there is a calcareous shale which goes further south and is found in several layers, but always in the lower part of the Traverse (Plate 5). Therefore, the name basal Traverse shale zone would perhaps be more appropriate than the name Bell shale.

The basal shale is light gray, dark gray, or bluish gray. It has fissile structure although not too well developed. The rock is calcareous and may contain fossils and pyrite. One of the distinctive characteristics of this shale is its tendency to change to a mud while being drilled and a light gray powder when dry. Because of this it is sometimes washed out of--or lost in--the sample collection.

The basal shale is a complicated deposit. In general, it thins from over 100 feet in the northeast to nothing in the southwest. Specifically, it changes in thickness a substantial amount between closely spaced wells. For example, well #145 has gone through an accumulation of 79 feet of shale. Well #146, located one and a half miles east of #145, has penetrated only 23 feet; well #144, a little over two miles north of #146, has penetrated 13 feet of shale. The thinning between these wells is contrary to the direction of regional thinning.

The basal shale zone usually comprises three layers, or less, of shale separated by limestone or shaly limestone. In the northeast part of the Lansing area the shale occurs in one or two relatively thick layers. In Ingham County it usually is in two layers, each in the order of 15 feet thick,

separated by about 50 feet of limestone. Of the 5 wells in Eaton County which have reached the lower Traverse, well #156 found a 16 foot layer of shale while the others found only traces of shale. In Ionia County the shale zone seems to be one or two layers close together totaling 30 feet, but variations can be found anywhere. Clinton County wells show two or three layers in the southern part, but again variations are common.

Many factors combine to make the shale deposit in the basal shale zone difficult to interpret. Already mentioned is the fact that the shale can be lost during sample collection. The unconformity below may have left an undulating surface on the Dundee limestone; the associated low areas may have been filled with a greater thickness of shale than the surrounding high areas. No correlation has been observed between the thickness of the Dundee and the thickness of the shale accumulation. Further complicating the deposit is the probability that the shale laterally changes to limestone in the Lansing area. This may have created inter-tonguing and unequal distribution. In addition to these factors there is the possibility that variation of currents and source areas affected the deposition of shale in the Lansing area.

Gray-brown Limestone

Directly above the basal shale zone and interlayered with it, is an argillaceous limestone. Its color varies

from gray to brown, but it is usually gray-brown. This limestone may contain chert, fossils, and thin layers of shale. It also varies from fine and coarse crystalline to fragmental. Quartz grains have been reported throughout this part of the Traverse section in Ionia County.

The gray-brown limestone tends to be gray and argillaceous in the eastern half of the Lansing area, but brown and not as argillaceous in the western half. Because this corresponds to the thinning of the basal shale, it is interpreted as representing the lateral variation or facies change from shale east of the Lansing area to pure carbonates west of this area.

The gray-brown limestone is the largest single unit in the Traverse section. In the extreme south of the Lansing area it is about 100 feet thick, in the northwest, about 200 feet, and in the northeast, 150 feet.

Buff Limestone

Above the gray-brown limestone, and separated from it in certain places by a thin shale layer, is the relatively pure buff limestone. This horizon, on the average, is about 80 feet thick and easily recognized in the south half of the Lansing area. It is also recognized in some wells of the north half, but in others becomes gray and difficult to distinguish from the limestone above and below. The buff limestone is not composed entirely of buff colored limestone, but is a combination of white, buff, tan, light brown, and

gray limestone layers. There appears to be a gray-brown zone in the center of the buff. This gray-brown zone becomes better developed in northern Clinton County and splits the buff lime into two parts.

The buff limestone horizon may contain dolomite, weathered or fresh chert, fossils, coralline material, quartz grains, fragmental limestone, and fine or coarse crystalline limestone. The most persistent salt water horizon of the Traverse group is found at the top or near the top of the buff limestone. Porosity causing this is probably of the vuggy type, which is readily observed in the samples.

Gray Cherty Limestone

Above the buff limestone is a section of gray or gray-brown limestone. This unit is of varying thickness but usually amounts to 50 feet. Like the other units described it is really a series of thin limestone layers of varying color and crystalline characteristics. It may in places carry dolomite, pyrite, and traces of shale. By far, the most distinctive characteristic of the gray limestone is its consistency in carrying large amounts of chert. Although chert is common in the other units, this horizon usually contains a larger proportion and is the first encountered in the Traverse with substantial amounts. An unusual but interesting example is well #32 (Plate 2), which penetrated 31 feet of mainly gray and light brown chert. Infrequently, salt water is found in this section of the Traverse.

Traverse Formation

Above the gray cherty limestone and interlayered with it is gray calcareous shale. This shale has many of the same lithologic characteristics as the basal shale. Limestone, dolomite, or dolomitic limestone are interlayered with this deposit and the shale may give way almost entirely to limestone in certain localities. This calcareous shale, and associated limestone and dolomite, continues upward and appears to be interlayered with the black non-calcareous Antrim shale above.

The Traverse formation is the most complicated section of the Traverse group. It should be divided into three separate parts, as it usually is seen in the samples. Directly above the gray cherty limestone is gray shale. Above this gray shale is a persistent bed of brown, tan, buff, or brown-gray limestone, dolomite, or dolomitic limestone. This bed frequently contains salt water and is sometimes called the Squaw Bay in well logs. Between this carbonate and the overlying Antrim shale is another zone of gray calcareous shale.

These three divisions comprise the Traverse formation. Limestone, dolomite, or black shale layers may be found among the three divisions complicating the above simplification. Any division may disappear or become too thin to be noticed. The Traverse formation varies greatly in thickness from well to well, but is usually between 10 and

100 feet thick. It is doubtful if any one division by itself would be over 50 feet thick.

No evidence has been discovered to support the thought of an unconformity in this part of the Traverse section.

Traverse Formation in Eaton County

In Eaton County the Traverse formation takes on a different aspect than that already mentioned. Here the thickness of sediments between the Traverse limestone and definite Antrim shale is usually 100 feet. Normal upward sequence of beds in the Traverse formation as previously mentioned was gray calcareous shale, dolomitic brown, or gray-brown limestone (usually correlated with the Squaw Bay), gray calcareous shale, and then typical black Antrim shale. In contrast, the wells in Eaton County show, for the same interval, approximately 20 feet of black and dark gray shale, 40 feet of gray-brown shaly limestone, 30 feet of black shale, 10 feet of gray dolomitic shale, and then typical Antrim shale.

The simplest explanation for this apparent change in the Traverse formation would be that the normal gray calcareous shales have become black or dark in Eaton County and the "Squaw Bay" limestone has become thick and shaly. However, careful examination of well logs of the Lansing and surrounding area indicates differently. Proceeding west and southwest of Eaton County the 40 foot section of gray-brown shaly limestone becomes less shaly. Proceeding east

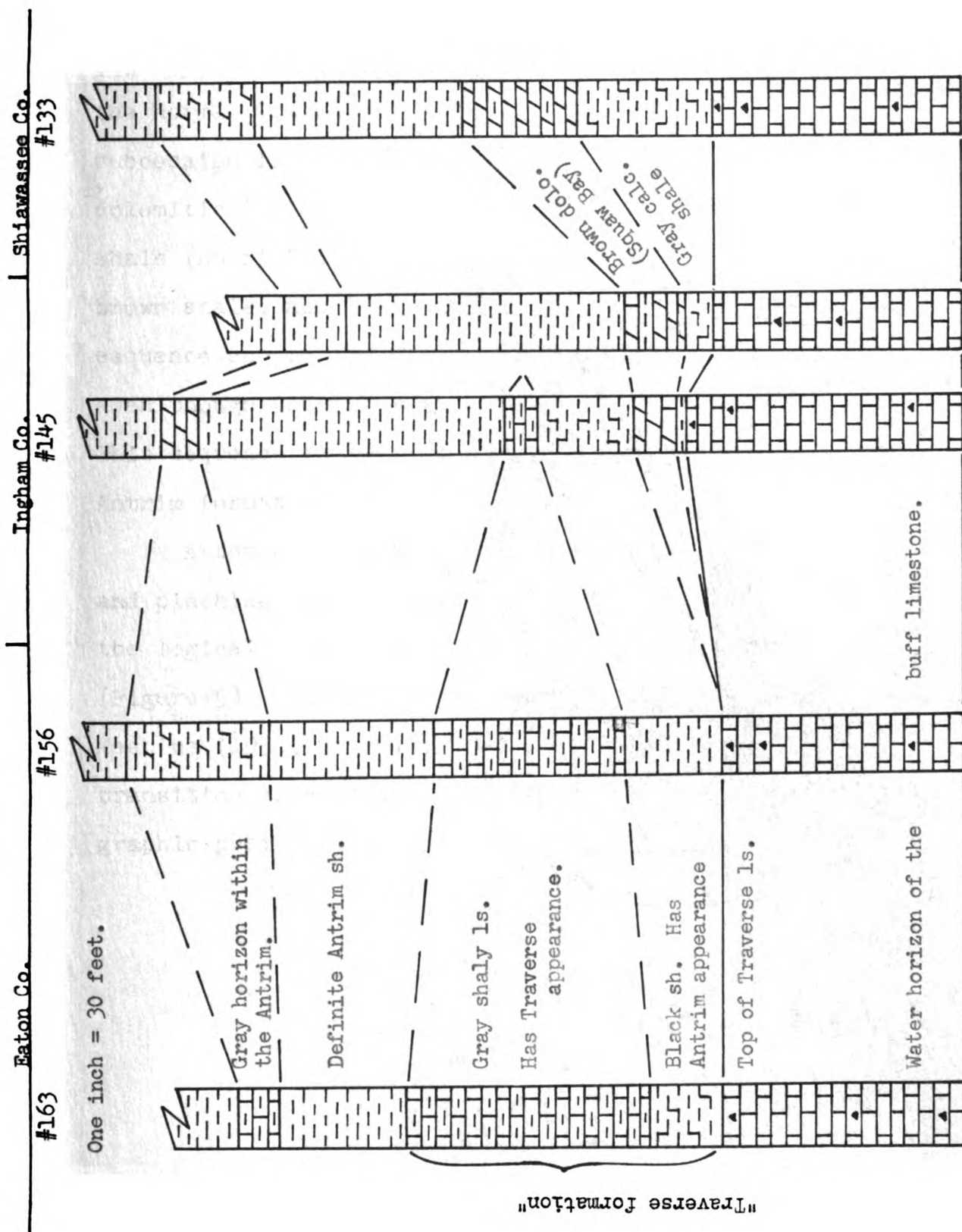


Figure 5. Traverse - Antrim contact.

and northeast of Eaton County the same limestone becomes thinner and eventually goes unnoticed in well logs. In Ingham County well #145 the Eaton County sequence overlies the normal Traverse formation sequence. Here the upward succession is 2 feet gray calcareous shale, 9 feet brown dolomitic limestone (Squaw Bay?), 19 feet black or brown shale (Antrim?), 7 feet gray-brown shaly limestone, 63 feet brown shale, and 8 feet gray dolomite. The Eaton County sequence can be traced throughout most of the Lansing area, even though the included limestone layer is quite thin. This sequence is usually placed in the basal part of the Antrim formation.

A tongue of Traverse formation coming from the west and pinching out to the east in Antrim shale seems to be the logical conclusion concerning the above relationship (Figure 5). This was proposed by Cohee (1947). Hake and Maebius (1938, p. 457) believe that the Traverse-Antrim transition zone of western Michigan corresponds in stratigraphic position to Antrim shale in eastern Michigan.

REGIONAL STRUCTURE

The Lansing area is in the south central portion of the Michigan basin. The Michigan basin is surrounded by positive structural elements which have been intermittently active throughout the Paleozoic. To the southeast is the Findlay arch and to the southwest is the Kankakee arch. The Wisconsin highland is to the northwest and the Laurentian highland is to the northeast. Most Michigan strata dip away from these regional structures and thicken toward the center of the basin (Plate 7).

Traverse rocks form a saucer structure in the Michigan basin with the northern rim much thicker than the southern rim. Top of the Traverse group reaches a depth of about 2300 feet below sea level in central Michigan. The main axes of subsidence during Traverse time were in the northern Lower Peninsula with a northwest trend (Newcombe, 1933, p. 108). Newcombe (1930, pp. 734-735) believes that the Traverse strata overlap successively older rocks to the southwest.

Folding has occurred in Traverse rocks as well as other Paleozoic sediments of the Michigan basin. This folding takes the form of asymmetrical anticlines, troughs, terraces, domes, structural noses, and bending of strata over reef structures. It ranges from the smallest imaginable

to as large as that exemplified by the Howell anticline which extends for more than 50 miles. Causes of the folding are numerous. Most important are regional stresses, deep seated faulting, vertical compaction, solution, and reef effects (Newcombe, 1933, pp. 113-120).

Michigan folds can be classified into four groups based on direction. The most prominent direction is northwest-southeast. Other directions are northeast-southwest, north-south, and east-west (Newcombe, 1933, p. 116). The folds everywhere seem to plunge toward the center of the basin. This indicates, perhaps, that the folds are mainly the result of deep seated faulting rather than the direct result of laterally transmitted forces.

Periods of folding for Michigan rocks are difficult to determine. In general, most of the folds which affect the Traverse group appear to have begun by the middle Devonian and to have continued at least until the Appalachian revolution. Every disturbance, major or minor, close enough to be felt in Michigan, probably accentuated the development of these folds (Newcombe, 1933, pp. 94-95).

LOCAL STRUCTURE

General

Traverse rocks in the Lansing area form a deposit which dips generally northward and thickens from about 300 feet to 450 feet, also northward. The top of the Traverse group ranges from 420 feet below sea level in T5N, R2E, to 1840 feet below sea level in T8N, R5W.

A comparison between Plate 3 (top of the Traverse limestone), and Plate 6 (base of the Traverse group) shows the Traverse group to have almost exactly the same structures as the underlying rocks. Structures in Plate 3 are more detailed than those in Plate 6, due to the increase in well data. When Plates 3 and 6 are compared to Plate 4 (thickness of Traverse limestone), a relationship is seen to exist between high structures and thinning of the Traverse limestone.

Traverse high structures and thinning may have resulted from one or more of three causes: vertical compaction of Traverse sediments over pre-existing topography during and after Traverse time, buckling of beds during Traverse sedimentation, post Traverse folding and thinning of beds at the crest of folds. Traverse structures were probably the result of all of the above causes and began forming during Traverse time. That there was erosion of the pre-Traverse

(Dundee) surface is generally accepted (Newcombe, 1930). Newcombe (1933, p. 95) believes that this erosion along with contemporaneous folding resulted in Traverse folds which were later accentuated by other period of folding.

Howell-Owosso Anticline

Traverse rocks of the Lansing area contain many structures. The most prominent of these is that which is shown on the northeast edge of the map (Plate 3). This is the "north extension" of the Howell anticline (Newcombe, 1933, p. 259). The Howell-Owosso anticline trends northwest-southeast in Livingston County and enters Ingham County and Shiawassee County in T⁴N, R²E, and T⁵N, R²E. It then plunges a few degrees west of north.

The western dip off the north extension is two degrees, at a minimum, between Shiawassee County wells #134 and #135. The actual dip is probably somewhat greater. Off the crest the dip becomes north and northeast at about one-half of one degree. In general, the north extension appears to be the west edge of a tilted block which is raised on the southwest and dips to the northeast. The trend of this structure is seen to continue with a lessening of dip north and off the map. Newcombe (1933, Plate III) has suggested that the north extension along with the main anticline in Livingston County may be faulted.

There is a northwest-southeast high trend across the northeast part of Clinton County (Plate 3). This trend is

in perfect alinement with the southern or main part of the Howell-Owosso anticline which trends northeast-southwest across Livingston County (Newcombe, 1933, p. 206).

On the extreme southeast edge of Plate 3 there appears a structure which is not well defined and which lies mainly in the southwestern Livingston County and northwestern Washtenaw County. This structure seems to have a north-south trend and a steep western dip. If this is true then this structure is in general alignment with the north extension of the Howell-Owosso anticline and quite similar to it.

Further to the south in northwestern Ohio the Bowling Green fault (Carman and Stout, 1934, p. 521) and its associated monocline, which enter southeastern Michigan (Newcombe, 1933, Figure 40), have a steep western dip and trend a few degrees west of north. The Bowling Green fault, the structure in northwestern Washtenaw County, and the north extension of the Howell-Owosso anticline are in general alignment with and similar to one another.

It appears that there are two distinct zones of faulting or folding, one trending a few degrees west of north and the other trending northwest. The intersection of the two has produced the sharp change in direction of the Howell-Owosso anticline from northwest to north. Newcombe (1933, p. 206) has suggested that the north extension of the Howell-Owosso anticline may not be directly related to the southern part of the Howell-Owosso anticline.

The Eaton County High Trend

Trending from the southwest corner to the northeast corner of Eaton County there is a "high" which is defined by several wells (Plate 3). The possible existence of this structure was surmised in 1912 (Smith, 1912, p. 158) when the Delta well (#151) was compared to the Charlotte well (#158). This structure in Eaton County appears to be a fold which plunges toward the northeast. The eastern dip off the fold is steeper than the northern dip on the northwestern flank. Exact location of the crest is difficult to determine from the sparse data available, but it appears to run from the Charlotte well to the Delta well. The direction of this structure agrees closely with one of the major directions of folding in the Michigan basin (Newcombe, 1933, p. 117). No closure has been found on this structure.

The remainder of Eaton County is clear of folds, based on information presently available.

Ingham County Structures

Little can be inferred about the structures of Ingham County from Plate 3, due to the lack of well data. The dip is generally north at less than one-half of one degree. The eastern half of the county has a northwest dip. One well, #150, seems higher than expected and may be part of a large structure. The Howell anticline enters the extreme northeast corner of Ingham County from Livingston County. Configuration of the Traverse rocks in the southeastern most

township of Ingham County is in question, but well data in Livingston County indicate a structure just east of the Ingham County line.

Clinton County Trough

The main structural feature in Clinton County is the trough which extends from the northwest to the southeast. This trough is distinguished by a lessening of northward dip. Center of the trough dips northward at about seven minutes of angle. It is bounded on the northeast by the northwest-southeast trending high which is aligned with the Howell anticline. The trough is bounded on the southwest by the greater normal dip of Eaton and southern Ionia Counties. The Clinton County trough diminishes in width as Ingham County is approached on the south, where the dip becomes greater. Continuation of the trough with a change of direction to southwest may parallel the Eaton County high trend on its eastern side.

Ionia County

No structures are shown in southeastern Ionia County by Plate 3. The dip here is northeast at less than one-half of one degree. Northeastern Ionia County and northwestern Clinton County have had much drilling activity. The Traverse limestone surface is quite irregular in this area. However, there seems to be two north-south high trends paralleling each other, but separated by the Ionia-Clinton County line. These trends are shown best by Plates 4 and 6.

GEOLOGIC HISTORY

The history of the Traverse group begins with the Dundee unconformity. At this time the land surface was undergoing erosion and slight folding (Newcombe, 1933, p.95).

As the water level rose and the Traverse sea spread southward a clastic mud was distributed and laid down as the first Traverse deposit. This sediment later became lithofied to a calcareous shale. The basal shale zone is represented in the Lansing area by a maximum of 100 feet of Traverse rock.

As could be expected of a wave distributed sediment on a low but undulating surface it thins and thickens irregularly (see Local Stratigraphy). The shale changes laterally westward to an argillaceous limestone (Plate 2) indicating that the source area was to the east. The Lansing area appears to have been on the western fringe of shale deposition, consequently the shale deposit is interrupted by limestone layers.

These limestone layers within the basal shale zone may be due to westward advance and eastward retreat of the area of shale deposition. They may equally as well be due to currents which deposited the shale in lobes. The lobes may or may not have covered the same area as before. Well logs

report sometimes one, sometimes several layers of shale in the basal zone.

Finally, the clastic source could not supply enough sediment to form shale in the Lansing area. The area of shale deposition moved further east and northeast closer to the source. Lime deposition, which was active in the west, then began to dominate sedimentation in the Lansing area. Clastics were still arriving, however, at least in Clinton, Shiawassee, and Ingham Counties, but only with enough influence to cause the lime-muds to be argillaceous in places. This limestone together with the underlying shale zone compose the lower half of the Traverse section. Lime deposition was prevalent in the Lansing area during most of Traverse time.

Shale deposition must have retreated still further as the argillaceous character of the lime-muds disappeared in all but the northern part of Clinton County. The record of this period of time consists of light colored pure limestone, chert, fragmental limestone, coralline material, and dolomite (whether primary or secondary is not clear). This section of the Traverse group represents a time during sedimentation when the sea was shallow, the water was relatively calm, and the highlands were low or far away. A persistent water horizon occurs at the top of this zone. This porosity probably originated in fragmental limestone with recrystallization and secondary dolomitization modifying it somewhat.

After a period of clean limestone deposition the water again began transporting argillaceous material into the Lansing area. This clastic material was back to stay for the rest of the Devonian time. The record shows argillaceous limestone above the clean limestone, and calcareous shale above the argillaceous limestone. Within the calcareous shale are layers of limestone. One of these is widespread and relatively pure, although rather thin. It testifies to the interruption of shale deposition for a short period. Above the gray calcareous shale is the black, non-calcareous shale of the Antrim formation.

The base of the Antrim and the top of the Traverse appear to be intertongued in the western half of the Lansing area. Therefore, the upper Traverse beds in the west may be equivalent to the lower Antrim in eastern Michigan. An unconformity is believed by Kirkham (1932, pp. 136-137) to be located at the top of the Traverse group.

The ages of folding in Traverse rocks can not be determined by this investigation. Newcombe (1933, p. 95) believes there was folding during the Dundee-Rogers City erosion interval and later folding along the same structures during Post-Traverse periods. Thinning in Plate 4 indicates that folding was proceeding while Traverse sediments were being laid down. The Howell anticline in Livingston County began to fold and fault during Coldwater time, according to Kilborne (1947, p. 21). A different age may be possible for the "north extension."

PETROLEUM POSSIBILITIES IN THE LANSING AREA

General

When considering the petroleum possibilities of the Traverse group in the Lansing area certain facts are evident. These facts are as follows: the Traverse group is productive in other parts of the state, oil is present in the Traverse group in the northwest corner of the Lansing area, the sequence of rocks in Central Michigan (a productive region) is the same as those in the Lansing area, Traverse strata are thinner in the Lansing area than the Central Michigan region. Only the last fact mentioned is detrimental to the likelihood of oil being present in the Lansing area. This last fact is not considered too important. Traverse rocks in the Muskegon oil field, of approximately the same thickness as those in the Lansing area, produced oil.

Another consideration which is important in determining the oil possibilities of an area is the presence of reservoir rocks. A reservoir rock is present in the Traverse of the Lansing area in the form of the persistent water horizon of the Buff limestone. This porous zone is usually several feet thick. Quite frequently it causes a well hole full of water, indicating that the porous zone transmits the expected hydrostatic pressure and probably ranges as far as one of its surface exposures. However, not all wells have

found porosity at this horizon. Some wells received less than a hole full of water. This lessening of permeability may have been caused by an original lack of permeability, cementation at the time of deposition, or chemical action after consolidation. No relationship was seen to exist between Traverse structure and permeability in this water horizon. Other possible reservoir rocks indicated by water zones are the Gray Cherty limestone and the limestone of the "Traverse formation." Also, possible reservoirs might be found in the Traverse in the form of reefs, fractured rock, or layers of a fragmental texture.

Since there is the possibility of both petroleum and reservoir rocks being in the Traverse of the Lansing area the only consideration remaining is that of favorable structures. The possibility of favorable structures being in the area is fair. However, no traps either stratigraphic or structural have been defined by this investigation. Several structures are of interest for future exploration or investigation.

Eaton County High Trend

The structure in Eaton County, which trends northeast-southwest across probably the entire county, is a prime exploration target. This structure is asymmetrical with the southeastern dip greater than the northwestern dip. The crest is narrow in comparison to length. It plunges northeast and shows no closure along its length. However, if

closure should be found this structure would become a possible trap.

Two gas shows and a rainbow of oil have been reported from different wells in the area of the high trend. All shows have been at different horizons. No shows were reported from well #158 which seems to be near the crest of the anticline.

Thinning of the Traverse and succeeding formations over this structure indicate that it began during or prior to Traverse time.

North Extension of the Howell-Owosso Anticline

More information is needed before much can be said or interpreted about this structure. Its plunge is slightly west of north. The western limb of this structure dips west at a rate of at least 2 degrees. The age of this part of the Howell anticline and its cause are unanswered questions.

No closure has been found on this structure. However, closely spaced wells may bring out irregularities along the crest, much the same as that in T7N, R2E. Here well #131 shows a reversal of the normal dip. Well #132 discovered a small accumulation of oil. If the north-extension has been created by faults which extend into Traverse rocks, such faults may have caused traps to form. If these faults do not extend into Traverse but are at depth, then the extension of their fault planes into Traverse rocks may locate porous zones.

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Clinton County Extension of the Howell Anticline

This structure trends northwest-southeast across the northeast corner of Clinton County. By its location and direction it appears to be related to the Howell anticline. The Clinton County extension is broad in relation to its length. No closure has been found on this structure.

Six wells all within approximately three miles of each other have had shows of oil on this structure. Two of these wells have had shows in the Dundee formation, as well as in the Traverse. Such an association of shows strongly suggest the possibility of an oil trap somewhere in this vicinity. If not in the Traverse, then perhaps in the Dundee.

Northwestern Corner of the Lansing Area

Three small but commercial oil pools have been found in this corner of the Lansing area. All seem to be controlled by structural and porosity conditions. Pay zones are in the Cherty limestone. Some Dundee production has been found in this area also.

A great amount of drilling activity has taken place in this northwest corner. Structural conditions at the top of the Traverse are very irregular and complicated. Plates 4 and 6 show the general structural picture. Two highs paralleling each other extend northward. One is on the Clinton side and one is on the Ionia side of their mutual county line. Compaction over Dundee structures and uneven compaction due to varying sediments has probably caused the

Traverse surface to be uneven and irregular. Oil has been trapped in these minor high structures where porosity was good. This is exemplified by the three oil pools in this area. Similar irregularities at the top of the Traverse are probably present throughout the Lansing area.

Clinton County Trough

The Clinton County trough and its southwest extension into Ingham and Eaton Counties can be considered an area of possible petroleum traps. It is unlikely that the top of the Traverse could dip evenly at seven minutes of angle. Very likely there are high and low irregularities in the trough area, just as there are in the northwest corner. In the trough area little height is necessary to gain closure. Few shows of oil or gas have been reported from the trough.

Stratigraphic Traps

Many shows of oil in the Lansing area occur at the base of the Antrim or the top of the "Traverse formation." These shows occur in rock which is usually brown dolomite or dolomitic limestone. They appear to be caused by porosity traps and not by structural traps.

The oil shows might also be caused by minor interfingering at the base of the Antrim, where brown dolomitic limestone layers, from the Traverse, pinch out in the Antrim shale above.

CONCLUSIONS AND RECOMMENDATIONS

The Traverse group in the Lansing area can be divided into several lithologic units. These units are from bottom to top: basal shale zone, gray-brown limestone, buff limestone, gray-cherty limestone, and "Traverse formation."

"Traverse formation" can be divided into three parts: lower gray shale, brown dolomitic limestone, and upper gray shale.

These units are present throughout the Lansing area, with the exception of the basal shale zone which thins to the southwest and is missing in parts of Eaton County. All units except the "Traverse formation" thin to the south or southwest. The "Traverse formation" appears to thin eastward.

The dip of the Traverse group in the Lansing area is generally to the north, but in the eastern part of the area the dip is northwest. In the western part of the area it is northeast.

Large structures in the Lansing area include the Eaton County high trend, the north extension of the Howell anticline, and the Clinton County trough. The Eaton County high trend is an asymmetrical anticline or nose which plunges northeast. The east limb dips steeper than the west limb. The north extension of the Howell anticline is in Shiawassee County. It is an asymmetrical anticline which plunges a few

degrees west of north and has a steep western dip. The eastern flank of this structure dips northeast. The north extension may be the result of faulting. The Clinton County trough is a synclinal structure. It is wide in northern Clinton County and narrows down to the southeast as it approaches Ingham County. From northwest Ingham County this trough extends southwest across Eaton County. The Clinton County trough dips more gently to the north than the surrounding area.

Closely spaced wells show the top of the Traverse limestone to be irregular with small domes, noses, and other structures.

It is reasonable to believe that there are petroleum traps in the Lansing area. However, no traps were located by this investigation. Several structures or areas are of interest for future exploration and investigation. These are: the Eaton County high trend, the north extension of the Howell anticline, the Clinton County extension of the Howell anticline, the undefined structure in central Ingham County, the undefined structure in southeastern Ingham County and southwestern Livingston County, and the entire Clinton County trough.

EXPLANATION OF PLATES 2, 3, 4, 5, and 6

Plate 2--Well Log Correlation

This drawing was constructed to illustrate the thickness and southward thinning of the Traverse group. It also shows the relationship between the Traverse group and the Antrim shale. Between the Traverse limestone and the base of the Antrim shale is a transition zone composed of intercalated calcareous shale and limestone.

Cross section A-C shows the absence of the basal shale zone (Bell shale?). Wells #153 and #115 contain shaly limestone in the interval which corresponds to the basal shale zone of other wells. The same relationship occurs in wells #32 and #65 of cross section A-B. This introduces the question of whether the basal shale is absent due to lateral gradation and facies change.

Plate 3--Structural Contour Map of the Traverse Limestone

Top of the Traverse limestone was used for a marker horizon in the construction of this map. The top of the Traverse limestone is the upper limit of reservoir rock. All rock above is shale with the exception of the Squaw Bay and thin carbonate layers in the base of the Antrim, which are difficult to correlate. Top of the Traverse limestone is usually reported in well logs which otherwise give a minimum of information.

A 25 foot contour interval was used to allow for inaccuracies arising from depth measurements, correlation, poor sampling, and poor recording. The greatest inaccuracy is the means of location the top of the Traverse limestone. The limestone grades upward into shale, so the top of the Traverse limestone must be placed at that point below which there is no significant amount of shale.

In the Eaton County area the top of the Traverse is overlain by shale and also a significant amount of limestone (see Local Stratigraphy). When the top of this limestone is mapped the structure is found to be essentially the same as that shown in Plate 3.

The steep slope on the southwest side of the Howell anticline may indicate a fault, rather than the limb of a fold as shown.

Plate 4--Isopach Map of the Traverse Limestone

A contour interval of 50 feet was used in constructing this map. Most of the high trends seen on Plate 3 and Plate 6 are represented on Plate 4 as areas where the Traverse is thin. The north extension of the Howell-Owosso anticline is not clearly represented on this map. However, there is a lack of data of this area; faulting or abnormal dips may have complicated the existing data.

Too much reliance should not be placed on the isopach lines in the south half of Plate 4. Sufficient data was not obtained. Isopach lines in T5N, R2W, and T5N, R1W, are in

question. If the base of the lower shale zone is placed higher in the Traverse column than is actually true, then the formation would show thinning. This situation is possible in the above mentioned townships.

Plate 4 was constructed entirely from well information, and not by superimposing Plate 3 on Plate 6.

Plate 5--Panel Diagram of the Traverse Group

This diagram was constructed to illustrate the thinning and shale-limestone relationship of the Traverse group in the Lansing area. Traverse lithology has been generalized in this drawing.

Plate 6--Structural Contour Map on Base of Traverse Group

This map corresponds very closely to Plate 3. It was contoured with the same interval (25 feet). The southern half of this map has been contoured with a 100 foot interval. So also, has the north extension of the Howell-Owosso anticline. The north extension may be faulted. Information in T5N, R1W, and T5N, R2W, is in question here, as it was in Plate 4.

EXPLANATION OF TABLES

Code No.	Number assigned to a particular well by the author and used in the written material. Well samples have been examined if this number is underlined.
State Permit	Well permit number assigned by the State of Michigan.
Name and Location	Self-explanatory.
Elev.	Elevation of the rig floor in feet above sea level (approximate elevation in some cases).
Show	Depth in feet below sea level at which a show of oil or gas was encountered. An asterisk indicates a show of oil. Two apostrophes indicates a show of gas.
Water	Depth in feet below sea level at which a salt water horizon was encountered.
TTrL	Depth in feet below sea level to the top of the Traverse limestone.
BB	Depth in feet below sea level to the base of the Traverse group.
BB-TTrL	Difference between the depth to the base of the Traverse group and the depth to the top of the Traverse limestone.

IONIA COUNTY

Code No.	State Permit	Name and Location	Elev.	Show	Water	TTrL	BB	BB-TTrL
1	14094	Donahue #1, SW-1/2, SE-1/4, NW-1/4, Sec. 4, T8N, R5W.	796.6		1955	1875	2233	358
2	14293	W.F. McKenna #3, NE-1/4, NW-1/4, SE-1/4, Sec. 4, T8N, R5W.	788.3		1942	1884	2243	359
3	13200	W.F. McKenna #1, SW-1/4, NW-1/4, SE-1/4, Sec. 4, T8N, R5W.	782.1	1868*	1868	1868	2227	359
4	16130	W.F. McKenna #6, NW-1/4, SW-1/4, SE-1/4, Sec. 4, T8N, R5W.	784.6		1940	1867	2229	362
5	13798	T.&L. Donahue #1, NE-1/4, SE-1/4, SE-1/4, Sec. 4, T8N, R5W.	782.6		1937	1880	2234	354
6	13592	W.F. McKenna, SW-1/4, NE-1/4, NW-1/4, Sec. 9, T8N, R5W.	777.9		1932	1882	2246	364
7	15052	W.F. McKenna #4, SE-1/4, NE-1/4, SW-1/4, Sec. 4, T8N, R5W.	793.3		1917	1877	2225	348
8	15288	W.F. McKenna #5, SW-1/4, NE-1/4, SW-1/4, Sec. 4, T8N, R5W.	774.1		1911	1870	2227	357
9	15503	Wm. Clark #1, SE-1/4, NW-1/4, SW-1/4, Sec. 4., T8N, R5W.	764.8			1879	2227	348
10	11009	M.V. Wright #1, NW-1/4, NW-1/4, NE-1/4, Sec. 5, T8N, R5W.	777.6	1841	1888	1841		

IONIA COUNTY--Continued

Code No.	State Permit	Name and Location	Elev.	Show	Water	TTrL	BB	BB-TTrL
11	11186	Stevenson Comm. #1, NW-1/4, NE-1/4, NW-1/4, Sec. 5, T8N, R5W.	773.7	1858		1832		
12	10999	J.B. & M. Stevenson #1, NW-1/4, NW-1/4, NW-1/4, Sec. 5, T8N, R5W.	796.3	1820 1854		1838		
13	11231	Dalton #1, NW-1/4, NE-1/4, NE-1/4, Sec. 6, T8N, R5W.	816.6	1811 1835 pay		1818		
14	11859	R. Dalton #1, NW-1/4, NW-1/4, NE-1/4, Sec. 6, T8N, R5W.	807.2	1845*	1889	1830		
15	14151	A. Campbell #1, NE-1/4, NW-1/4, NW-1/4, Sec. 6, T8N, R5W.	825.5		1895	1864		
16	11539	Dalton #2, SE-1/4, NW-1/4, NE-1/4, Sec. 6, T8N, R5W.	803		1883	1848	2213	365
17	16945	I. Sessions, SE-1/4, SE-1/4, NE-1/4, Sec. 6, T8N, R5W.	795.7		2144 1896	1846	2222	376
18	16167	M. Depue #1, SW-1/4, NW-1/4, NW-1/4, Sec. 1, T8N, R5W.	711.8			1898	2280	382
19	17133	N.R. McKenna #1, SE-1/4, SW-1/4, SE-1/4, Sec. 3, T8N, R5W.	761.5		1913	1879	2238	359
20	16089	Ed. & M. Cusack #1, NW-1/4, NE-1/4, SW-1/4, Sec. 10, T8N, R5W.	763.1		1917	1845	2239	394

IONIA COUNTY--Continued

Code No.	State Permit	Name and Location	Elev.	Show	Water	TTrL	BB	BB-TTrL
21	16407	C.Thomas & M.Comm. #1, NE-1/4, SE-1/4, NE-1/4, Sec.10, T8N, R5W.	745.2		1895 2005	1861	2235	374
22	15564	I.Marion #1, SW-1/4, NW-1/4, NW-1/4, Sec.11, T8N, R5W.	742.3	1864*	1905	1864	2238	374
23	4701	Marion #1, NE-1/4, NW-1/4, NW-1/4, Sec.11, T8N, R5W.	748.7		1916	1871	2256	385
24	15099	A. Corey #1, SW-1/4, NW-1/4, SW-1/4, Sec.12, T8N, R5W.	761.4		1893	1856	2242	386
25	14206	M.Brayton #1, SW-1/4, SW-1/4, NE-1/4, Sec.23, T8N, R5W.	748.5		1886	1832	2192	360
26	13783	Leo & Thomas Fox #2, NW-1/4, NW-1/4, SW-1/4, Sec.23, T8N, R5W.	778.8		1821	1817	2169	352
27	13303	Leo & T. Fox #1, SE-1/4, SW-1/4, SW-1/4, Sec.23, T8N, R5W.	766.5	1823*	1858	1806	2175	369
28	20707	Hogan #1, SW-1/4, SE-1/4, SE-1/4, Sec.22, T8N, R5W.	772.5	1806	1806 1868	1815	2172	357
29	16534	Bussee #1, NE-1/4, NW-1/4, SE-1/4, Sec. 21, T8N, R5W.	787.7		1854	1815	2182	367
30	10985	St.Clair #1, C S-1/2, NW-1/4, SE-1/4, Sec.28, T8N, R5W.	791.9			1803	2154	351

IONIA COUNTY--Continued

Code No.	State Permit	Name and Location	Elev.	Show	Water	TTrL	BB	BB-TTrL
31	13634	Charles Wilder #1, NW-1/4, NW-1/4, SE-1/4, Sec. 29, T8N, R5W.	790.1	1796*		1805	2168	363
32	2648	Bank of Muir #1, NE-1/4, NE-1/4, SW-1/4, Sec. 30, T8N, R5W.	758.6			1764	2181	417
33	18407	Jay Howk #1, SW-1/4, SW-1/4, NW-1/4, Sec. 19, T8N, R5W.	762	1814*		1824	2188	364
34	1849	Moss #1, NE-1/4, SE-1/4, Sec. 19, T8N, R5W.	776	1799* 1924*	1839 1959	1793	2145	352
35	9826	F. Leomis #1, C SW-1/4, SE-1/4, Sec. 17, T8N, R5W.	766		1902	1823	2192	369
36	19547	J. Howk, et al, #A-1, SE-1/4, NW-1/4, NE-1/4, Sec. 19, T8N, R5W.	773.1	1946*	1856 1946	1821	2182	361
37	16915	Schafer #A-1, NW-1/4, NE-1/4, SW-1/4, Sec. 18, T8N, R5W.	802.1		1823 1858	1807	2186	379
38	16019	Schafer #1, SE-1/4, SE-1/4, SW-1/4, Sec. 18, T8N, R5W.	797	1862*	1862	1803	2170	367
39	15291	M.I. Stearns #1, NW-1/4, NE-1/4, NW-1/4, Sec. 12, T8N, R5W.	766.8			1847	2218	371
40	2619	E.E. Cutler #1, NW-1/4, SW-1/4, NW-1/4, Sec. 10, T8N, R6W.	856.2		1814 1879	1812	2226	414

IONIA COUNTY--Continued

Code No.	State Permit	Name and Location	Elev.	Show	Water	TTrL	BB	BB-TTrL
41	12713	R.L.Pierson #1, SE-1/4, SE-1/4, NW-1/4, Sec.13, T8N, R6W.	767.5			1835	2198	363
42	11290	Lyle Dickinson #1, NE-1/4, SE-1/4, SE-1/4, Sec.22, T8N, R6W.	790		1850	1766	2184	418
43	2773	J.B.Welch #1, NE-1/4, SW-1/4, NE-1/4, NE-1/4, Sec.33, T8N, R6W.	794.5			1722	2133	411
44	19817	G.Bertraw #1, NE-1/4, NW-1/4, SE-1/4, Sec. 36, T8N, R6W.	752		1901	1787	2177	390
45	20289	B. & Lower #1, SW-1/4, NE-1/4, SE-1/4, Sec.3, T7N, R6W.	793		1805	1747	2151	404
46	10327	N.Miller #1, NE-1/4, SE-1/4, SE-1/4, Sec. 36, T8N, R5W.	727.3		1885	1813	2180	367
47	12670	Leo Cook #1, SW-1/4, NW-1/4, NW-1/4, Sec.11, T7N, R5W.	733.8	1766"	1841	1755	2118	363
48	20200	L.P.Feldpausch #1, SW-1/4, SW-1/4, NE-1/4, Sec.16, T7N, R5W.	677.6			1738	2100	362
49	2919	S. H. Kimball #1, SE-1/4, SW-1/4, SE-1/4, Sec.15, T7N, R5W.	751			1738	2109	371
50	20535	L.Albright #1, SE-1/4, SW-1/4, NW-1/4, Sec.21, T7N, R5W.	768	1725*	1771 1905	1737	2094	357

IONIA COUNTY--Continued

Code No.	State Permit	Name and Location	Elev.	Show	Water	TTrL	BB	BB-TTrL
51	17227	G.Staley #1, SE-1/4,NW-1/4,NW-1/4, Sec. 29, T7N,R5W.	720.4	1720*	1800	1725	2084	359
52	17886	Consumers Power Co. #1, NW-1/4, NW-1/4,SW-1/4,Sec.28,T7N,R5W.	691.7	1720*	1770	1717	2079	362
53	11330	F.& M.Roose #1, N-1/2,N-1/2, NE-1/4, Sec.33, T7N,R5W.	676.2	1720*	1764	1720	2074	354
54	5993	Keifer #1, C E-1/2,SW-1/4,SE-1/4, Sec.5, T6N, R5W.	772		1658	1670	2016	346
55	3390	Wm. Mosser #1, NE-1/4,NE-1/4, NW-1/4, Sec.19, T6N, R5W.	772			1612	1970	358
56	14166	C. & C. Smith #1, SE-1/4, SE-1/4, SW-1/4, Sec. 11, T6N, R6W.	786.9		1693	1595	1963	368
57	10757 NW-1/4,	Creyton Est. #1, SW-1/4,SW-1/4, Sec. 4, T5N, R6W.	816.6	1490*	1551	1490		
58	10865	R. Patrick #1, SW-1/4,SW-1/4, NE-1/4, Sec.4, T5N, R6W.	819.4			1503	1941	438

CLINTON COUNTY

Code No.	State Permit	Name and Location	Elev.	Show	Water	TTrl	BB	BB-TTrl
59	18857	Joe Fitzpatrick #1, NE-1/4, NW-1/4, SE-1/4, Sec.2, T8N, R4W.	734.5		1937	1883		
60	3728	A.J.Fitzpatrick #1, NE-1/4, NE-1/4, NE-1/4, Sec.10, T8N, R4W.	735.8		1920	1889	2242	353
61	11082	James O'Connell #1, SE-1/4, SW-1/4, SE-1/4, Sec. 4, T8N, R4W.	749.3	2011*	1916 2011	1882	2242	359
62	13576	Helbeck-White Comm. #1, SW-1/4, SW-1/4, Sec.12, T8N, R4W.	715.1		1910	1836	2272	436
63	11712	Whittaker Bros.#1, SW-1/4, SW-1/4, NE-1/4, Sec. 22, T8N, R4W.	695		1895	1845	2230	385
64	13882	Lula B. Winans, NE-1/4, SW-1/4, NW-1/4, Sec. 21, T8N, R4W.	652.3	1824"	1918	1838	2203	365
65	10455	Jess Guernsey #1, NE-1/4, SW-1/4, NE-1/4, Sec.19, T8N, R4W	652.9	scum* 1842	1842 1897 1924	1776	2208	432
66	18744	Ward #1, NE-1/4, NE-1/4, NE-1/4, Sec. 30, T8N, R4W.	764			1830	2206	376
67	12514	M.& N.Hockstra #1, NW-1/4, NE-1/4, SW-1/4, Sec.28, T8N, R4W.	752.2	1785*	1824	1794	2175	380
68	19272	Angie Sillman #1, NW-1/4, NE-1/4, NE-1/4, Sec.27, T8N, R4W.	746.8			1832	2204	372

CLINTON COUNTY--Continued

Code No.	State Permit	Name and Location	Elev.	Show	Water	TTrL	BB	BB-TTrL
69	11271	Lee Kellam #1, SW-1/4, NE-1/4, NE-1/4, Sec.33, T8N, R4W.	751.8	1808* 1820*	1844 1852 1808	1797	2178	381
70	12209	C.H.Kirkham, NW-1/4, SW-1/4, NE-1/4, Sec.32, T8N, R4W.	764.3	scum* 1818	1818	1803	2176	376
71	15750	Lena Werner #2, NW-1/4, SW-1/4, SW-1/4, Sec.34, T8N, R4W.	751.1		1807 1819	1795		
72	14487	Lena Werner #1, SW-1/4, SW-1/4, SW-1/4, Sec.34, T8N, R4W.	750	1799*	1799	1784		
73	15046	Leo B. Esch #1, NE-1/4, NE-1/4, NE-1/4, Sec. 4, T7N, R4W.	751.3		1820	1809		
74	16360	Leo Luttig #1, SE-1/4, NE-1/4, NW-1/4, Sec.9, T7N, R4W.	738.2	1790*	1790 1842	1789	2150	361
75	13948	A.J.Mankey #1, NW-1/4, NE-1/4, SE-1/4, Sec.3, T7N, R4W.	742.4	1787*	1833	1789	2142	353
76	16984	M.L.Sturgis #1, SW-1/4, SW-1/4, NE-1/4, Sec.11, T7N, R4W.	747.9		1838	1789	2136	347
77	18630	Linus J.Pohl #1, NE-1/4, SE-1/4, NW-1/4, Sec.15, T7N, R4W.	748	1787*	1817 1839	1780		
78	10286	Oscar Simon #1, NW-1/4, SW-1/4, NE-1/4, Sec.21, T7N, R4W.	715.6	1755*	1756	1756		

CLINTON COUNTY--Continued

Code No.	State Permit	Name and Location	Elev.	Show	Water	TTrL	BB	BB-TTrL
79	16571	E.M.Rademacher #1,NW-1/4,NW-1/4, SW-1/4,Sec.21,T7N,R4W.	747.9		1838	1789	2136	347
80	9869	A.F.Spitzley #1, C S-1/2,SE-1/4, SW-1/4, Sec.21, T7N,R4W.	703.4	1754*		1754		
81	13175	J.L.& M.Goodman #1, SW-1/4,SW-1/4, NE-1/4,Sec.28, T7N,R4W.	720.6	1806"	1807	1752	2106	354
82	10136	A.Halfman #1, NW-1/4,SW-1/4, SW-1/4,Sec.22, T7N,R4W.	720.1	1763*	1811	1767		
83	9033	Linus Simon #1, NW-1/4,NE-1/4, SE-1/4,Sec.21, T7N,R4W.	728.2	1753*" 1755*	1753 1803	1756	2105	349
84	13586	R.McPherson #1, NW-1/4,NW-1/4, SE-1/4,Sec.9, T8N,R3W	722.2		1908	1835	2239	404
85	14458	Lansing Co. #1, SW-1/4,NW-1/4, NW-1/4,Sec.15, T8N,R3W.	725.6		1889	1809	2225	416
86	11390	L.N.Piggott #1,SE-1/4,SE-1/4, SW-1/4,Sec.30, T8N,R3W	734.2		1844 1906	1809	2182	372
87	2553	J.Becker #1, C of NW-1/4, SE-1/4,Sec. 35, T8N, R3W.	725.8	1821"	1822	1779	2137	358
88	18746	R.Estate #1, SE-1/4,SW-1/4, SE-1/4, Sec.7, T7N,R3W.	745.8		1844 1785	1744	2142	398

CLINTON COUNTY--Continued

Code No.	State Permit	Name and Location	Elev.	Show	Water	TTrL	BB	BB-TTrL
89	14767	A.L. # D.L.Mohnke #1, NW-1/4, NE-1/4, SW-1/4, Sec.22, T7N, R3W.	755.2		1836 1853	1740	2129	389
90	17980	W.& N.Castle #1, SE-1/4, SE-1/4, NW-1/4, Sec.13, T7N, R3W.	758.7			1761		
91	10335	P.Hankey #1, SE-1/4, SE-1/4, SE-1/4, Sec.3, T8N, R2W.	732.5			1776	2164	388
92	6948	Ed Fleagle, NW-1/4, SW-1/4, NW-1/4, Sec.15, T8N, R2W.	742.6			1753	2126	373
93	2732	M.C.Scott, NW-1/4, NW-1/4, NW-1/4, Sec. 22, T8N, R2W.	735			1732	2120	388
94	3045	H.W.Bross #1, NE-1/4, SW-1/4, NE-1/4, Sec.29, T8N, R2W.	716	1804*	1815	1734	2118	384
95	15762	S. & L. Daggett #1, NE-1/4, NE-1/4, NE-1/4, Sec.12, T8N, R2W.	694.4	1736*	1739	1783	2153	370
96	9656	F.W.Sommerville #1, NW-1/4, SE-1/4, NE-1/4, Sec.12, T8N, R2W.	698.3		1722	1762	2168	406
97	10319	L.G.Holbrook #1, C N-1/2, NW-1/4, SE-1/4, Sec.36, T8N, R2W.	731.6	1678" 1663*	1678	1663	2071	408
98	11803	John Kurncz, et al, NE-1/4, SW-1/4, NW-1/4, Sec.2, T7N, R2W.	723.8	1713*	1695 1713	1695	2051	356

CLINTON COUNTY--Continued

Code No.	State Permit	Name and Location	Elev.	Show	Water	TTrl	BB	BB-TTrl
99	19696	Mosher & Pattison Comm. #1, NW-1/4, SE-1/4, NE-1/4, Sec. 11, T7N, R2W.	747.1	1702*	1702	1686		
100	9427	W.L. Skutt #1, NE-1/4, SE-1/4, SE-1/4, Sec. 11, T7N, R2W.	766	1694*	1684 1728	1691	2027	336
101	3395	Carl Harris #1, NW-1/4, NE-1/4, SW-1/4, Sec. 14, T8N, R2W.	765	1688*	1715 1688	1666	2039	373
102	10733	Andrews #1, SE-1/4, NW-1/4, NW-1/4, Sec. 29, T7N, R2W.	760.3	2084*	1810	1745	2101	356
103	2341	A. Stratton #1, NW-1/4, NW-1/4, NE-1/4, Sec. 4, T8N, R1W.	687.5			1788	2188	400
104	10589	C. Walker #1, C W-1/2, SW-1/4, NW-1/4, Sec. 8, T7N, R1W.	755.1	1685**	1690 1703 1720	1670	2030	360
105	11278	G.M. Aldrich, SE-1/4, SE-1/4, SW-1/4, Sec. 3, T7N, R1W.	737.7		1705 1751	1669	2042	373
106	2853	J.E. Parker #1, NW-1/4, NW-1/4, NE-1/4, Sec. 32, T7N, R1W.	817.4		1688	1618	1983	365
107	3586	Ed Parker #1, SW-1/4, SW-1/4, NE-1/4, Sec. 25, T7N, R1W.	774.6		1695 1575	1563	1892	329
108	13619	G. Sexton #1, SW-1/4, NE-1/4, NW-1/4, Sec. 29, T6N, R1W.	819		1721	1641	2002	361

CLINTON COUNTY--Continued

Code No.	State Permit	Name and Location	Elev.	Show	Water	TTrL	BB	BB-TTrL
109	19858	N.X.Arthur #1,SW-1/4,NW-1/4,NW-1/4, NW-1/4, Sec. 29, T6N, R1W,	813.6		1731	1642		
110	3376	L.D.Arthur, NW-1/4, SW-1/4,NW-1/4, Sec. 29, T6N, R1W.	829	1652*	1652	1642	2024	382
111	19367	Vern & Agnes Viges #1,SW-1/4, SE-1/4,SE-1/4,Sec.2, T6N,R2W.	787.1		1728	1681	2013	332
112	10484	Elnora Clup #1, SW-1/4,SW-1/4, SW-1/4, Sec.17, T6N,R2W.	776.3		1694 1774	1671	2059	387
113	12925	E.B.Jones #1, NE-1/4,NE-1/4,NW-1/4, NW-1/4, Sec. 2, T6N, R3W.	757.1			1731		
114	5042	L. Koepfen #1, C E-1/2,SE-1/4, SE-1/4, Sec. 19, T6N,R3W.	779			1686	2028	342
115	8274	R.T.Zischke #1, SW-1/4,SW-1/4, NW-1/4,Sec. 14, T5N, R3W.	828.9		1626 1676	1606	1937	331
116	6433	Wm. Loesch, SE-1/4,SW-1/4, SW-1/4, Sec.18, T5N, R2W.	857			1605	1935	330
117	3495	G.Scheeberger #1, NE-1/4,SE-1/4, NW-1/4, Sec.11, T5N,R2W.	860		1756	1645	2026	381
118	3177	A.J.Cable #1, SE-1/4,NE-1/4,SE-1/4, Sec. 12, T5N, R2W.	856.7		1658 1728	1644	1980	336

CLINTON COUNTY--Continued

Code No.	State Permit	Name and Location	Elev.	Show	Water	TTrl	BB	BB-TTrl
119	9737	C.W. & A.Redmond #1, C N-1/2, NE-1/4,NE-1/4,Sec.20,T5N,R1W.	865.8		1684	1615	1907	292
120	10108	State of Michigan #1,NW-1/4, SE-1/4,SE-1/4,Sec.14,T5N,R1W.	834.8		1670 1589	1585	1891	306
121	19451	James Besko #1, NE-1/4,SW-1/4, SW-1/4,Sec.32, T5N, R1W.	845.2		1660	1612	1916	304

SHIAWASSEE COUNTY

Code No.	State Permit	Name and Location	Elev.	Show	Water	TTrl	BB	BB-TTrl
122	9396	H.Litschfield #1, SW-1/4, NE-1/4, NW-1/4, Sec.4, T8N, R1E.	717.5			1774	2177	403
123	8	D.D.Curtis #1, SE-1/4, SE-1/4, Sec.27, T8N, R1E.	745		1677	1677		
124		R.Mathews #1, NE-1/4, NE-1/4, SE-1/4, Sec.36, T8N, R1E.	772		1608	1588		
125		Chapman Bros.#1, SE-1/4, SW-1/4, Sec.17, T8N, R2E.	735	1605*	1605	1603		
126	2154	Haievs #1, NE-1/4, NE-1/4, NW-1/4, Sec. 34, T8N, R2E.	745.9			1536	1926	390
127	2098	James H. VanPelt #1, NW-1/4, NW-1/4, NE-1/4, Sec.35, T8N, R2E.	741	1506*	1555	1533		
128	14349	Glen Cudney #1, SE-1/4, SW-1/4, SE-1/4, Sec.3, T7N, R2E.	757		1473	1452	1832	380
129	7415	Shimunee #1, NW-1/4, NW-1/4, SE-1/4, Sec.5, T7N, R2E.	745.3			1453	1905	452
130		Pat Wade #1, SW-1/4, SE-1/4, SE-1/4, Sec.6, T7N, R2E.	745			1496		
131	13	Joe Jurica #1, NE-1/4, NW-1/4, Sec.8, T7N, R2E.	754			1486		

SHIAWASSEE COUNTY--Continued

Code No.	State Permit	Name and Location	Elev.	Show	Water	TTrl	BB	BB-TTrl
132		H.C.McGinnis #1, SW-1/4, SW-1/4, Sec. 5, T7N, R2E.	740	Oil?		1466		
133	8214	Glenn L. Gladden, #1, SE-1/4, NE-1/4, NW-1/4, Sec. 35, T6N, R2E.	834.4		938	886	1233	347
134	474	F.G.Morrice #1, SW-1/4, NW-1/4, NW-1/4, Sec. 3, T5N, R2E.	836		849	794	1224	430
135	1198	Crawford #1, NW-1/4, SE-1/4, Sec. 1, T5N, R1E.	848	1464*		1490	1812	322
136	16738	S.Nemcik Comm. #1, SW-1/4, NE-1/4, NW-1/4, Sec. 23, T5N, R2E.	913.3			606	917	311
137	8079	N.Garrity #1, NE-1/4, NE-1/4, NE-1/4, Sec. 27, T5N, R2E.	892.5			553	887	334
138	18557	W.A. & K.E.Service #1, NW-1/4, SE-1/4, SE-1/4, Sec. 24, T5N, R2E.	893		567	515	850	335
139	8109	R.M.Placeway #1, SW-1/4, SE-1/4, NW-1/4, Sec. 25, T5N, R2E.	929.3	501*"	421 521 501	451	781	330
140	14034	Roy D. Casady #1, SE-1/4, SE-1/4, SE-1/4, Sec. 34, T5N, R2E.	900.9			1419	1734	315

INGHAM COUNTY

Code No.	State Permit	Name and Location	Elev.	Show	Water	TTrL	BB	BB-TTrL
141	20566	M.B.Clark #1, SE-1/4, SW-1/4, NW-1/4, Sec.2, T4N, R1E.	942.1	1500* 1518*	1500 1518	1527	1850	323
142	792	Potter #1, NE-1/4, NW-1/4, NW-1/4, Sec.21, T4N, R2E.	915.3		1434	1420	1678	258
143	8132	R.T.Kendall #1, NE-1/4, NW-1/4, NW-1/4, Sec.15, T4N, R1E.	929		1578	1514		
144	3352	B.B.Smith #1, NW-1/4, NE-1/4, SE-1/4, Sec.9, T4N, R1W.	854.9			1608	1892	284
145	9987	Wm.Kirkpatrick #1, C N-1/2, SW-1/4, SW-1/4, Sec.22, T4N, R1W.	854.7		1583	1515	1813	298
146	7857	A.A.Schubel #1, SE-1/4, NW-1/4, SE-1/4, Sec.23, T4N, R1W.	867.1	1521*	1576	1514	1782	268
147	10011	J.G.Glaser #1, SE-1/4, SE-1/4, SE-1/4, Sec.14, T3N, R1E	908		1382 1446	1382	1647	265
148	9477	L.Rogers #1, SW-1/4, SE-1/4, SW-1/4, Sec.1, T2N, R1E.	898.4	1302*	1367	1304		
149	4918	Royston Farm #1, SE-1/4, SE-1/4, NW-1/4, Sec.23, T2N, R1W.	945.2	1304" 1466"	1315	1262	1523	260
150	4837	A.O'Sullivan #1, NE-1/4, SE-1/4, NW-1/4, Sec.28, T2N, R1W.	945		1284	1225	1463	238

EATON COUNTY

Code No.	State Permit	Name and Location	Elev.	Show	Water	TTrL	BB	BB-TTrL
151		Delta Well, NW-1/4, Sec. 10, T4N, R3W.	830			1479		
152	1090	Parker #1, NW-1/4, NE-1/4, Sec. 17, T4N, R5W.	862		1400	1400		
153	1806	H.A. & H.D. Woodworth #1, NE-1/4, SE-1/4, Sec. 5, T3N, R4W.	866	1414"	1396	1351	1637	286
154	8326	Hults #1, SW-1/4, SE-1/4, SW-1/4, Sec. 20, T3N, R4W.	942.4		1327	1248		
155	564	Wright #1, SW-1/4, SW-1/4, Sec. 28, T3N, R5W.	926		1239	1217		
156	12604	Martin Zuber #1, SE-1/4, NW-1/4, NW-1/4, Sec. 8, T2N, R3W.	877.4			1343	1607	264
157	2767	James Moon #1, C SE-1/4, SW-1/4, Sec. 11, T2N, R4W.	914	1396"	1326	1291	1499	208
158		Jas. Hiscock Farm, Charlotte Well, Sec. 18, T2N, R4W.	906		1144	1079		
159		C.E. Hubert Farm, S C NE-1/4, SE-1/4, Sec. 28, T2N, R4W.	890	1225*	1268	1185	1435	250
160	18459	James & Cecil Swan #1, NE-1/4, NE-1/4, NW-1/4, Sec. 14, T1N, R4W.	932		1133	1113		

EATON COUNTY--Continued

Code No.	State Permit	Name and Location	Elev.	Show	Water	TTrL	BB	BB-TTrL
161	924	Kruzen #1, SW-1/4, NW-1/4, Sec. 28, T2N, R5W.	904		1121	1071		
162	7319	M.E.Garms #1, NE-1/4, NE-1/4, NW-1/4, Sec. 4, T1N, R6W.	931.6		1026	983		
163	429	Alpha Portland Cement Co. #1, NW-1/4, SW-1/4, Sec. 28, T1N, R6W.	864		963	921	1166	245

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[REDACTED]

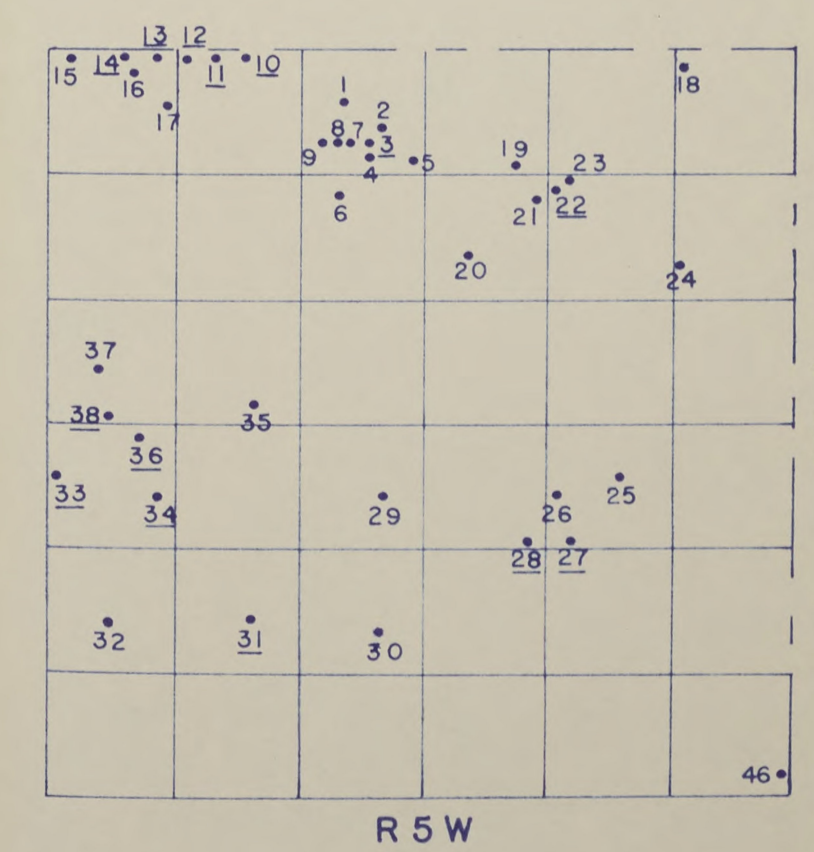
Beant has: 7 photos

[REDACTED]

JUL 15 1961

JUL 26 1961

~~JUL 20 1961~~ (C)

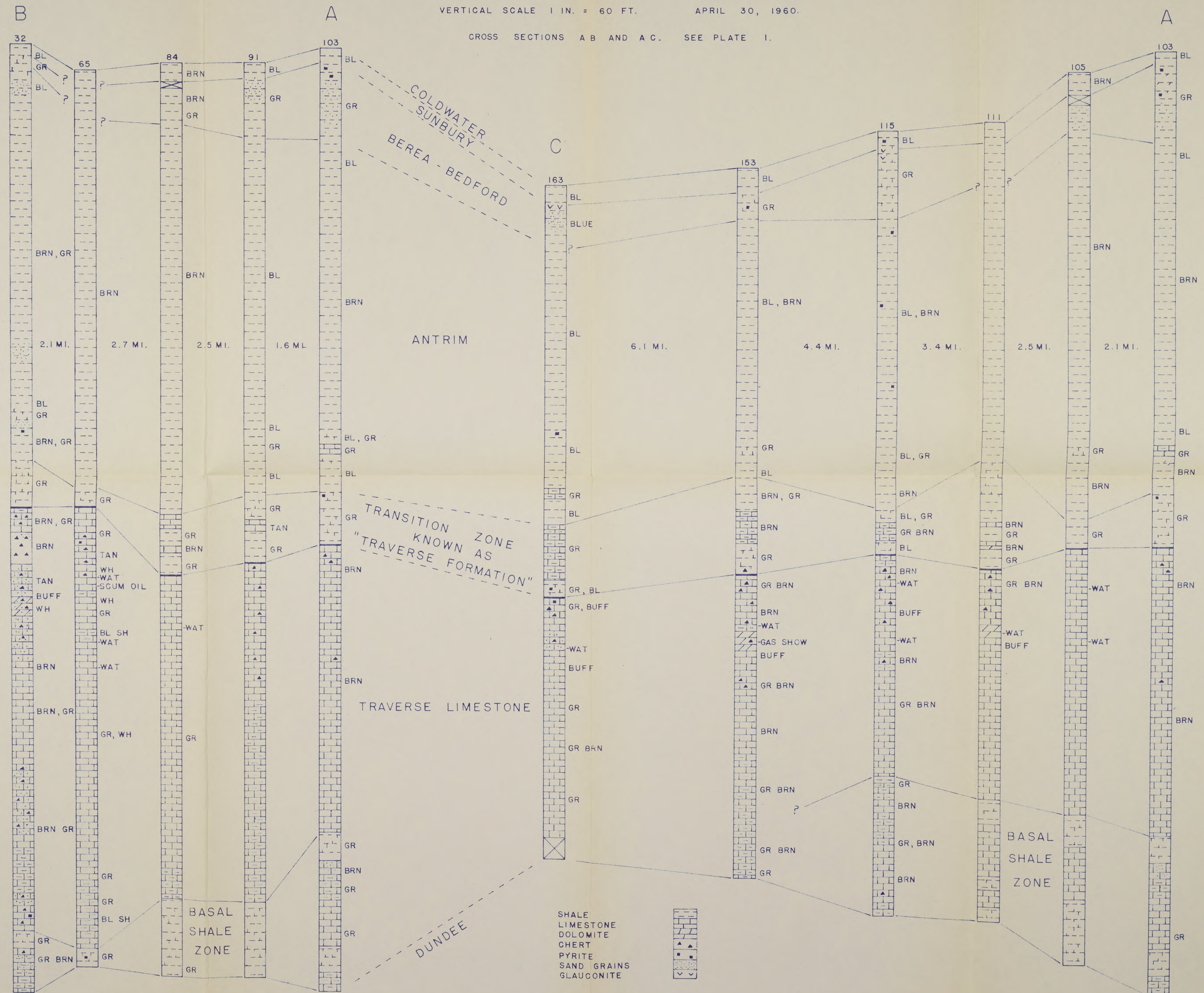


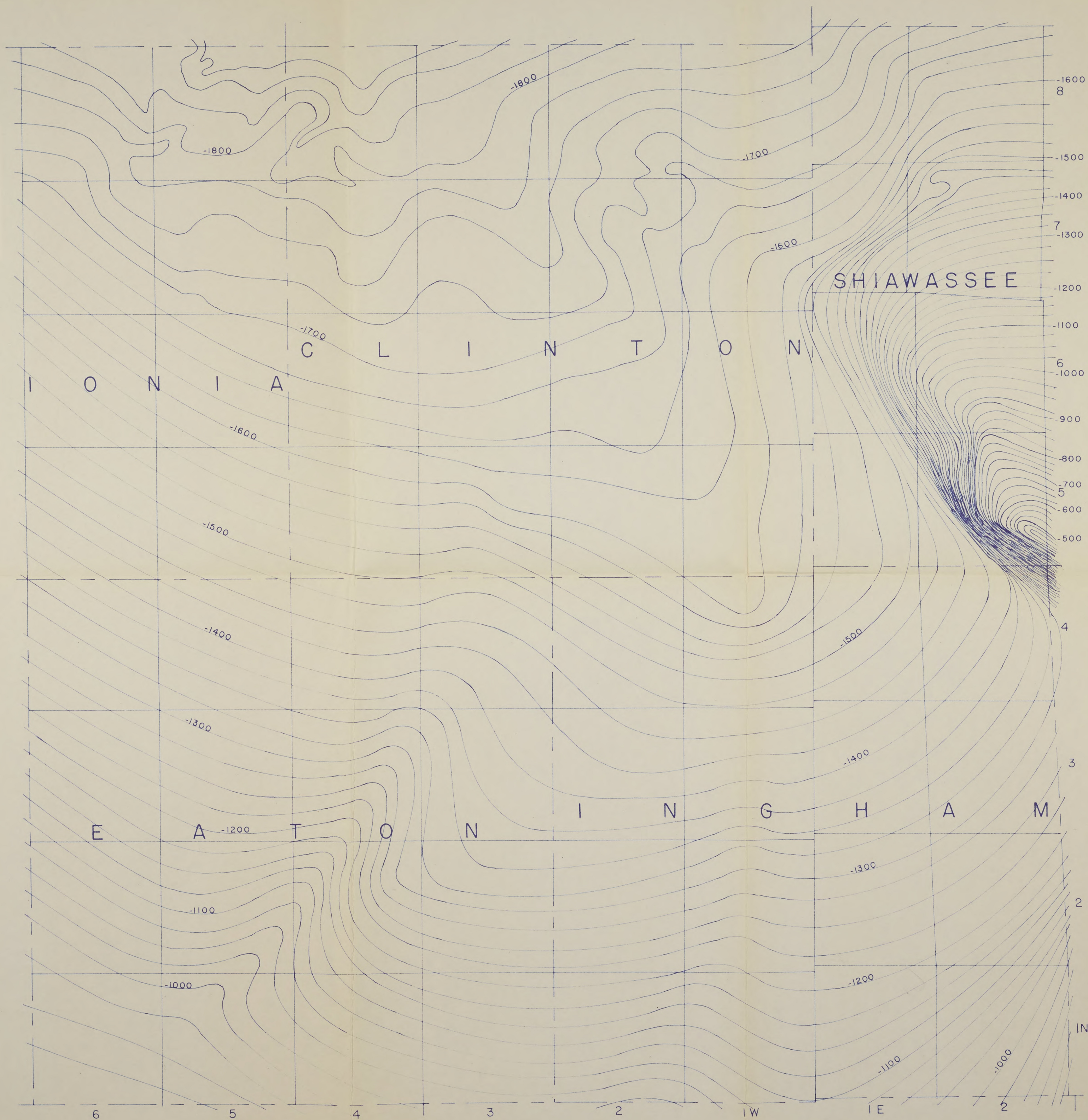
WELL LOG CORRELATION

VERTICAL SCALE 1 IN. = 60 FT.

APRIL 30, 1960.

CROSS SECTIONS A B AND A C. SEE PLATE 1.





TRUE
NORTH

PLATE 3

STRUCTURAL CONTOUR MAP
LANSING AREA
TOP OF TRAVERSE LIMESTONE

CONTOUR INTERVAL 25 FEET

DATUM PLANE SEA LEVEL

0 1 2 3
SCALE IN MILES

FEBRUARY 21, 1960



TRUE
NORTH

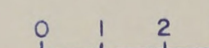
PLATE 4

LANSING AREA

ISOPACH MAP OF THE TRAVERSE GROUP
EXCLUDING THE "TRAVERSE FORMATION"

CONTOUR INTERVAL 50 FEET

SCALE IN MILES



APRIL 29, 1960



TRUE
NORTH

PLATE 6

STRUCTURAL CONTOUR MAP
LANSING AREA
BASE OF THE TRAVERSE GROUP

CONTOUR INTERVAL 25 FEET

DATUM PLANE SEA LEVEL

SCALE IN MILES

0 1 2 3

APRIL 30, 1960

PLATE 7
LOWER MICHIGAN
STRUCTURAL CONTOUR MAP
TOP OF THE TRAVERSE GROUP

AFTER COHEE, 1947, FIGURE 1

CONTOUR INTERVAL 100 FEET

DATUM MEAN SEA LEVEL

SCALE
20 MI.

T N

LEGEND

LIMIT OF TRAVERSE GROUP

FAULT

