THE PALEOECOLOGY OF CENTRAL MICHIGAN

Thesis for the Degree of M. S.
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Joseph Bacon Long

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This is to certify that the

thesis entitled

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Dr. A. Kelly
Major professor

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IN BACK OF BOOK

THE PALEOGEOLOGY OF CENTRAL MICHIGAN

By

Joseph Bacon Long

A THESIS

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INTRODUCTION

Virtually all of Michigan petroleum discoveries have been accounted for by means of subsurface interpretation including shallow drilling information, trend geology, and geophysical methods. The Gulf Petroleum Company conducted an extensive core drilling campaign and a supplemental geophysical program through the Kawkawlin block in Bay County before making the initial successful Dundee test. Seismic methods of exploration are not generally applicable to central Michigan because of the great thickness of glacial drift which dampens the energy of reflected seismic waves.

Michigan wildcatters have been able to use the vast amount of exploratory data to interpret structures most favorable for the accumulation of petroleum. Paleogeological studies also may serve to integrate this well information for more effective subsurface exploration.

A paleogeologic map drawn from well data, shows the distribution of formations at a surface which existed at some specific time in the geologic past. Such a map shows the changing areal and structural geology during geologic time.

HISTORY OF PALEOGEOLOGIC INVESTIGATIONS

Weirich (11) first used paleogeologic maps in 1929 to illustrate the areal distribution of the pre-Pennsylvanian rocks in the Cushing Field of Oklahoma. During the same year White (12) published paleogeologic maps showing the subsurface distribution of the Ordovician Wilcox sand series of northeastern Oklahoma. McClellan (9) included paleogeologic maps in his study of the pre-Mississippian rocks of Kansas and Oklahoma. Levorsen (6) used paleogeologic maps to illustrate the important structural differences which occur beneath the Mississippian overlap of the Midcontinent area. Eardley (4) employed paleogeologic maps to show the developing complexity of the geological pattern at the close of the lower Pennsylvanian, the Triassic, and the Jurassic periods.

Paleogeologic maps constructed by the Midcontinent geologists were based on regional unconformities. With the exception of the unconformable contact between the Pleistocene glacial drift and the underlying Paleozoics there is no datum surface within depths of 7,000 to 11,000 feet in central Michigan comparable to the regional unconformities employed by the Midcontinent geologists. The Centennial Geologic Map of Michigan compiled by Martin (8) is in reality a paleogeologic map for the reason that Paleozoic formations are indicated below the cover of glacial drift. The West Branch anticline is well shown on the Centennial Map by the older Coldwater shale encircled by the younger lower Marshall. This inlier is known to correspond to the anticlinal West Branch pool.

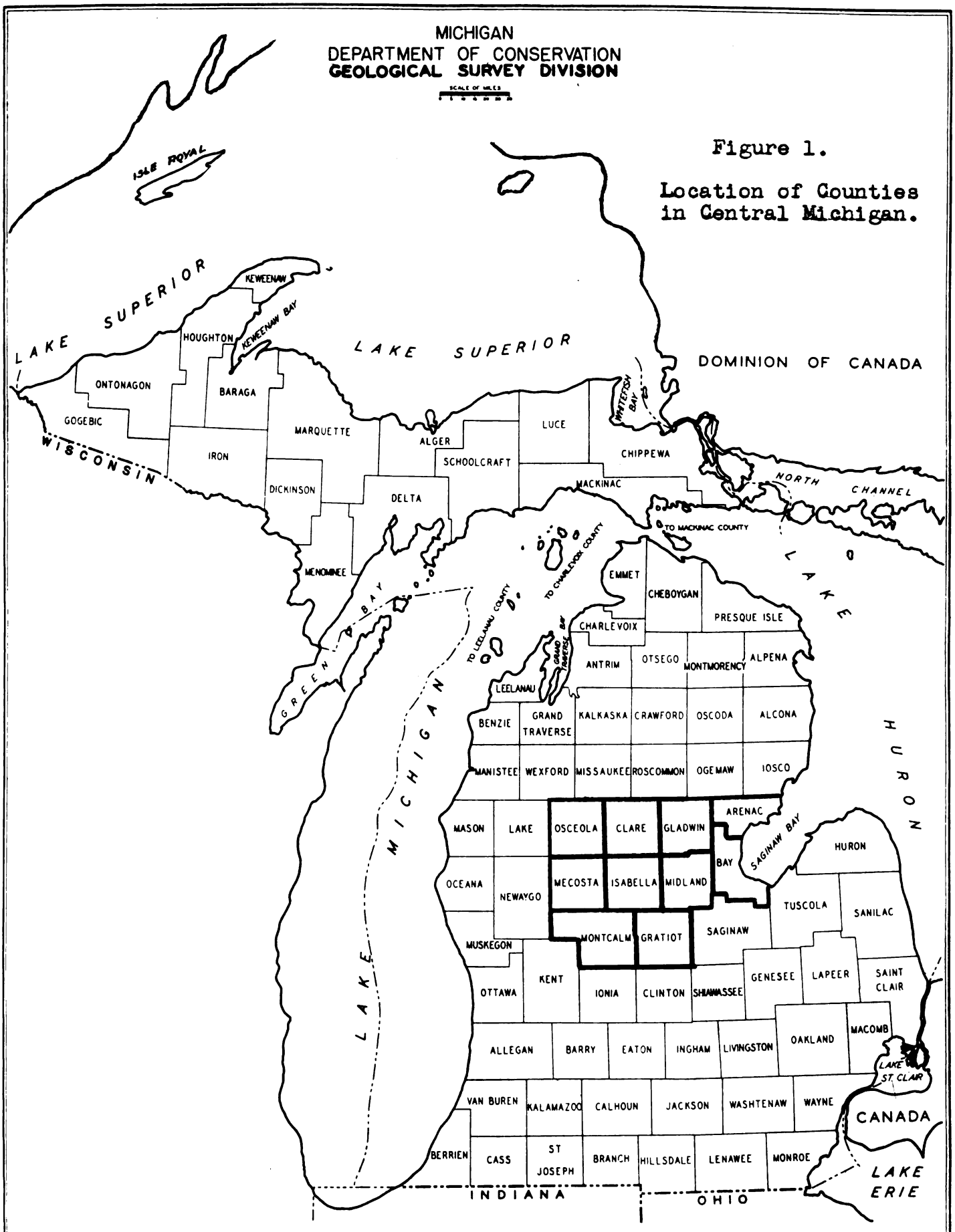


Figure 1.

Location of Counties in Central Michigan.

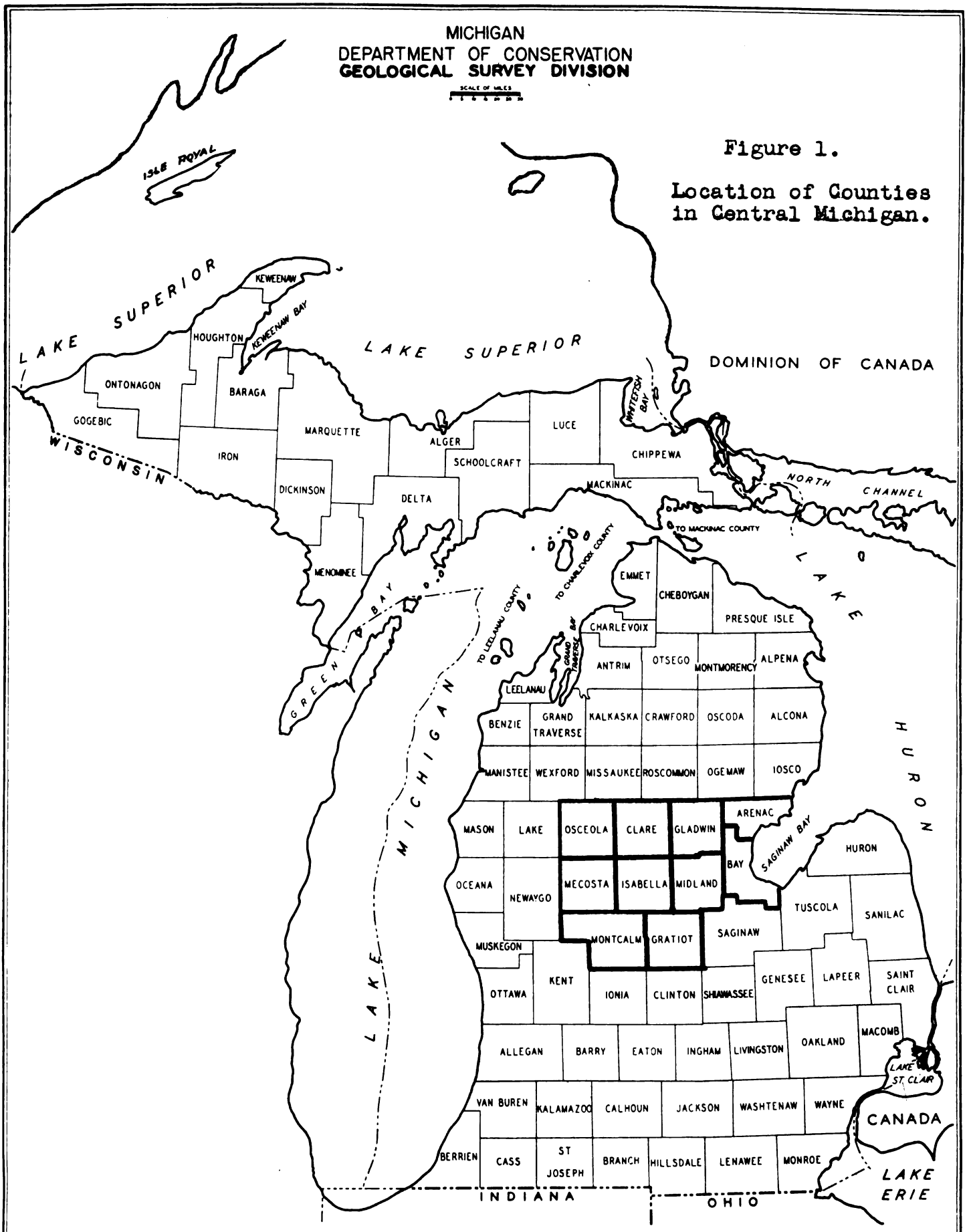


Figure 1.

Location of Counties in Central Michigan.

Unconformities at the base of the Pennsylvanian and middle Mississippian are not readily discernible. Those known to occur in the Ordovician and Cambrian sequences are at too great depths to be used as datum surfaces in central Michigan. Formation depths used in compiling the data for the construction of paleogeologic maps should be readily accessible by shallow drilling. In addition, the construction of paleogeologic maps requires that the contact of the unconformity be defined as clearly as possible if the maps drawn are to be feasible and employed to displace other methods of subsurface interpretation.

REVIEW OF PREVIOUS WORK IN MICHIGAN

The formations of Michigan which may be accessible by shallow drilling are an essentially conformable sequence and therefore a new datum surface for paleogeological studies is desirable. Kay (5) suggested that a sea level, or an arbitrary horizontal datum plane, be applied and formations in turn mapped below this plane. Students in stratigraphy at Michigan State College have constructed paleogeologic maps of Michigan counties by using an arbitrary horizontal datum surface calculated from a constant elevation below sea level. Well records were read to the datum surface and the corresponding formation at that depth was recorded on a base map by using a specific symbol or color. This procedure naturally results in a change in the stratigraphic formational units appearing on the map, and in effect, presents several local maps.

STATEMENT OF THE PROBLEM

An idea was formulated by R. B. Colten (2) in 1947 that a concave surface might be constructed and used as a datum for a paleogeological study of the Michigan basin. Colten's suggested procedure necessarily involves the determination of the average inclination of the gently dipping formations over extensive distances. The present report is based largely on Colten's idea of a curved datum surface.

The average inclination of the formations must be calculated on an easily identifiable contact which is present over a broad area of the Michigan basin. The contact between the base of the Traverse and the underlying formation approaches the prerequisites for calculating the average inclination of the formations.

The use of arbitrary data and radial profiles in which spacing is not subjectively selected might demonstrate the applicability of the curved datum surface in the virtually undrilled areas of Emmet, Presque Isle, Alpena, Alcona, Cheboygan, Otsego, and Kalkaska counties in the northern part of the southern peninsula of Michigan.

Subsurface interpretation in Michigan has been enhanced by information from more than 17,000 wells. The available data from this great number of wells can present evidence to support or disprove the hypotheses advanced by paleogeological studies. By using only a few wells in each county studied, conditions simulate those under which exploration programs are normally conducted, and under which they may be applied to the northern counties.

THE TRAVERSE-DUNDEE CONTACT

In applying the principle of Colten's curved datum surface the contact of the Traverse-Dundee formation was used. Because of similarities in color, texture, and lithology, well records usually include the Rogers City formation with the Dundee.

The Traverse-Dundee contact is generally identifiable from samples, electric logs, and published records of wells. The lithologic break between the lowest Traverse member, or the Bell shale, and the Dundee limestone and dolomites is apparent in most investigations (Fig. 2). Exceptions may be found in well samples from the Wise pool of Isabella County, where the shale above the Dundee limestone is thin, or the normal sequence of shale interfingers with relatively thick limestone members.

The contact approximates the regional dip of the formations and is the basis for calculating the basinal dip surface.

BASINAL DIP

Basinal dip is the average inclination along radial profiles of a formational contact. It differs from regional dip in that it represents the mean curve between the high and low areas of a contact surface. Regional dip, on the other hand, is the average inclination of a formation over a considerable distance.

Figure 2

GENERALIZED STRATIGRAPHIC DIVISIONS OF MICHIGAN

System, Series	Formation, Group	Lithology	Thickness
Recent			
Pleistocene	Glacial Drift	Sand, Gravel, Clay, boulders marl	0-1000
"Permo-Carboniferous"	"Red-Beds"	Shale, Clay, Sandy Shale, gypsum	
Pennsylvanian	Grand River	Sandstone, sandy shale	80-95
	Saginaw	Shale, Sandstone, limestone, coal	20-535
Mississippian	Bay Port	Limestone, Sandy or Cherty Limestone, Sandstone	2-100
	Michigan	Shale, gypsum, anhydrite, sandstone	0-500
	"Michigan Stray"	Sandstone	0-80
	Marshall	Sandstone, sandy shale	100-400
	Coldwater	Shale, sandstone, limestone	500-1100
	Sunbury	Shale	0-140
	Berea-Bedford	Sandstone, Shale	0-325
	Ellsworth-Antrim	Shale, limestone	100-950
Devonian	Traverse	Limestone, Shale	100-800
	Bell	Shale, Limestone	0-80
	Rogers City-Dundee	Limestone	0-475
	Detroit River	Dolomite, limestone, salt anhydrite	150-1400
	Sylvania	Sandstone, Sandy Dolomite	0-550
	Bois Blanc	Dolomite, Cherty Dolomite	0-1000

Continued next page

Figure 2 - Continued

System, Series	Formation, Group	Lithology	Thickness
Silurian	Bass Island	Dolomite	50-570
	Salina	Salt, Dolomite, Shale, anhydrite	50-4000
	Niagaran (Guelph-Lockport-Engadine) (Manistique-Burnt Bluff) (Cataract)	Dolomite, limestone shale	150-800
Ordovician	Cincinnatian (Richmond) (Maysville-Eden)	Shale, Limestone	250-800
	Trenton-Black River	Limestone, Dolomite	200-1000
	St. Peter	Sandstone	0-150
Ozarkian or Canadian	Prairie Du Chien	Dolomite, Shale	0-410
	Hermansville	Dolomite, Sandy Dolomite, sandstone	15-500
Cambrian	Lake Superior (Munising) (Jacobsville)	Sandstone	500-2000
Algonkian	Keweenaw (Copper formations)	Lava Flows, conglomerate, shale, sandstone	9800-35000
	Killarney Granite	Granite, Gneiss, diorite, syenite	
	Huronian (Iron formations)	Slates, Hematite, Schist, Quartzite, Granite, marble, dolomite	2000+
Archean	Laurentian	Schist, Gneiss, Granite	
	Keewatin	Schist, Greenstone, Slate	

CONSTRUCTION OF BASINAL DIP CURVES

Basinal dip curves were drawn by plotting subsurface profiles of the Traverse-Dundee contact on cross section paper to a vertical scale of one inch equal to 250 feet and a horizontal scale of one inch equal to four miles.

These curves were calculated from each profile by means of half values which represent the coordinate points of the average depth and distance between wells (Fig. 3). Local dips of the Traverse-Dundee contact then were corrected to the basinal dip curve.

Intervals of 100 feet were marked off vertically on each profile. The intersection points of the 100 foot intervals and the basinal dip curves were transferred to a base map of central Michigan and the values were contoured.

This map will differ from one constructed by Cohee (1) who shows the structural contours on the top of the Dundee-Rogers City sequence. Basinal dip contours on Map I show the inclination of the contact, but do not present local structural relationships as drawn on Cohee's map. Both maps show the gently inclined basin structure with the deepest part being in southwestern Gladwin County.

CONSTRUCTION OF COUNTY PALEOGEOLOGIC MAPS ON A CURVED SURFACE

The paleogeologic maps in this report were constructed to an interval of 2200 feet above the curved datum surface. By increasing the value of each basinal dip contour ~~to~~ 2200 feet, conditions of shallow exploratory

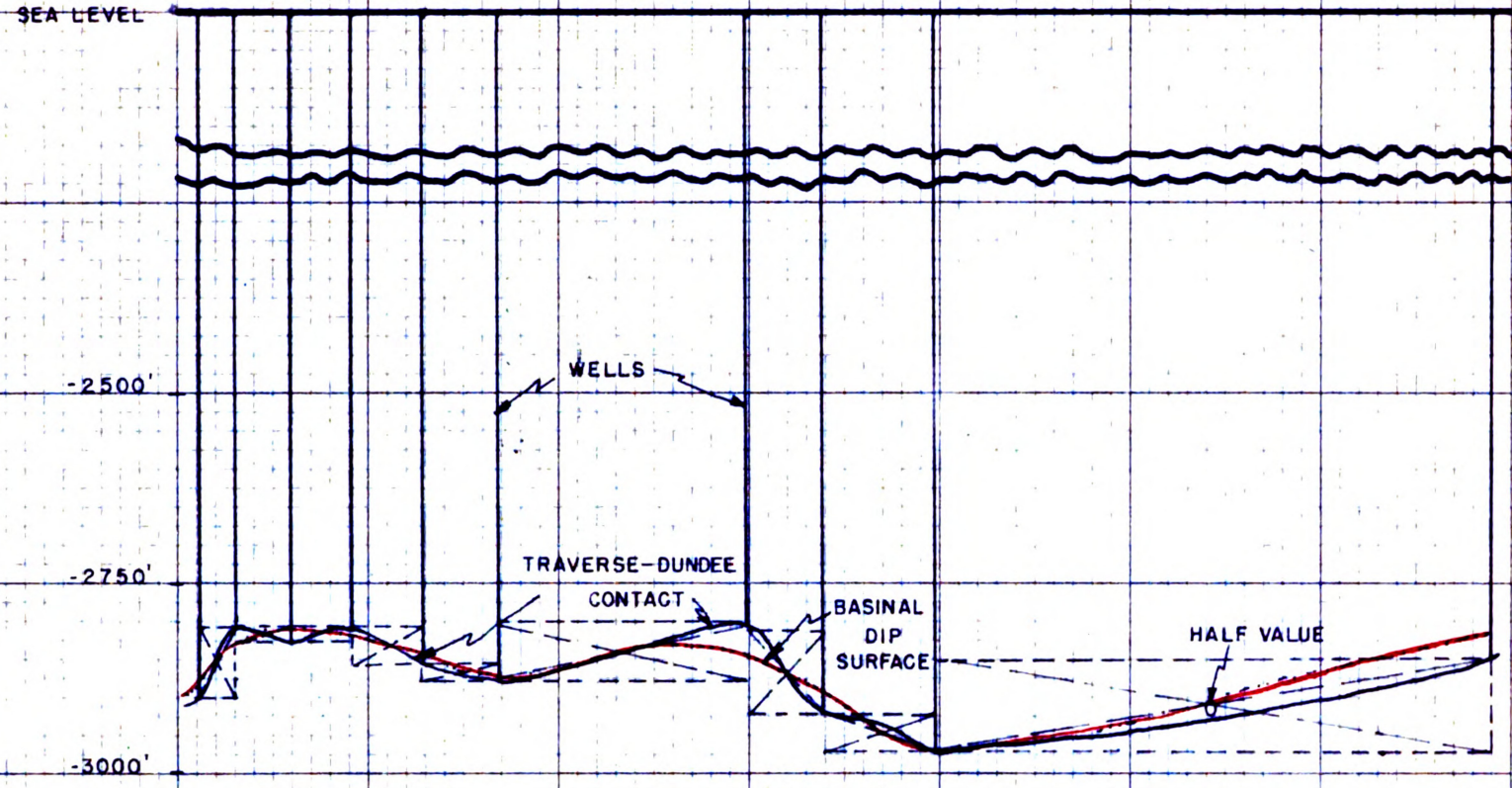


Figure 3. Calculation of Basinal Dip Curves From Half Values.

drilling at depths of 1200 to 1000 feet were simulated. This method is thought to be justified because shallow drilling continues to be the most widely used method of exploration by Michigan oil operators.

The 2200 foot increase of each basinal dip contour raises the datum surface to approximately the stratigraphic position of the Napoleon formation. Thomas (10) describes this Marshall formation member as a massive yellow-white sandstone, rather coarse grained, and characteristically with scattered green chloritic and red quartz grains. The formation is 50 to 100 feet thick and has been used interchangeably with "Upper Marshall" to describe the section from the Michigan series to the fine grey to red micaceous sandstones of the Lower Marshall.

PLOTTING PROCEDURE

A well in Union Township in Isabella County, serves to furnish data for the sample calculations in this report. The well is located in the SE 1/4, NE 1/4, SE 1/4 of section 7 at a surface elevation of 817 feet above sea level.

For purposes of plotting the location, the position of the well is properly superimposed on a transparent overlay sheet, under which is placed a base map of the central Michigan area. The base map is contoured at 100 foot intervals on the "raised" basinal dip surface. The well is spotted on the -730 foot contour of the basinal dip surface. Intermediate values between the 100 foot contours must necessarily be interpolated. The interpolated value, as read from the datum surface, is algebraically subtracted from the height of the well above sea level as follows:

Height of well above sea level	-	Interpolated basinal dip value	=	Depth from collar of well which formation is read on the record.

817 feet - (-730 feet) = 1547 feet

A glance at the well record shows that at the calculated depth of 1547 feet a white sand of the Napoleon formation is indicated. A symbol or color is marked at the well position on the overlay sheet to designate the Napoleon formation.

Areas of formations older or younger than the Napoleon are departures from the basinal dip surface. Older formations suggest anticlinal areas, which may be favorable for oil accumulation, while younger formations suggest synclinal structures. The basinal dip surface is so constructed that if there were no local departures from the basinal dip surface, the Napoleon formation would be found at any arbitrary depth on the datum surface.

The last step in the construction of paleogeologic maps involves the drawing of formational boundaries between the older and younger formations after the well data for each county are placed on the overlay sheet.

CENTRAL MICHIGAN PALEOGEOLOGY

The paleogeology of central Michigan based on a raised curved surface is illustrated on Map II, which shows that formations other than the Napoleon may be expected at a given depth below sea level, and that the pattern of distribution resembles that of an areal geologic map. Anticlinal structures are suggested by areas of older formations bordered, or surrounded by younger formations.

Many of the suggested anticlines are reflected by underlying structures. The Chippewa-Greendale anticline in Isabella and Midland Counties, reflects structure from depth. Anticlinal structures reflected in younger formations are broader than these at greater depth.

A broad belt of the Napoleon formation is evident throughout the central part of Osceola, Isabella, and Gratiot counties. The datum surface closely corresponds to the Napoleon-Lower Marshall contact within this belt.

LIMITATIONS

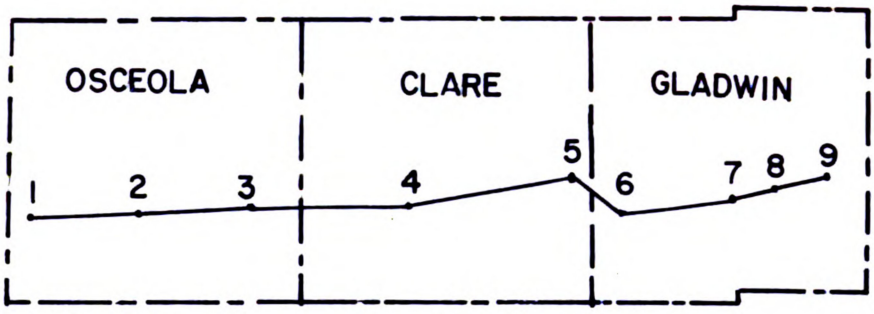
The northern and northeastern parts of Map II in Arenac, Clare, and Osceola Counties show areas of the Coldwater formation which are stratigraphically low in comparison to the Napoleon datum. These areas suggest paleogeologic "highs" but do not correspond everywhere to structural contour "highs".

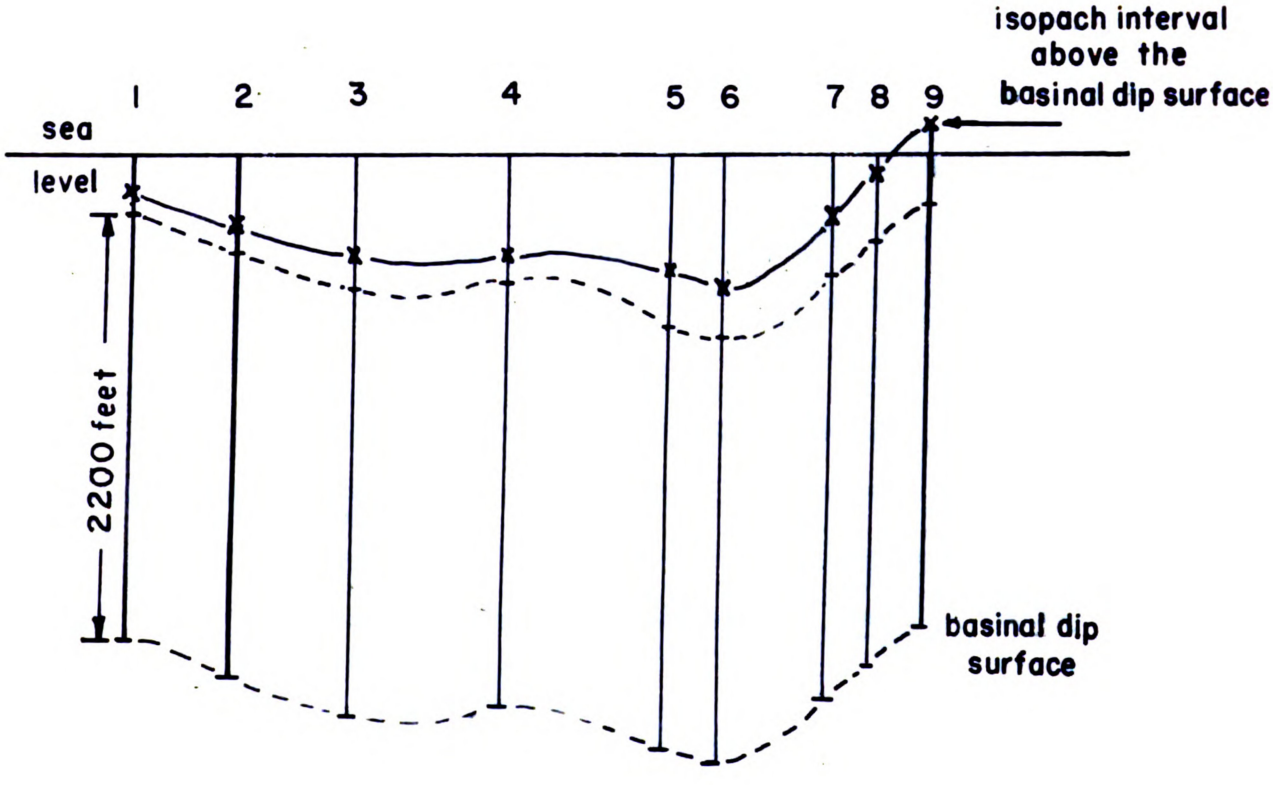
The comparatively large mapped area of the Coldwater formation shown on Map II is undoubtedly due to changes in thickness of the stratigraphic interval between the base of the Traverse and the Napoleon. An additional correction factor must be made to compare all plotted data on the map to the Napoleon horizon.

The necessity of this correction factor is substantiated by the record of a well at 744 feet in the NE 1/4, SE 1/4, NE 1/4 of Section 28 in Beaverton Township, Gladwin County. At this location the thickness between the top of the Napoleon and the base of the Traverse is 2,466 feet and the upper datum horizon is 2200 feet above the base of the Traverse (Fig. 4). By employing a Napoleon-Traverse isopach it can be proven that

FIGURE - 4

APPLICATION OF A REGIONAL ISOPACH TO THE DATUM SURFACE.





Vertical Scale : 1 inch = 1000 feet

there is a differential thickness of 266 feet between the upper datum surface and the isopach value. The descrepancy of 266 feet may be adjusted by a calculation which includes variations in thickness. A sample calculation explaining the apparently anomalous position of the Coldwater mapped at this location is as follows:

$$H - [Y + Z] = X$$

where:

H = Height of the well above sea level

Y = Upper datum surface contour

Z = Differential thickness

X = Corrected depth from well collar which is read on the published record.

744 feet - (-950 + 266 feet) = 1428 feet.

At the depth of 1428 feet on the well record the Napoleon formation is indicated, where formerly a "high" suggested by the Coldwater was recorded. The Napoleon does not suggest a paleogeological "high", but rather an horizon close to the upper basinal dip surface. As a result then, this location would not be worthy of exploration.

It is suggested that paleogeologic maps constructed from a curved datum surface be corrected by the use of an isopach map determined from the sequence of formations employed as subdivisions, such as the Marshall-Traverse used in this report.

The construction of an isopach map should precede the drawing of a paleogeologic map. Relatively few deep wells are sufficient to construct an isopach map and shallow wells may furnish the paleogeological data required.

CONCLUSIONS

Subsurface interpretation by studies in paleogeology are admittedly generalized in any area of exploration. Favorable structure may be indicated by interpretation of paleogeologic maps, but because of the general nature of exploratory drilling programs and the relatively small areas which are favorable for accumulation, many structures will be overlooked.

Much of the expense in drilling test wells in the unexplored northern Michigan counties can be reduced by the construction and interpretation of paleogeologic maps. By merely identifying the formation found at the basinal dip surface, geologists can ascertain whether or not the area is favorable as to subsurface structure, and need not drill to a deeper marker formation if the information is unfavorable.

Favorable structures are suggested by areas of "old" rock in relation to the datum formation of a sequence chosen for stratigraphic divisions, while synclinal areas are in turn suggested by younger formations. Corrections for change of the "deep" basinal dip and "upper datum surface" are necessary.

Datum horizons too deep to be of economic value in central Michigan paleogeological studies may be employed near the periphery of the basin structure. Paleogeological studies may be of considerable importance in determining the structural relationships of older formations such as the Coldwater-Antrim sequence in the northern counties of the Lower Peninsula. Here the younger rock strata which occur in the upper horizons in the central basin have been removed by glacial and pre-glacial erosion.

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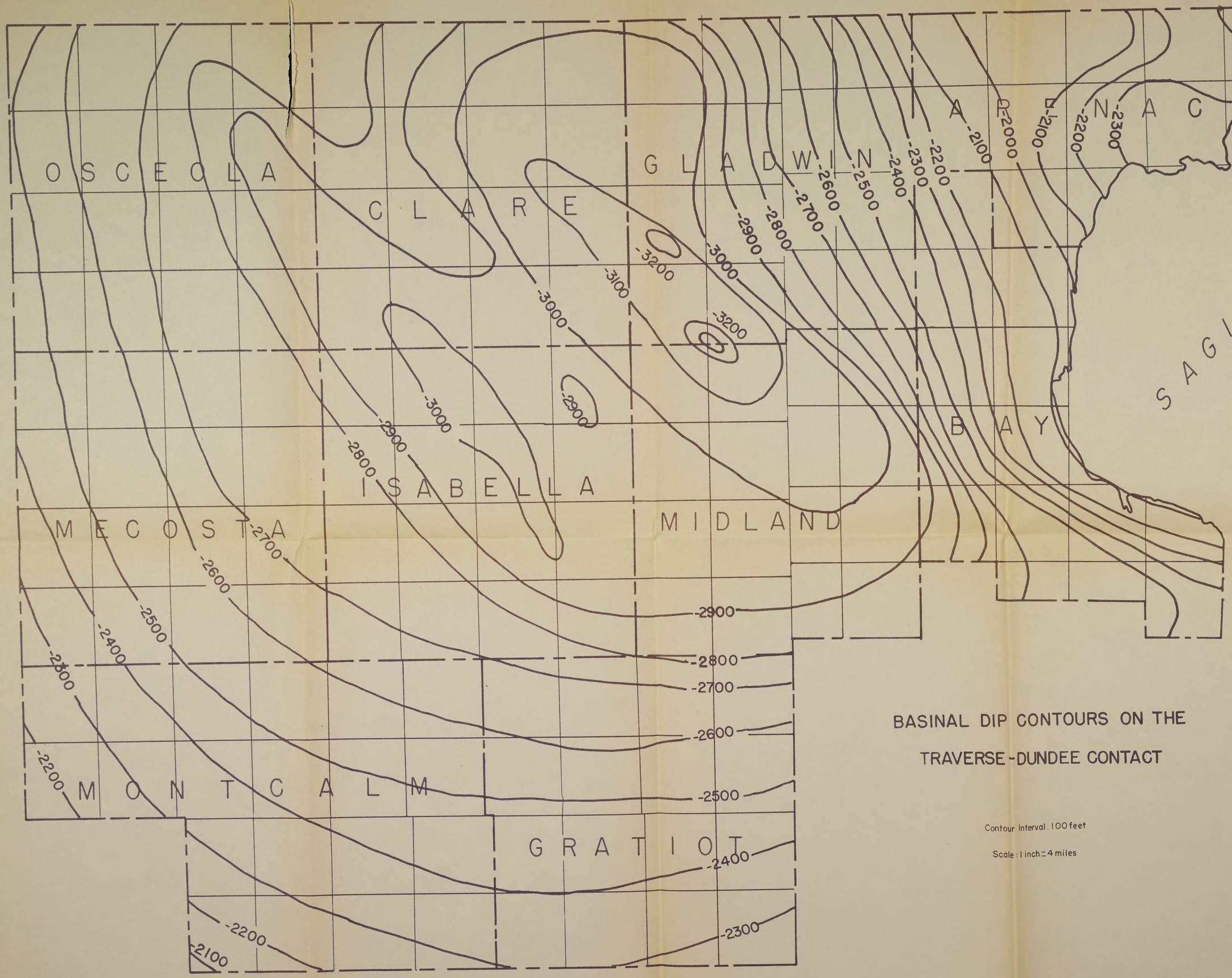

BASINAL DIP CONTOURS ON THE TRAVERSE-DUNDEE CONTACT

Contour Interval: 100 feet

Scale: 1 inch = 4 miles

OSCEOLA

CLARE

GLADWIN

ARENAC

SAGINAW BAY

ISABELLA

MIDLAND

MECOSTA

MONTCALM

GRATIOT

-200 -100 0 +100 -200 -100 0 -100 -200 -300 -400 -500 -600 -700 -800 -900 -1000 -1000 -800 -700 -800 -700 -600 -500 -400 -300 -200 -100 0 +100 -700 -600 -500 -400 -300 -200 -100 +100

PALEOGEOLOGY OF CENTRAL MICHIGAN

LEGEND

- UPPER MICHIGAN
- MIDDLE MICHIGAN
- LOWER MICHIGAN
- NAPOLEON
- LOWER MARSHALL
- COLDWATER

SCALE: 1 inch=4miles