

A PETROGRAPHIC CORE ANALYSIS OF THE
LOWER AND MIDDLE ORDOVICIAN ROCKS,
PULASKI FIELD, JACKSON COUNTY, MICHIGAN

Thesis for the Degree of M. S.
MICHIGAN STATE UNIVERSITY

William H. Kirschke

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ABSTRACT

A PETROGRAPHIC CORE ANALYSIS OF THE LOWER AND MIDDLE ORDOVICIAN ROCKS, PULASKI FIELD, JACKSON COUNTY, MICHIGAN

By William H. Kirschke

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NW NE SW

A detailed petrographic analysis was made on a core taken from the Lower and Middle Ordovician rocks in the Pulaski field, Jackson County, Michigan. The core was studied by thin sections and observations on the stained and etched surface of the entire core.

A comparison between the Gamma Ray-Neutron log and the core was made to determine if any petrofabric types give distinctive deflections on the log. No relationship existed between sedimentary fabric and deflections on the log.

The Black River is a microcrystalline limestone containing dolomite of four different occurrences. Dolomitization is penicontemporaneous and only that dolomite occurring as an interlocking mosaic of crystals could be traced stratigraphically. The Oneota dolomite has an epigenetic origin. A zone of dolomite in the Black River limestone could be traced throughout Calhoun, Jackson, and Hillsdale Counties. It might be inferred that this is one of the few stratigraphically significant zones in the Black River.

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PULASKI FIELD, JACKSON COUNTY, MICHIGAN**

By

William H. Kirschke

A THESIS

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Recognition is also given to Martin Horowitz for his constructive criticism of this work.

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INTRODUCTION

Purpose of Study

A comprehensive study is currently being prepared of a core given to the Geology Department by the Sun Oil Company. The interval cored is Ordovician, beginning in the Black River limestone, passing through the Glenwood shale, and ending in the Oneota dolomite which is Lower Prarie du Chien. Paleontological and calcium-magnesium ratio investigations are being prepared by other students. The purpose of this study is to make a detailed petrographic analysis of this core, examining the lithology, fabric, and general composition with the aid of thin sections and examination of stained surfaces. This includes any information concerning the occurrence of dolomite. It is hoped that this data will then be added to existing information gained solely from well cutting studies and megascopic examinations of cores in this interval.

This analysis will then be compared to the Gamma Ray-Neutron log of the well to determine if any petrofabric types give distinctive deflections on the log. In addition, the writer will try to determine whether those types, if present, can be used as marker horizons for future well log correlations.

Previous Work

In recent years much interest in the Middle Ordovician rocks of Michigan has developed with the discovery of new oil reserves in these strata. Regional stratigraphic studies have been made by a number of workers. Much of their work is cited in the discussion of the general stratigraphy of Michigan. After a thorough search of the literature it

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became evident to the writer that present descriptions of this interval are based entirely on well cutting analyses and megascopic core descriptions. Published petrographic studies of a detailed nature have not been prepared and detailed descriptions of these rocks do not exist. The limited area of this study provides an opportunity for making such a detailed description, possibly as a guide to future work.

Location

This well, the Peterson-Howard Well #1, was drilled to a total depth of 4395 feet and cored from 4100 feet to 4395 feet. Its location is the NW $\frac{1}{4}$ NE $\frac{1}{4}$ SW $\frac{1}{4}$ of Sec. 17, T45, R3W, Pulaski Twp., Jackson County, Michigan. See Figure 1.

GENERAL STRATIGRAPHY OF THE LOWER AND MIDDLE ORDOVICIAN ROCKS IN MICHIGAN

The lower and middle Ordovician rocks can be seen in outcrop in the Northern Peninsula of Michigan, Wisconsin, Illinois and in Ontario eastward to the Frontenac axis (Fig. 2). Regional thinning and thickening and erosional unconformities control the thickness of the formations in the Michigan basin (Cohee, 1948). A discussion of the general stratigraphy of this interval in Michigan is presented in this paper. No attempt has been made to correlate these strata on a regional basis.

Lower Ordovician

The Prairie du Chien has a threefold division. The members, in ascending order, are the Oneota dolomite, the New Richmond sandstone, and the Shakopee dolomite.

Oneota dolomite

Overlying the Trempealeau formation (Upper St. Croixan) in the Southern Peninsula (Fig. 3) is the Oneota which is a buff to light brown dolomite. Sand and chert are abundant with some oolitic chert. Associated with the dolomite are minor amounts of light green to green-gray shale. In southwestern Michigan the Oneota dolomite is principally sandstone with subordinate amounts of chert and dolomite (Cohee, 1948).

New Richmond sandstone

This unit has been recognized in drill cuttings from some wells in southwestern Michigan and is from 5 to 10 feet thick.

Figure 2 - Outcrop of Ordovician rocks (after Cohee, 1948)

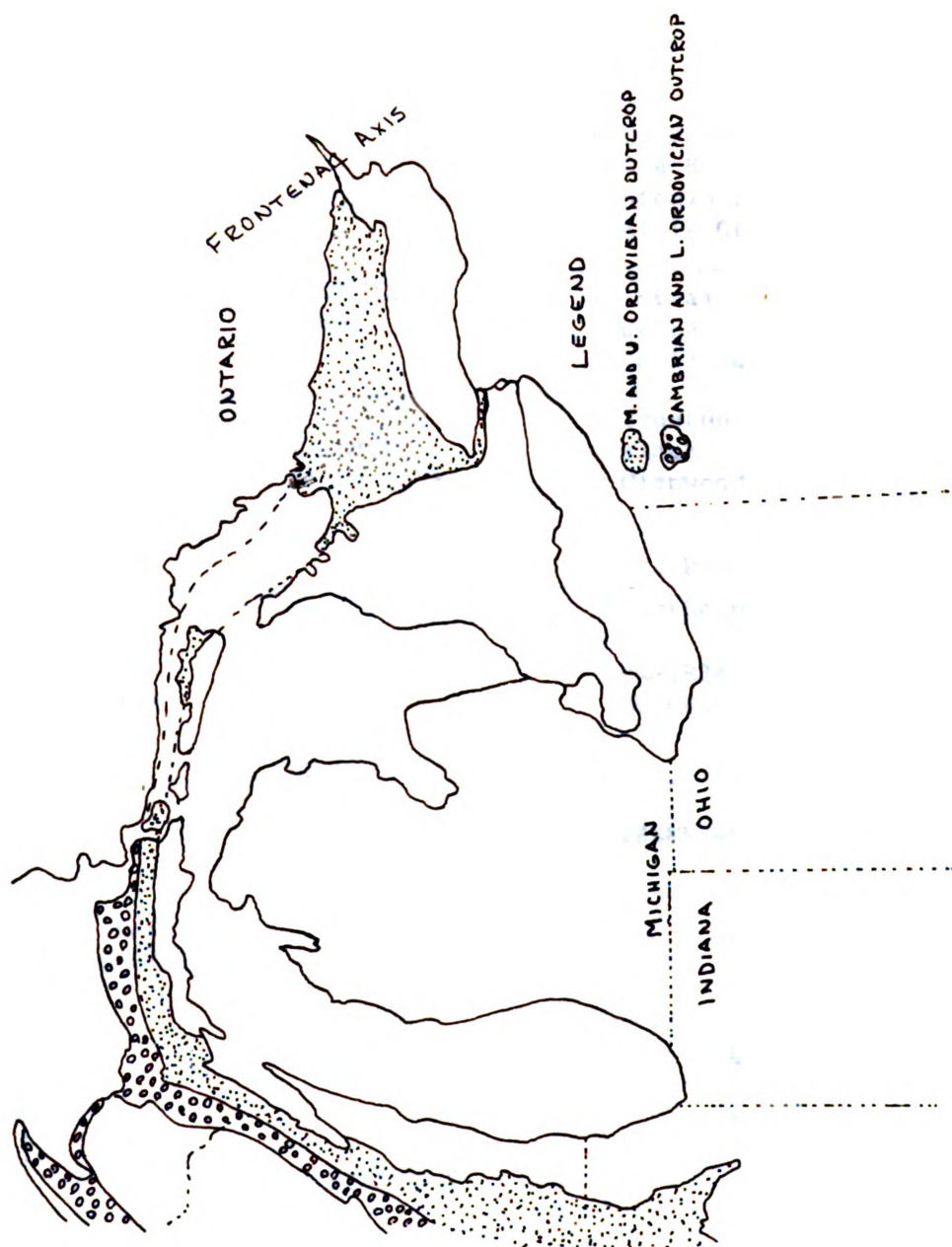


Figure 3 - Generalized section of Cambrian and Ordovician systems of Michigan modified from Cohee, 1945a, and Ehlers, Landes, and Cohee, 1947

ORDOVICIAN	CINCINNATIAN		RICHMOND	Queenstown Big Hill Stonington Bills Creek
			MAYSVILLE EDEN	Lorraine Utica Collingwood
	MOHAWKIAN		TRENTON BLACK RIVER	Trenton Black River Glenwood
	CHAZYAN			St. Peter
	CANADIAN		<u>Northern Peninsula</u> HERMANSVILLE	<u>Southern Peninsula</u> PRAIRIE Shakopee DU CHIEN New Richmond Oneota
CAMBRIAN	St. Croixan	LAKE SUPERIOR	MUNISING	TREMPEALAU Jordan Lodi St. Lawrence
				Franconia
				Dresbach
				Eau Claire
				Mt. Simon
			JACOBSVILLE	Jacobsville

Shakopee dolomite

The Shakopee dolomite consists of a buff, brown and gray dolomite which may be sandy, cherty, and shaly in part. Northward and eastward in the Southern Peninsula this unit is largely sandstone, shaly dolomite, and dolomitic shales.

St. Peter sandstone

The St. Peter in Michigan is a white to brown, predominately pure, friable sandstone. Chert fragments and pyrite are locally common. The quartz in the St. Peter is fine to medium grained, well-rounded to sub-rounded, frosted and pitted (Horowitz, 1961). This unit conformably overlies Lower Ordovician beds in southwestern Michigan. The unconformable relationship is due to pre-St. Peter erosion of the Prairie du Chien.

Middle Ordovician

Glenwood shale

In southwestern Michigan the Glenwood consists principally of sandstone and sandy dolomite. In many areas it is green-gray, sandy, pyritic shale and dolomite. In southeastern Michigan a sandy and sometimes pyritic green, brown, or gray shale, 5 feet or more in thickness, has been found below the Black River limestone where the St. Peter sandstone is absent. In places quartz grains are abundant, particularly at the contact with the underlying dolomites.

Black River limestone

The Black River is a brown and gray fossiliferous limestone containing interbedded dolomite in some places. There are areas where it

is dolomite and limestone or entirely dolomite. The basal part of this unit may be a fine grained dark gray to black argillaceous limestone or a limestone and shale. The Black River ranges from 150 to 517 feet in thickness.

Trenton limestone

The Trenton overlies the Black River limestone and is similar to it in lithology. The boundary between these two units is a very argillaceous limestone and shale section at the base of the Trenton. The total thickness of the Trenton ranges from 203 to 479 feet. Where the Trenton-Black River becomes largely dolomite the contact is not easily recognized. The regional thickening of the Trenton-Black River rocks in the Chatham sag in Kent County, Ontario suggests that this was a structurally low area between the Michigan Basin and the Black River seas to the east.

LABORATORY TECHNIQUES

Method of Sampling

The core was initially sampled at regular intervals of 5 feet through each megascopically similar "unit". Any changes in color, dolomite content, abundance of partings, or fabric were regarded as a "unit". Only samples of the dominant lithology within these "units" were taken. After the core had been stained it was examined with a binocular microscope. Additional samples were cut at microscopic changes in lithology, fabric, and at any unique lithology within a previously defined "unit".

Staining Techniques

The entire limestone section was stained to determine its gross lithological character. Staining of the least abundant constituent of the limestone was desired, which in most instances was dolomite.

Dolomite can be stained blue by immersing the samples in a five percent solution of hydrochloric acid, to which a few drops of a freshly prepared concentrated solution of potassium ferricyanide have been added (Steidtmann, 1917). The sedimentary calcite remains unaffected. The blue reaction of the dolomite is due to its FeO content, which Steidtmann found to be present in all the samples he studied. The same was true for all samples in this study.

The samples were not etched by conventional methods as described by Lamar (1950). The sections of core, which had been previously sliced, were placed in the staining solution with the surface to be etched facing down. The sections were supported so that the surfaces

which were submerged in acid did not rest on the bottom of the container. No appreciable channeling due to etching developed from this method.

All the samples were immersed in the staining solution from one to two minutes (increasing the time as the solution became weaker). This produced ample relief in the unstained constituents making their identification and distribution as readily apparent as the dolomite.

The stained surfaces were studied with particular emphasis on the following:

1. Texture, grain size, distribution and amount of dolomite.
2. Type, distribution, and amount of insoluble material.
3. Fossil content.
4. Relation of insolubles to bedding.

Preparation of Thin Sections

All thin sections were made perpendicular to the bedding. To keep the orientation of the thin sections with respect to the top of the core an arrow was penciled on the flat surface of the core produced by the first cut. A second cut produced an oriented slab approximately 1/16 of an inch thick which was perpendicular to the bedding. The position at which the thin section was to be made was marked and the slab stored in a sample envelope until all sections were cut. Blanks were made from the slabs by the following method:

1. Lines were inscribed around the desired area with a knife.
2. The inscribed lines were gently tapped with a hammer and chisel.
3. The blanks were then cut out and trimmed with tile cutters.

The blank was ground by hand (#600 carborundum powder on a glass plate) on one side to provide a smooth and flat surface for mounting on a glass slide.

The equipment used for mounting consists of a bunsen burner, ring stand, metal plate, mounting medium (Aroclor), eraser pencil, and clean frosted glass slides. The glass slides were frosted with #180 grit on a lap wheel.

The mounting process is as follows: The blank and glass slide were laid with the clean side up on the heated metal plate. The temperature of the plate was adjusted so that the Aroclor, when applied to the glass slide, melted in approximately one minute. Most of the bubbles were "cooked" out in three to five minutes. When the Aroclor was properly "cooked", the slide and blank were removed. The blank was then placed on the slide, care being taken to first place one side down and let the rest of the blank gradually settle into place. This method removed most of the remaining bubbles. The next step was to work out the excess Aroclor and bubbles by pressing down on the blank with the eraser pencil. The slide was then marked to show the depth and top of the core orientation.

The final step in the preparation was grinding the blanks to an approximate thickness of .03mm. Initial grinding was on a lap wheel with #180 carborundum powder. Grinding was continued with this grit until the edges of the slide began to wear away. The grinding was then continued with #400 powder until more of the edges were worn away. This step minimized the amount of hand grinding required. The final grinding was done by hand on a glass plate with #800 powder until the desired thickness was obtained. The completed sections were then studied in detail as to fabric, composition, and occurrence of dolomite.

MEGASCOPIC DESCRIPTION OF CORE

Included under this heading are the observations made on the stained surfaces with a binocular microscope. Arenaceous, as used in this description is a term indicating size and not composition. Any unit requiring a compositional term for detrital quartz grain content will be prefixed by sandy. The numbers in parentheses refer to the gamma-ray-neutron curve (Fig. 4).

<u>BLACK RIVER LIMESTONE</u>	Depth from <u>Surface</u>
Unit 1 - Limestone, light brown and gray-brown aphanitic with zones and patches of arenaceous limestone; clusters of sparry calcite with some dolomite, scattered dolomite rhombs, dolomitic partings with argillaceous and silty material; some pyrite, styolitic parting, fossil fragments - bryozoans, brachiopods, corals, ostracods.....	4100.0 4107.8
Unit 2 - Limestone, light brown (taffy colored), aphanitic with many clusters of sparry calcite. Calcite filled vertical fractures, profusely scattered dolomite rhombs, few partings, styolites, some pyrite. Dark gray-brown 4108.9 - 09.9 feet, (1) arenaceous in patches with abundant dolomitic partings. Occasional fossil fragment becoming very fossiliferous at 4122, corals, brachiopods....	4122.0
Unit 3 - Limestone, gray and brown-gray, aphanitic with many zones and patches of arenaceous limestone; clusters of sparry calcite with some dolomite - not present 4122 - 22.6 feet; dolomite rhombs sparse, dolomitic partings with argillaceous and silty material; some fossil fragments - brachiopods, ostracods, with corals being most abundant.....	4127.5
Unit 4 - Limestone, light brown at change grading into brown gray, aphanitic with some arenaceous limestone; clusters of sparry calcite with little dolomite (more abundant at change continuing to 4129); sparsely scattered dolomite rhombs, dolomitic partings with argillaceous and silty material, chert nodule at 4134.3, styolites, pyrite; some fossil fragments, corals in abundance 4129.2 - 32.9 feet - biolithite at 4131.4, brachiopods.....	4142.9

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- Unit 5 - Limestone, brown-gray, aphanitic with clusters of sparry calcite, very little dolomite - confined mostly to scattered rhombs; some pyrite, fossil fragments - mostly corals, some brachiopods..... 4143.6
- Unit 6 - Limestone, brown-gray, aphanitic with clusters of sparry calcite - some dolomite; dolomite confined to what few partings are present, calcite filled vertical fractures; no fossils observed..... 4145.6
- Unit 7 - Limestone, gray-brown, aphanitic with many zones and patches of arenaceous limestone; clusters of sparry calcite with dolomite; scattered dolomite rhombs - most abundant in arenaceous zones, dolomitic partings with caly and silt - thick regular bands 4170.8 - 73.2 feet (2); some stylolites, disseminated pyrite, vertical fractures; cross laminae 4171.2 - 71.7 - dolomite rhombs and detrital quartz grains; scattered fossil fragments - brachiopods (zone 4164.4), abundant bryozoans, ostracods..... 4175.4
- Unit 8 - Limestone, gray to light gray-brown, aphanitic with few clusters of sparry calcite; increase in dolomite rhombs over last unit; stylolites, some pyrite; occasional fossil fragment, brachiopods.... 4176.0
- Unit 9 - Dolomite, light gray to gray-brown; finely crystalline, some pyrite (3)..... 4177.8
- Unit 10- Limestone, gray to light gray-brown, aphanitic with clusters of sparry calcite, profusely scattered dolomite rhombs, thick bands of dolomite; alternating dolomite and carbonaceous partings - with pyrite 4180.4 - 80.7 feet. Limestone becomes darker with sparsely scattered dolomite rhombs and partings 4180.0 - 80.3 feet and 4182.0 - 82.6 feet. Some pyrite; fossil fragments - brachiopods, ostracods, one Tetradium at 4186.3..... 4186.5
- Unit 11- Limestone, gray and brown-gray, aphanitic with some arenaceous limestone; clusters of sparry calcite and dolomite, profusely scattered dolomite rhombs, dolomitic partings with some clay and silt - dolomite content increases at 4193.0 - 97.0 feet (4) and 4201.0 - 04.0 feet (5). Some pyrite, cross laminae at 4187.1, scattered fossils and fossil fragments - brachiopods, ostracods..... 4205.5

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- Unit 12 - Limestone, dark gray and brown-gray, aphanitic with arenaceous and rudaceous zones and patches; clusters of sparry calcite and minor amounts of dolomite; sparsely scattered dolomite rhombs, dolomitic partings with abundant clay and silt; stylolites, calcite filled vertical fractures near base; fossil fragments - brachiopods, ostracods, crinoid, bryozoans, and a few Tetradium..... 4277.0
- Unit 13 - Limestone, medium brown, aphanitic; clusters of sparry calcite - some dolomite; dolomite rhombs sparse, dolomite filled vertical fractures, some pyrite. Change to unit below is gradational..... 4228.4
- Unit 14 - Limestone, dark brown-gray, aphanitic with many zones and patches of arenaceous limestone; few clusters of sparry calcite; scattered dolomite rhombs, dolomitic partings with clay and silt; chert nodule at 4230.4, cross laminae at 4228.9 and 4230.6 feet. Sparse fossil fragments..... 4230.9
- Unit 15 - Limestone, dark brown-gray, aphanitic; profusely scattered dolomite rhombs having a vague alignment to bedding, thick irregular bands of dolomite (6) with very little argillaceous and silty material; only an occasional brachiopod observed..... 4239.0
- Unit 16 - Limestone, dark brown-gray, aphanitic with arenaceous and rudaceous zones and patches; clusters of sparry calcite and dolomite; scattered dolomite rhombs - more abundant at base, partings with abundant clayey material, zones containing rounded detrital quartz grains; stylolites, thin stringers of calcite, fossils - brachiopods, ostracods, bryozoans..... 4262.7
- Unit 17 - As the previous unit but with an increase in argillaceous and carbonaceous material in the partings (7)..... 4290.0
- Unit 18 - Alternating limestone and dolomite (9).
Limestone, brown, aphanitic; clusters of dolomite crystals; scattered dolomite rhombs, very few partings except at base where they are highly bituminous; some fossil fragments, possible metabentonite 4290 - 93.(8).
Dolomite, brown, fine crystalline..... 4314.6

Section 4292.1 - 97.0 feet missing.

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GLENWOOD SHALE

Unit 19 - Shale, black bituminous grading to gray-green in bottom 6 inches (10).....	4313.6 4314.7
Unit 20 - Dolomite, light green, very fine crystalline; argillaceous, numerous sand grains.....	4317.1
Unit 21 - Dolomite, very light gray (almost white), very fine crystalline - numerous sand grains.....	4320.7
Unit 22 - Shale, gray-green, brittle, with many small pyrite inclusions becoming very abundant in last 2 feet, numerous sand grains, greater concentration in bottom 10 inches (11). Dolomite, light gray, very fine crystalline, 4322.0 - 22.4 feet.....	4326.7

ONEOTA DOLOMITE

Unit 23 - Dolomite, light brown, fine to medium crystalline, thin gray-green shale partings, great amount of pyrite in upper 2 feet, sand grains, Breccia at 4329, mud cracks 4330.2.....	4332.7
Unit 24 - Dolomite, alternating light brown and gray-brown, very fine to fine crystalline, numerous white impure cherty inclusions; sandy, some glauconite..	4344.1
Unit 25 - Dolomite, brown, medium crystalline, few oolites and sand grains.....	4345.1
Unit 26 - Dolomite, buff with greenish cast at points, fine crystalline, some white impure cherty material and some glauconite, sand grains, banding caused by zones of higher content of carbonaceous material, conglomerate at 4357.2, fossils at 4354 - 54.5 feet and at 4357.0.....	4367.0
Unit 27 - Dolomite, buff-gray to white, fine to medium crystalline, increase in glauconite over previous section, sand grains, cherty, carbonaceous partings at 4373.1 and 4378 - 84.1 feet (12); appears to be coarse crystalline 4380.2 - 82.3, oil stains 4378.7 - 79.3 feet..	4389.0

MICROSCOPIC DESCRIPTION

The classification used in this description is that of Folk (1959). The reader is referred to this publication for a complete description of the classification and to Table 1 for details compiled into table form. Percentages were approximated using the method described in Johannsen (1917).

Discussion of terms (Folk, 1959)

Allochems - detrital constituents (intraclasts, pellets, etc.)

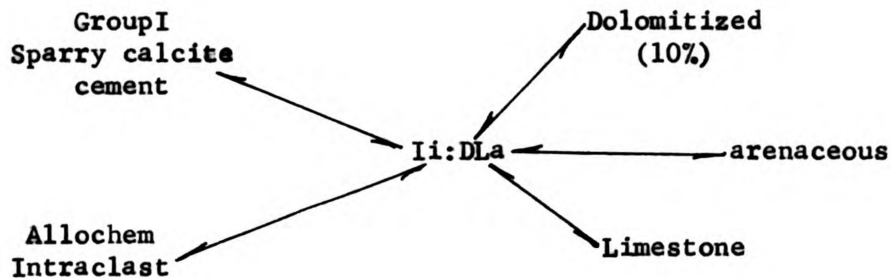
Dismicrite - literally a disturbed micrite; a sack term for rocks of diverse and obscure origin, caused by one or more of the following conditions:

1. Animals (worms, mollusks, etc.) that burrow in and chew up the homogeneous carbonate mud. The void formed is later filled with spar.
2. Ancient algal mats - if these are definitely algal plates the rock should be called an algal biolithite.
3. Soft sediment slumping or mud cracking.
4. Openings caused by passage of gas bubbles.
5. Soft, unconsolidated carbonate mud is partly torn up by an increase in current velocity and rapidly redeposited. This causes irregular patches of spar.
6. Partial recrystallization in patches would simulate a desmicrite.

Fossils - sedentary and transported fossil excluding coral or alga structures growing in situ and forming relatively immobile resistant masses.

- Intraclasts** - fragment of penecontemporaneous, usually weakly consolidated sediment that have been eroded from adjoining parts of the sea bottom and redeposited to form a new sediment.
- Micrite** - microcrystalline calcite ooze.
- Oolites** - particles showing either radial and/or concentric structure.
- Pellets** - rounded, spherical to elliptical or ovoid aggregates of microcrystalline calcite ooze, devoid of any internal structure.
- Sparite** - sparry calcite cement and calcite formed by recrystallization of finer carbonate grains.

Use of formula



Description

BLACK RIVER LIMESTONE

Unit i - Dominant lithology: Micrite (IIIIm:L1); 5% dolomite, dolomite rhombs show no relation to bedding. Unidentifiable fossil fragments.

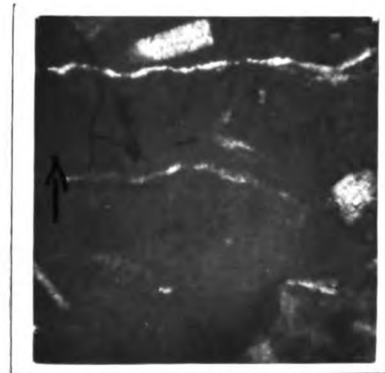


TABLE I. CLASSIFICATION OF CARBONATE ROCKS

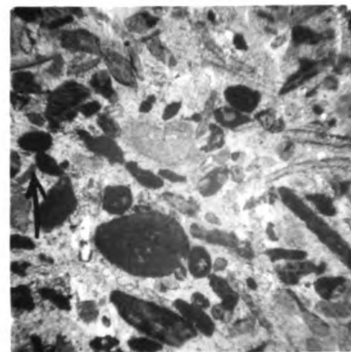
Limestones, Partly Dolomitized Limestones, and Primary Dolomites (see Notes 1 to 6)						Replacement Dolomites* (V)	
Allochemical Rocks (I and II)		<10% Allochemicals Microcrystalline Rocks (III)		Undis- turbed Bioherm Rocks (IV)	Allochem Ghosts	No Allochem Ghosts	
Sparry Calcite Cement > Micro- crystalline Ooze Matrix	Microcrystalline Ooze Matrix Sparry Calcite Cement	1-10% Allochemicals	<1% Allochemicals				
Sparry Allo- chemical Rocks (I)		Microcrystalline Allochemical Rocks (II)		Evident Allochem			
Intrasparudite (II: Lr) Intrasparite (II: La)	Intramicrocrudite* (III: Lr) Intramicrocrite* (III: La)	Intracrystals: Intracrystal- bearing Micrite* (III: Lr or La)		Biolithite (IV: L)	Finely Crystalline Intracrystalline Dol- omite (Vi: D3) etc.	Medium Crys- talline Dolo- mite (V: D4)	
Oösparudite (Io: Lr) Oösparite (Io: La)	Oömicrudite* (IIo: Lr) Oömicrite* (IIo: La)	Oolites: Oolite-bearing Micrite* (IIIo: Lr or La)			Coarsely Crystalline Oolitic Dolomite (Vo: D5) etc.	Finely Crys- talline Dolo- mite (V: D3)	
Biosparudite* (Ib: Lr) Biosparite (Ib: La)	Biomicrocrudite (IIb: Lr) Biomicrocrite (IIb: La)	Fossils: Fossiliferous Micrite (IIIb: Lr, La, or Li)			Aphanocrystalline Biogenic Dolomite (Vb: D1) etc.		
Biopelsparite (Ibp: La)	Biopelmicrocrite (IIbp: La)	Pellets: Pelletiferous Micrite (IIIp: La)			Very Finely Crystalline Pellet Dolomite (Vp: D2) etc.		
Pelsparite (Ip: La)	Pelmicrocrite (Iip: La)					etc.	
Volumetric Allochem Composition							
<25% Intracrystals		<25% Oolites		Volume Ratio of Fossils to Pellets			
>1:3		>3:1					

NOTES TO TABLE I

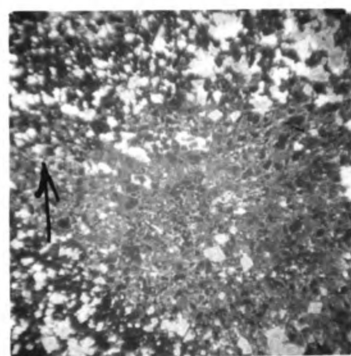
- * Designates rare rock types.
 1 Names and symbols in the body of the table refer to limestones. If the rock contains more than 10 per cent replacement dolomite, prefix the term "dolomitized" to the rock name, and use DLr or DLa for the symbol (e.g., dolomitized intrasparite, Li: DLa). If the rock contains more than 10 per cent dolomite of uncertain origin, prefix the term "dolomitic" to the rock name, and use dLr or dLa for the symbol (e.g., dolomitic pelsparite, Ip: dLa). If the rock consists of primary (directly deposited) dolomite, prefix the term "primary dolomite" to the rock name, and use Dr or Da for the symbol (e.g., primary dolomite intramicrite, III: Da). Instead of "primary dolomite micrite" (IIIm: D) the term "dolomitic micrite" may be used.
 2 Upper name in each box refers to calcinities (median allochem size larger than 1.0 mm); and lower name refers to all rocks with median allochem size smaller than 1.0 mm. Grain size and quantity of ooze matrix, cements or terrigenous grains are ignored.
 3 If the rock contains more than 10 per cent terrigenous material, prefix "sandy," "silty," or "clayey" to the rock name, and "Ts," "Tz," or "Tc" to the symbol depending on which is dominant (e.g., sandy biosparite, TsIb: La, or silty dolomitized pelsparite, TzIp: DLa). Glauconite, colophane, chert, pyrite, or other modifiers may also be prefixed.
 4 If the rock contains other allochemicals in significant quantities that are not mentioned in the main rock name, these should be prefixed as qualifiers preceding the main rock name (e.g., fossiliferous intrasparite, oolitic pelmicrite, pelletiferous oösparite, or intracrystalline biomicrocrystalline). This can be shown symbolically as Li(b), Io(p), IIb(f), respectively.
 5 If the fossils are of further uniform type or one type is dominant, this fact should be shown in the rock name (e.g., pelocypod biosparite, crinoid biomicrocrystalline).
 6 If the rock was originally microcrystalline and can be shown to have recrystallized to microspar (5-15 micron, clear calcite) the terms "microsparite," "biomicrosparite," etc. can be used instead of "micrite" or "biomicrite."
 7 Specify crystal size as shown in the examples.

(after Folk, 1959)

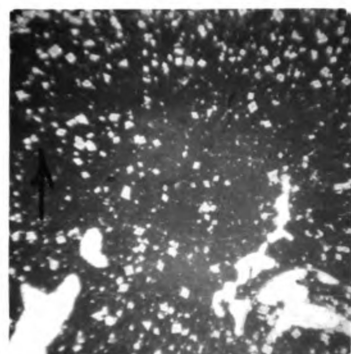
Fossiliferous intrasparrudite (Ii'
(b):Lr); .2' thick. 3% dolomite.
Predominantly bryozoans - Eschara-
pora sp.



Unit 2 - Dolomitized pelmicite (IIp:DLa);
20 - 25% dolomite predominantly
rhombs. Shows partial recrystal-
lization - after dolomitization.
4108.9 - 09.9 feet.



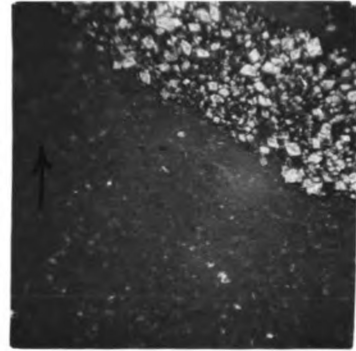
Dominant lithology: Dolomitized
dismicrite (IIIImX:DL1); 10 - 15%
dolomite - rhombs and partings;
dolomite stylolite; origin of spar
clusters attributed in part to fos-
sils - others unknown.



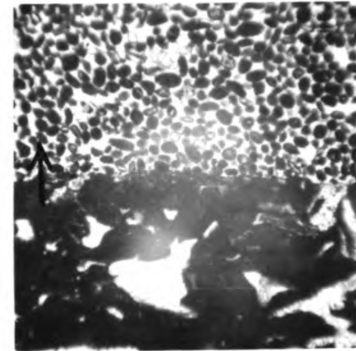
Biomicrosparite (RIIb:L1); origin-
ally a biomicrite that has been
partially recrystallized 4% dolo-
mite, scattered rhombs; corals most
abundant - Tetradium cellulsum.
(Hall)



Unit 3 - Dominant lithology: Dolomitized micrite (IIIm:DLl); shows some recrystallization; 10% dolomite almost entirely in partings and crystal clusters. Abundant microstyolitic partings. Occasional fossil fragments - unidentifiable, few detrital quartz grains.

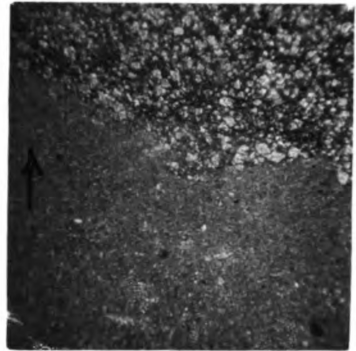


Pelsparite (Ip:La); well sorted rounded pellets, very little dolomite.

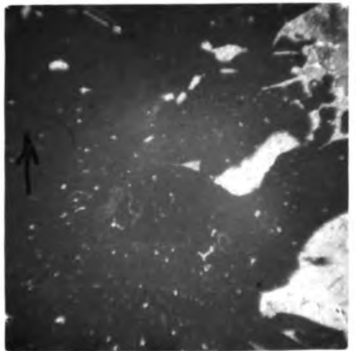


Unit 4 - Dismicrite (IIImy:Ll); unknown origin of spar clusters, little dolomite.

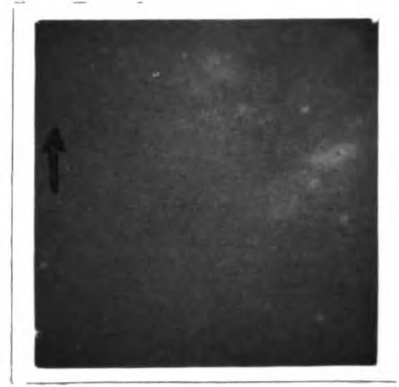
Dominant lithology: Micrite (IIIm:Ll); thin zones of pelmicrite (not shown), dolomite found primarily in partings.



Unit 5 - Dismicrite IIImX:Ll); this borders on a biomicrite, some spar clusters are partially or wholly recrystallized Tetradium sp; 1% dolomite - scattered rhombs, calcite filled vertical fracture (not shown).



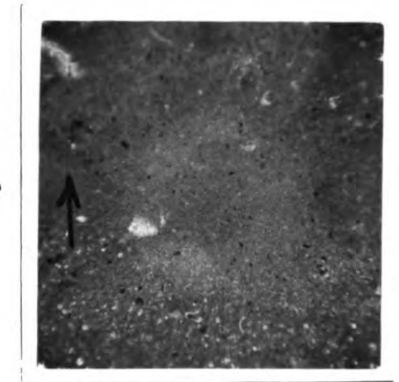
Unit 6 - Micrite (III_m:L1).



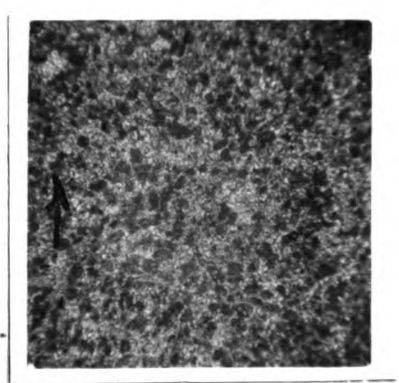
Unit 7 - Biomicrite (II_b:L1); 7 % dolomite confined to partings; pyrite disseminated throughout, some recrystallization of microcrystalline ooze to sparry calcite has occurred. Bryozoans predominate - Escharopora sp. and Rhinidictya cf R. grandis. Ulrich.



Dominant lithology: Dolomitized fossiliferous dismicrite (III_mX(b):DL1); 10% dolomite - mostly in partings; scattered pyrite, some detrital quartz grains, fossil fragments unidentifiable as to genus.

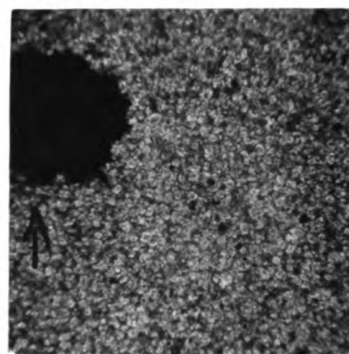


Dolomitic pelsparite (Ip:DL_a); 10% very fine dolomite rhombs, ½% scattered quartz grains both of which follow the cross-laminae.

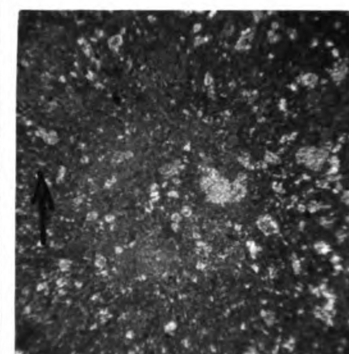


Unit 8 - No sample taken for thin section. Micrite (III_m:L1).

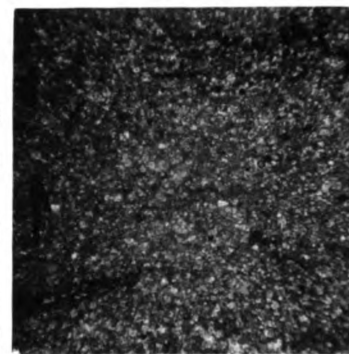
Unit 9 - Fine crystalline biogenic dolomite (Vb:D3); mosaic of dolomite crystals; pyrite; some fossil fragments partially replaced by dolomite.



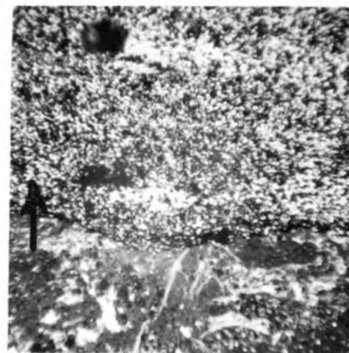
Unit 10 - Dominant lithology: Dolomitized dismicrite (III_mX:DL1); 15% dolomite rhombs; spar clusters in some cases are fossils, some pyrite, 2% detrital quartz grains.



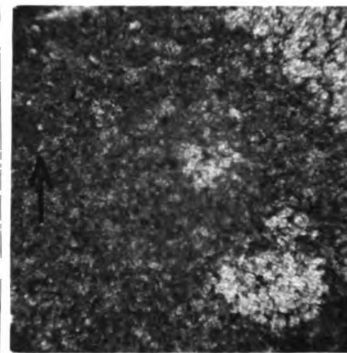
Fine crystalline dolomite (V:D3); alternating bands of dolomite and thin stringers of pyrite and clay.



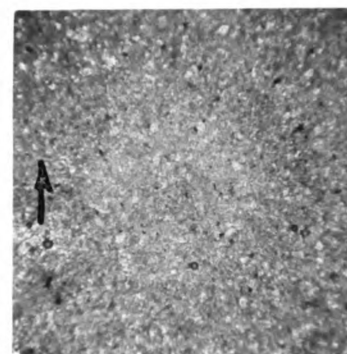
Sandy parting in dismicrite (III_mX:L1).



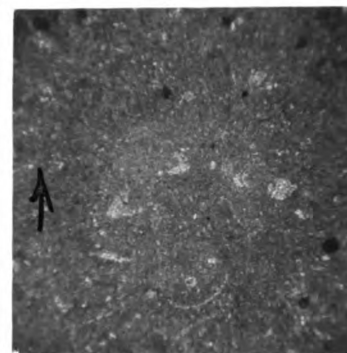
Unit 11 - Dolomitized pelmicrite (IIp:DLa); microcrystalline ooze has recrystallized to microspar in some places; pyrite, occasional quartz grain.



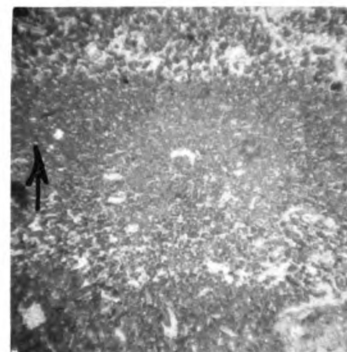
Dominant lithology: Dolomitic micrite (IIIm:dLl); 15% dolomite - mostly in partings but also scattered rhombs, disseminated pyrite; fossil fragments unidentifiable.



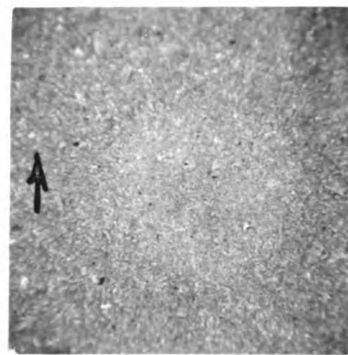
Unit 12 - Dominant lithology: Fossiliferous micrite (IIIImb:La); very little dolomite - partings predominately clay material; fossil fragments unidentifiable.



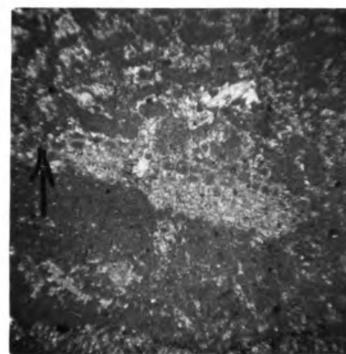
Micrite (IIIIm:Ll); with zones of pelsparite (Ip:La) 5% dolomite - scattered rhombs and some in partings.



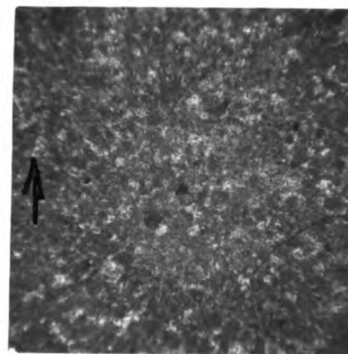
Unit 13 - Micrite (III_m:L₁); 1% dolomite -
rhombs; finely disseminated pyrite.



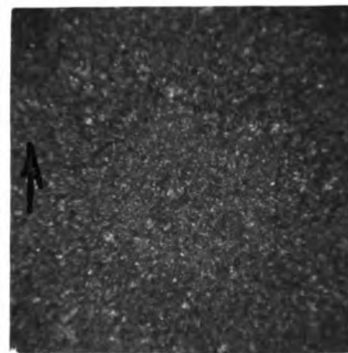
Unit 14 - Dominant lithology: Micrite (III_m:L₁);
27% dolomite mostly in partings; zone of
intrasparite (I_i:L_a) with some fossils
unidentifiable.



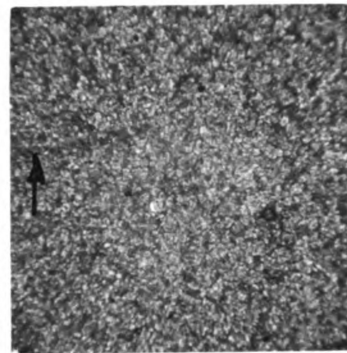
Pelmicrite (I_p:L_a); very little
dolomite.



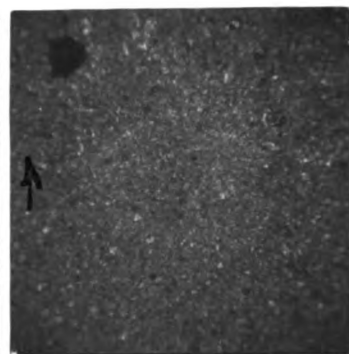
Unit 15 - Dominant lithology: Micrite (III_m:
L₁); 5% dolomite - scattered rhombs.



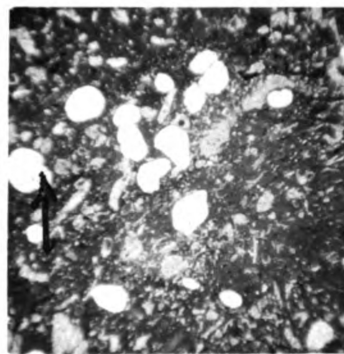
Finely crystalline dolomite (V:D3);
this lithology makes the thick bands
found in this unit.



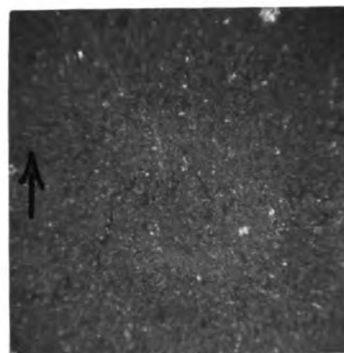
Unit 16 - Dominant lithology: Micrite (IIIm:
L1); 2% dolomite - scattered rhombs;
partings largely carbonaceous mat-
terial; dolomite is concentrated in
the crystal clusters.



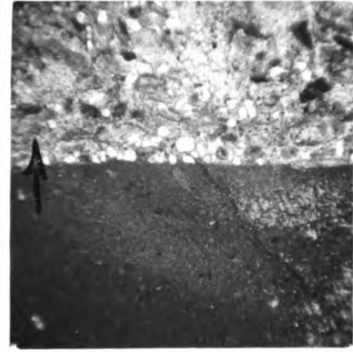
Sandy biomicrite (TsIIb:La); sandy
zone within this unit.



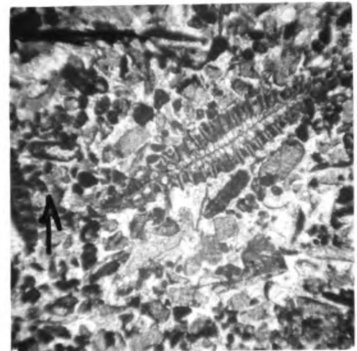
Unit 17 - Dominant lithology: Micrite (IIIm:
L1); very little dolomite - found in
clusters; microstyolitic partings.



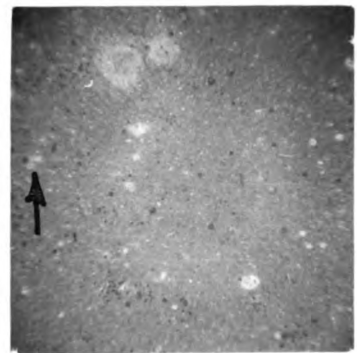
Sandy fossiliferous intrasparrudite (TsIi:Lr); abundant detrital quartz at contact decreasing upward, very little dolomite, some chert.



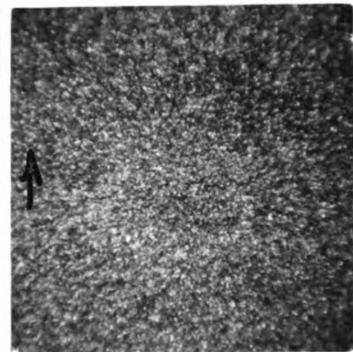
Fossiliferous intrasparrudite (Ii(b):Lr); 3% dolomite, pelletoidal, fossils are predominantly bryozoans - Escharopora sp. from 4288 - 89.



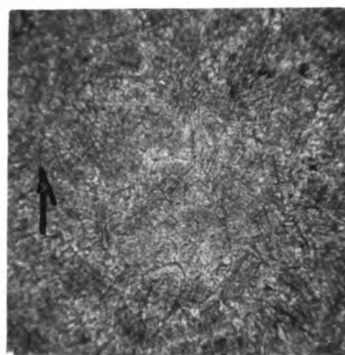
Unit 18 - Dominant limestone lithology:
Micrite (IIIm:Ll); 7% dolomite -
in clusters - finely crystalline.



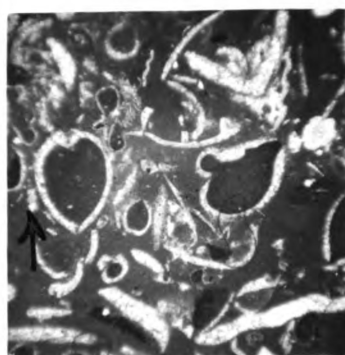
Fine crystalline argillaceous Dolomite (TcV:D3); mosaic of fine crystalline dolomite.



Dominant dolomite lithology: Medium crystalline dolomite (V:D4); this slide - medium crystalline pellet dolomite (Vp:D4); pellet ghosts in medium crystalline mosaic; $\frac{1}{2}\%$ detrital quartz; disseminated pyrite.



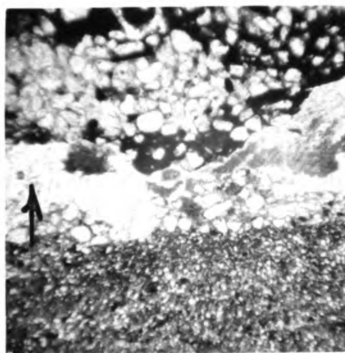
Ostracod biomicrite (IIb:L1); few scattered quartz grains; very little dolomite.



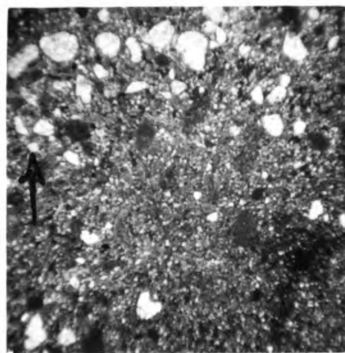
GLENWOOD SHALE

Unit 19 - No sample taken - black shale.

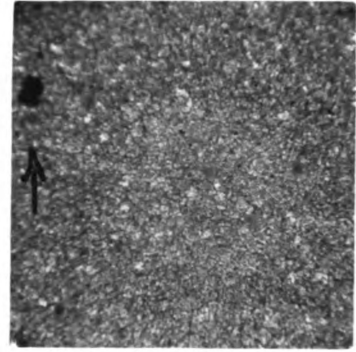
Unit 20 - Dolomite - black shale contact. Fine crystalline sandy dolomite (V:D3); 20% detrital quartz - coarse above contact - fine in dolomite, abundant pyrite.



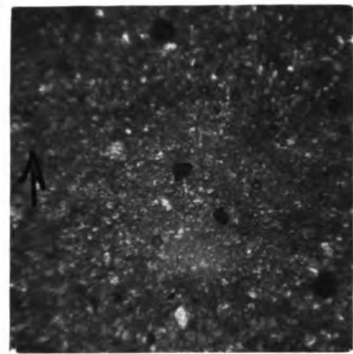
Fine crystalline sandy dolomite (TsV:D3); 30% detrital quartz grains; chert fragments - partial oolites; pyrite.



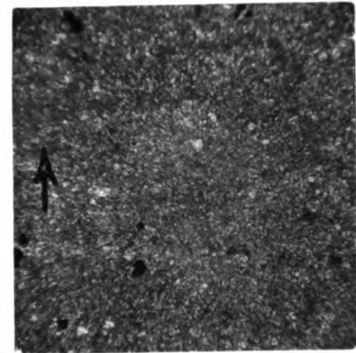
Unit 21 - Fine crystalline dolomite (V:D3);
2% quartz; some chert, pyrite.



Unit 22 - Dominant lithology: Dolomitic
shale; 5% quartz, abundant pyrite.

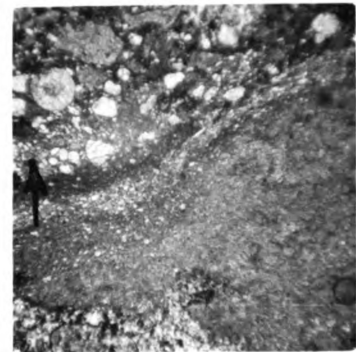


Fine crystalline dolomite (V:D3);
2% quartz, pyrite, some chert.

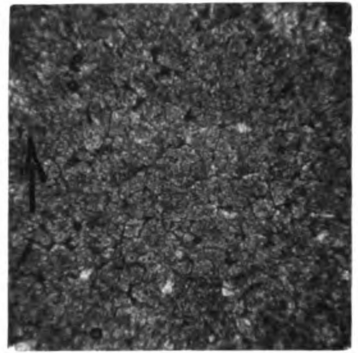


ONEOTA DOLOMITE

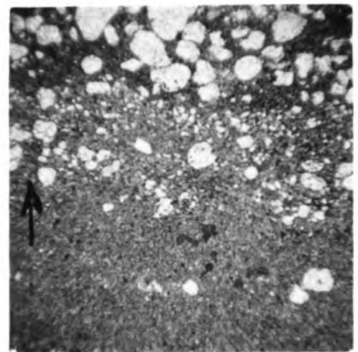
Unit 23 - Medium crystalline sandy dolomite
(V:D4); partings- large grains of
quartz with some chert and siliceous
oolites. Quartz content below
partings is 35% with much argil-
laceous material.



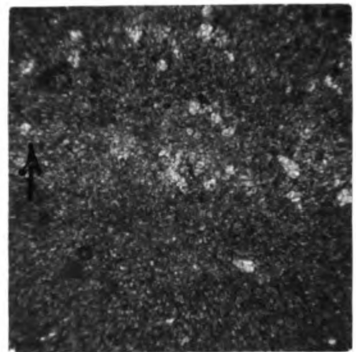
Dominant lithology: Medium crystalline dolomite (V:D4); 1% quartz; occasional chert fragments, some pyrite.



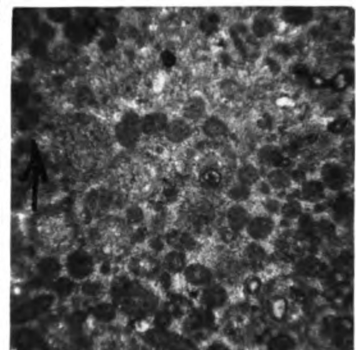
Unit 24 - Fine crystalline sandy dolomite (TsV:D3); mosaic of fine crystals of dolomite with 30% quartz.



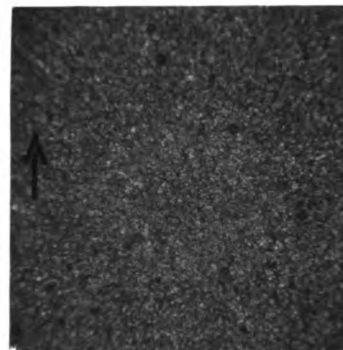
Fine crystalline dolomite (V:D3); mosaic of dolomite crystals; sandy band shows.



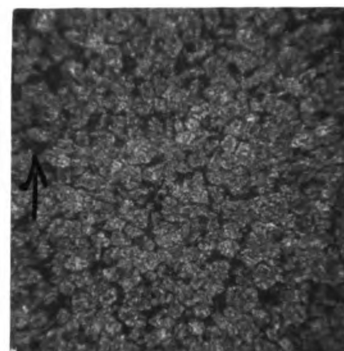
Unit 25 - Medium crystalline oolitic dolomite (Vo:D4); complete mosaic of dolomite crystals with oolite ghosts; occasional sand grain.



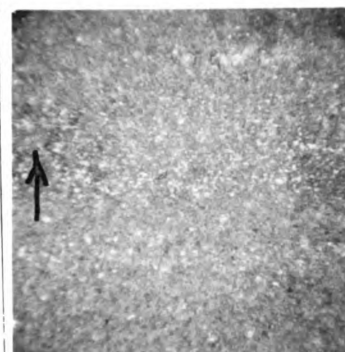
Unit 26 - Fine crystalline dolomite (V:D3).



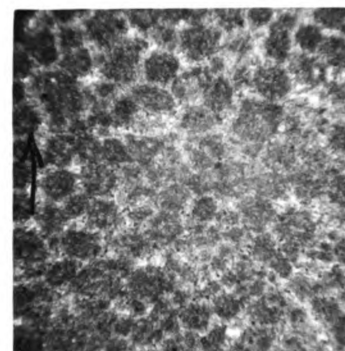
Medium crystalline dolomite (V:D4);
increase in argillaceous material
over last 4346.



Fine crystalline dolomite (V:D3);
argillaceous and sandy bands shown.

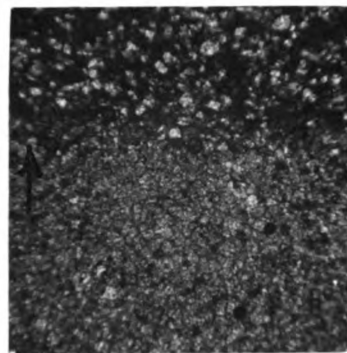


Unit 27 - Medium crystalline oolitic dolomite
(Vo:D4); complete mosaic of dolomite
crystals with oolite ghosts.



31.

Medium crystalline dolomite (TsV:D4);
alternating dolomite with bands of
sandy carbonaceous dolomite, quartz
content varies from 20 - 40 % - un-
iform within each band.



OBSERVATIONS AND CONCLUSIONS

Petrography

BLACK RIVER LIMESTONE

The predominant lithology in this section is a very fine micro-crystalline limestone suggesting quiet water conditions during sedimentation. Many zones and patches, as opposed to distinct beds, of arenaceous and rudaceous limestone were found in the section possibly indicating sporadic increases of energy in the environment. The origin of most of these desmicrites is unknown. Certainly some are organic. Partial and selective recrystallization is a possible answer to the origin of others, thus explaining the irregular distribution of the allochems found in some of the arenaceous patches. The writer believes this to be the origin of many of the dismicrite zones. The occurrence of pellets within many of these patches, some of which have an irregularly tubular shape, suggests a worm origin for at least some of the dismicrites.

Observations made on the stained surface of the core revealed four occurrences of dolomite: (1) a mosaic of interlocking dolomite crystals, (2) scattered and irregular distribution of dolomite rhombs throughout the limestone matrix, (3) abundant dolomite rhombs in the clay partings, and (4) partial to complete replacement of fossil fragments. The last suggests a replacement origin for the dolomite. The lack of appreciable pin-point or vuggy porosity would infer replacement dolomitization, possible early diagenetic, origin. The predominant occurrence of dolomite in this section is found in the dolomite-clay partings with only a few distinct beds of dolomite composed of an interlocking mosaic of dolomite crystals. Only the

APPENDIX

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1. Description of the Model and the Simulation Results (1000-1010)

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1.3. Simulation Results (1010-1015) 1.3.1. Simulation Results (1010-1012) 1.3.2. Simulation Results (1012-1015)

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latter could be traced stratigraphically and correlated on the gamma-ray neutron logs.

GLENWOOD SHALE

This is predominantly a greenish-gray shale containing abundant detrital quartz and some detrital chert. There is some question as to the origin of the quartz and chert in the Glenwood, possibly being indigenous to the Glenwood or reworked from the sandstones and cherts in the Oneota or St. Peter. The reader is referred to Horowitz (1961) for a discussion on this problem.

ONEOTA DOLOMITE

The Oneota dolomite is composed of a complete mosaic of fine to medium interlocking dolomite crystals containing sparsely scattered quartz grains, some glauconite, and several beds containing oolite ghosts.

These oolites are not of the siliceous variety generally found and described in the Oneota dolomite. They are dolomitized and the crystal size does not vary from oolite to matrix. The dolomite crystals cut across the oolite boundaries and only a color variation outlines the oolite ghosts. Dolomitization appears to be epigenetic even through abundant vuggy porosity as seen in most epigenetic dolomites is absent.

Comparison with Gamma Ray-Neutron log

The deflections on the radioactive log are due to the presence of dolomite, silt, and clay, and not to sedimentary fabric types. Generally each unit is defined by a plateau with irregular variations within the plateau. Not all units are well defined, due to lithologic similarities within the Black River limestone and the Oneota dolomite sections

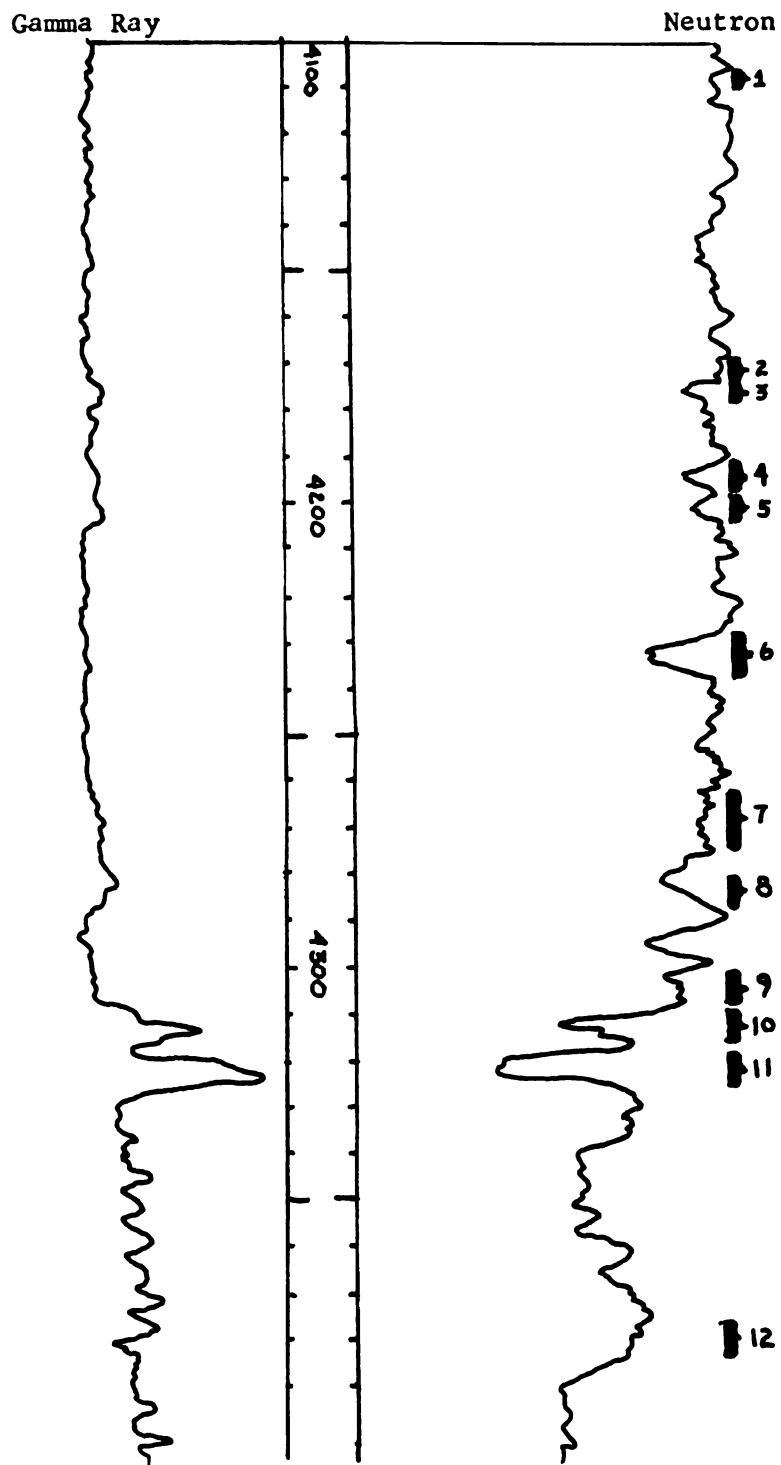
respectively. The negative "kick" at 4177 (Unit 9) and 4235 (Unit 15) indicate dolomite in large quantities (Fig. 4). Unit 9 is entirely dolomite whereas Unit 15 has thick irregular bands of dolomite. This dolomite is composed of an interlocking mosaic of dolomite crystals. The negative neutron and positive gamma-ray "kicks" at 4282 are persistent throughout the area but the cause is unknown. This is possibly a meta-bentonite or metabentonitic shale.

The argillaceous banding and porosity in the Oneota dolomite is believed to account for the major deflections.

Key Horizons

Radioactivity logs from Calhoun, Jackson, and Hillsdale Counties were examined to determine if deflections were traceable. Unit 15 could easily be picked in all logs examined. The extent beyond the Albion-Scipio trend was not determined. Due to this regularity of occurrence Unit 15 could be used for well log correlations. The deflection on this log is believed due to the porosity in the dolomite. It might then be inferred that this zone represents one of the few stratigraphically significant zones in the Black River.

Figure 4 - Gamma Ray-Neutron log, Howard-Peterson #1 well
Numbered rectangles represent thin-sections.



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