Champlainian biostratigraphy in northern Michigan

E. Charles Guldenzopf
Iowa State University

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Iowa State University, Ph.D., 1968
Geology

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IN NORTHERN MICHIGAN
by
E. Charles Guldenzopf

A Dissertation Submitted to the
Graduate Faculty in Partial Fulfillment of
The Requirements for the Degree of
DOCTOR OF PHILOSOPHY

Major Subjects: Geology
             Zoology

Approved:

Signature was redacted for privacy.

In Charge of Major Work

Signature was redacted for privacy.

Heads of Major Departments

Signature was redacted for privacy.

Dean of Graduate College

Iowa State University
Of Science and Technology
Ames, Iowa
1968
# TABLE OF CONTENTS

**PART I. CONODONT-BIOSTRATIGRAPHY OF MIDDLE ORDOVICIAN STRATA IN NORTHERN MICHIGAN**

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>INTRODUCTION</td>
<td>1</td>
</tr>
<tr>
<td>Purpose of the Investigation</td>
<td>2</td>
</tr>
<tr>
<td>Previous Work</td>
<td>3</td>
</tr>
<tr>
<td>Location and Physiography</td>
<td>7</td>
</tr>
<tr>
<td>Methods of Investigation</td>
<td>10</td>
</tr>
<tr>
<td>Acknowledgments</td>
<td>11</td>
</tr>
<tr>
<td>STRATIGRAPHIC NOMENCLATURE</td>
<td>13</td>
</tr>
<tr>
<td>CONODONT-BIOSTRATIGRAPHY</td>
<td>17</td>
</tr>
<tr>
<td>Multielement-species Nomenclature</td>
<td>17</td>
</tr>
<tr>
<td>Conodont Faunas</td>
<td>20</td>
</tr>
<tr>
<td>Midcontinent fauna</td>
<td>20</td>
</tr>
<tr>
<td>European fauna</td>
<td>21</td>
</tr>
<tr>
<td>Discussion</td>
<td>21</td>
</tr>
<tr>
<td>Conodont distribution in the Escanaba Group</td>
<td>25</td>
</tr>
<tr>
<td>Correlation</td>
<td>30</td>
</tr>
<tr>
<td>SYSTEMATIC DESCRIPTIONS</td>
<td>42</td>
</tr>
<tr>
<td>Multielement-species</td>
<td>43</td>
</tr>
<tr>
<td>Genus AMORPHOGNATHUS</td>
<td>43</td>
</tr>
<tr>
<td><strong>A. ordovicica</strong> Branson and Mehl</td>
<td>43</td>
</tr>
<tr>
<td>Genus BELODINA</td>
<td>45</td>
</tr>
<tr>
<td><strong>B. compressa</strong> (Branson and Mehl)</td>
<td>45</td>
</tr>
<tr>
<td>Genus CYRTONIODUS</td>
<td>46</td>
</tr>
<tr>
<td><strong>C. flexuosus</strong> (Branson and Mehl)</td>
<td>46</td>
</tr>
<tr>
<td>Genus DREPANODUS</td>
<td>Page</td>
</tr>
<tr>
<td>--------------------------</td>
<td>------</td>
</tr>
<tr>
<td><em>D. suberectus</em> (Branson and Mehl)</td>
<td>47</td>
</tr>
<tr>
<td>Genus OULODUS</td>
<td></td>
</tr>
<tr>
<td><em>O. oregonia</em> (Branson, Mehl and Branson)</td>
<td>48</td>
</tr>
<tr>
<td>Genus OZARKODINA</td>
<td></td>
</tr>
<tr>
<td><em>O. obliqua</em> (Stauffer)</td>
<td>49</td>
</tr>
<tr>
<td>Genus PANDERODUS</td>
<td></td>
</tr>
<tr>
<td><em>P. gracilis</em> (Branson and Mehl)</td>
<td>50</td>
</tr>
<tr>
<td>Genus PERIODON</td>
<td></td>
</tr>
<tr>
<td><em>P. grandis</em> (Ethington)</td>
<td>51</td>
</tr>
<tr>
<td>Genus PHRAGMODUS</td>
<td></td>
</tr>
<tr>
<td><em>P. undatus</em> Branson and Mehl</td>
<td>52</td>
</tr>
<tr>
<td>Genus PLECTODINA</td>
<td></td>
</tr>
<tr>
<td><em>P. aculeata</em> (Stauffer)</td>
<td>53</td>
</tr>
<tr>
<td><em>P. furcata</em> (Hinde)</td>
<td>54</td>
</tr>
<tr>
<td>Genus PRAVOGNATHUS</td>
<td></td>
</tr>
<tr>
<td><em>P. idonea</em> (Stauffer)</td>
<td>54</td>
</tr>
<tr>
<td>Genus TETRAPRIONIODUS</td>
<td></td>
</tr>
<tr>
<td><em>T. delicatus</em> (Branson and Mehl)</td>
<td>55</td>
</tr>
<tr>
<td>Residual Form-species</td>
<td></td>
</tr>
<tr>
<td>Genus ACONTIODUS</td>
<td></td>
</tr>
<tr>
<td><em>A. alveolaris</em> Stauffer</td>
<td>56</td>
</tr>
<tr>
<td>Genus CARDIODELLA</td>
<td></td>
</tr>
<tr>
<td><em>C. tumidus</em> Branson and Mehl</td>
<td>56</td>
</tr>
<tr>
<td>Genus CURTOGNATHUS</td>
<td>57</td>
</tr>
<tr>
<td>Genus</td>
<td>Species</td>
</tr>
<tr>
<td>--------------------</td>
<td>----------------------------------</td>
</tr>
<tr>
<td>DISTACODUS</td>
<td>C. limitaris Branson and Mehl</td>
</tr>
<tr>
<td></td>
<td>C. typa Branson and Mehl</td>
</tr>
<tr>
<td>ERISMODUS</td>
<td>D. falcatus Stauffer</td>
</tr>
<tr>
<td>POLYCAULODUS</td>
<td>P. bidentatus Branson and Mehl</td>
</tr>
<tr>
<td></td>
<td>P. inclinatus Branson and Mehl</td>
</tr>
<tr>
<td>SCANDODUS</td>
<td>S? dissimilaris (Branson and Mehl)</td>
</tr>
<tr>
<td>SCOLOPODUS</td>
<td>S. insculptus (Branson and Mehl)</td>
</tr>
<tr>
<td>TRUCHEROGNATHUS</td>
<td>T. distorta Branson and Mehl</td>
</tr>
<tr>
<td>Section</td>
<td>Page</td>
</tr>
<tr>
<td>----------------------------------------------</td>
<td>------</td>
</tr>
<tr>
<td>REFERENCES CITED</td>
<td>65</td>
</tr>
<tr>
<td>PART II. STRATIGRAPHIC RELATIONSHIPS OF MIDDLE ORDOVICIAN STRATA IN NORTHERN MICHIGAN</td>
<td>81</td>
</tr>
<tr>
<td>INTRODUCTION</td>
<td>82</td>
</tr>
<tr>
<td>Previous Work</td>
<td>82</td>
</tr>
<tr>
<td>Acknowledgments</td>
<td>87</td>
</tr>
<tr>
<td>STRATIGRAPHIC PROBLEMS</td>
<td>88</td>
</tr>
<tr>
<td>DESCRIPTION OF LITHOLOGIC UNITS</td>
<td>100</td>
</tr>
<tr>
<td>Escanaba Group</td>
<td>101</td>
</tr>
<tr>
<td>McFarland Formation</td>
<td>104</td>
</tr>
<tr>
<td>Bony Falls Formation</td>
<td>109</td>
</tr>
<tr>
<td>Trenary Formation</td>
<td>113</td>
</tr>
<tr>
<td>Chandler Falls Formation</td>
<td>120</td>
</tr>
<tr>
<td>Groos Quarry Formation</td>
<td>126</td>
</tr>
<tr>
<td>Summary</td>
<td>128</td>
</tr>
<tr>
<td>REFERENCES CITED</td>
<td>129</td>
</tr>
</tbody>
</table>
LIST OF FIGURES

Figure 1. Locality map, showing type and reference sections. 6

Figure 2. Map of surficial deposits in Delta, Alger, Marquette, and Menominee counties, Michigan. 9

Figure 3. Stratigraphic section for the Escanaba Group (Middle Ordovician) in the Northern Peninsula of Michigan 15

Figure 4. Range chart of Champlainian conodonts in the Escanaba Group in northern Michigan. 29

Figure 5. Relative-abundance log of Phragmodus undatus and Panderodus gracilis-Belodina compressa in New York-Ontario, Minnesota, and northern Michigan. 35

Figure 6. Correlation chart of the Escanaba Group with other midcontinent areas. 40

Figure 7. Stratigraphic relationships in Middle Ordovician strata in northern Michigan according to Hussey (1952). 86

Figure 8. Correlation of Middle Ordovician strata in northern Michigan, central Ontario, and Wisconsin. 99
LIST OF PLATES

<table>
<thead>
<tr>
<th>Plate</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plate 1.</td>
<td>Conodonts from the Escanaba Group</td>
<td>73</td>
</tr>
<tr>
<td>Plate 2.</td>
<td>Conodonts from the Escanaba Group</td>
<td>77</td>
</tr>
<tr>
<td>Plate 3.</td>
<td>Conodonts from the Escanaba Group</td>
<td>80</td>
</tr>
</tbody>
</table>
PART I

CONODONT-BIOSTRATIGRAPHY OF MIDDLE
ORDOVICIAN STRATA IN NORTHERN MICHIGAN
INTRODUCTION

Purpose of the Investigation

Ordovician strata of Champlainian age are exposed in stream valleys, roadcuts, and quarries in the Upper Peninsula of Michigan (U.S.A.). The stratigraphic relationships between these strata are imperfectly known because of the relatively low relief of the area and because of the Pleistocene glacial deposits that cover the greater portion of the Upper Peninsula. Comparisons of the lithology of the strata that are exposed with the lithology of core samples indicates that tens of feet of Champlainian strata are not exposed anywhere in the Upper Peninsula (northern Michigan).

The unknown local relationships and lack of exposures also complicate the regional correlation of these rocks with those of other areas. In eastern Wisconsin, strata of Champlainian age are buried under an even thicker cover of glacial drift so that the relationships between strata of that age (and other ages as well) in northern Michigan and the Upper Mississippi Valley are obscured. To the east, strata of Champlainian age are submerged beneath the waters of Lake Huron. Thus, the detailed correlation of the strata of the Upper Peninsula with those of similar age in south central Ontario and the type areas in New York State is not clear.

This paper presents the results of an investigation of the conodont-biostratigraphy of the Champlainian strata of northern Michigan, the purpose of which is to contribute to the solution of two related problems. The first is the
determination of the relative position of strata exposed in this region while the second is the determination of the distribution of conodonts and other fossils within these strata.

**Previous Work**

The Middle Ordovician exposures along the Escanaba River were first described by James Hall in 1851. He correlated them with the Chazy, Birdseye, Black River, and Trenton horizons in New York. Rominger (1873) also described these exposures as well as those along the Menominee, Ford, and Whitefish rivers and on St. Joseph Island, Ontario.

Case and Robinson (1915) noted and described three Paleozoic outliers in the vicinity of Pelkie, Houghton County, Michigan, where strata of Champlainian age are exposed. These features were further studied by Thwaites (1943).

Hussey (1936, 1950, 1952) correlated the Middle Ordovician deposits of Michigan with the New York section on the basis of megafossil content and recognized two formations, the Black River and Trenton, and four members. He assigned the lowest strata exposed on the Escanaba River to the Bony Falls Member of the Black River Formation (dolomite) and the succeeding strata to the Trenton Formation. He divided the Trenton into three members, which he named, in ascending order, the Chandler Falls (argillaceous limestone), the Groos Quarry (fossiliferous limestone), and the Haymeadow Creek (carbonaceous shale) members.
Thwaites (1943) presented a summary of his surface and subsurface studies of Cambrian and Ordovician sediments in northern Michigan and correlated these strata with those of Wisconsin on the basis of similar lithology. The Black River and Trenton were correlated by Cohee (1948) from the outcrop areas rimming the Michigan Basin into the center of the basin. All conclusions were based on subsurface lithologic information.

Some generalized stratigraphic information concerning the Middle Ordovician unavailable from other sources is contained in a series of ground water reports published by the Michigan Geological Survey for Delta (Sinclair, 1960), Menominee (Vanlier, 1963a), and Alger (Vanlier, 1963b) counties.

Templeton and Willman (1963, pp. 181-188) discussed the lithologic and temporal relationships between the strata of northern Michigan and those of the Upper Mississippi Valley in a report on the Champlainian Series in the stable interior of North America.

A series of papers dealing with the Black River ostracodes from strata at Bony Falls has been written by Kesling and his associates (Kesling et al., 1960; Kesling, 1960a; Kesling, 1960b; Kesling, Hall and Melik, 1962). The stratigraphy and paleontology of the Middle Ordovician strata of northern Michigan have been the subject of numerous additional articles. Stumm and Kauffman (1958) discussed the stratigraphy of this area in a study dealing with the calymenid trilobites
Figure 1  Locality map showing type and reference sections. Inset map on lower right shows location of study area. The numbered type and reference sections are as follows:
1. Bark River reference section
2. Groos Quarry type section
3. Chandler Falls South reference section
4. Chandler Falls type section
5. Bony Falls type section
6. Location of Perkins #2 reference section
7. Whitefish River reference section
8. Trenary type section
9. Haymeadow Creek (Hussey, 1952) type section
10. McFarland type section.
LOCALITIES

Type & reference sections
Other sections
Lower Ordovician
Middle Ordovician
Middle & Upper Ordovician
of the Middle Ordovician. Another study on trilobites of these strata was published by Darby and Stumm (1965). Kesling (1961a, 1962) reported on the occurrence of cystoids and cephalopods and Stumm (1963) on the occurrence of streptelasmid corals in the Middle Ordovician of northern Michigan.

Location and Physiography

The strata studied in this report are exposed in Alger, Marquette, Menominee, and Delta counties of Michigan. Middle Ordovician exposures also occur in Chippewa County, Michigan, on Encampment d'Ours Island and St. Joseph Island, Ontario, and at Limestone Mountain, an isolated outlier resting on Precambrian rocks in Houghton County, Michigan.

The outcrop belt of the Middle Ordovician strata in northern Michigan has been placed in the "eastern lowlands" province of the Great Lakes physiographic section (Fenneman, 1938). The Paleozoic layers dip gently to the south and east in this portion of the state. In the Escanaba area, the bedrock is overlain by glacial lake clays and stabilized sand dunes derived from glacio-lacustrine deposits. A series of northeast-southwest trending drumlinoid ridges occur in western Delta County and in Menominee County. End moraines over 100 feet high occur in both the eastern and western portions of the study area. A north-south trending lowland termed the Trenary-Au Train Lowland by Leverett (1929) extends from Lake Superior to Green Bay in the center of the study
Figure 2  Map of surficial deposits in Delta, Alger, Marquette, and Menominee counties, Michigan. The unshaded portions of the land area shown on this map are covered by glacial ground moraine and outwash as well as post-glacial swamp deposits. Data is adapted from the Geological Society of America glacial map and numerous topographic maps of the United States Geological Survey.
The majority of the localities sampled occur in this lowland. In addition to these physiographic features, the bedrock is overlain by ground moraine featuring a number of prominent eskers, and outwash deposits. The region is poorly drained, so the lowlands are very swampy. Even though the bedrock is very near to the surface in the Trenary-Au Train Lowland, a one- to three-foot layer of humic material covers all but a few exposures. So extensive is this cover that thick and/or widespread outcrops in northern Michigan are rare. This makes the tracing of lithologic units from one exposure to another very difficult.

Methods of Investigation

Over 300 samples were taken from 73 exposures in the Escanaba region. All of the exposures sampled are located within 60 miles of Escanaba, thus assuring fairly close local control. Each section was measured, described, and sampled at two-foot intervals. A portion of these samples was digested in 15 percent concentrated acetic acid or 15 percent formic acid. The residues were then dried and searched for microfossils under a binocular microscope. The conodonts that were found have been picked and mounted on standard micropaleontological slides. The type specimens have been stored in the paleontological repository at the University of Iowa, Iowa City. The remaining portion of the samples was studied and
described with the aid of a binocular microscope in the laboratory. The samples have been stored at the Department of Earth Science, Iowa State University, Ames.

Acknowledgments

The writer wishes to express his appreciation to the many people who have offered advice and encouragement in the preparation of this manuscript. Drs. K. M. Hussey and C. F. Vondra of Iowa State University have advised the writer throughout the study. Mr. A. K. Slaughter and Dr. G. E. Eddy of the Geological Survey Division, Michigan Department of Conservation, gave invaluable assistance in locating most of the exposures sampled and in allowing the writer to sample and describe core material that is kept by the survey. Dr. M. E. Ostrom of the Wisconsin Geological and Natural History Survey permitted the writer to use the facilities of that agency during the summer of 1966.

Dr. W. C. Sweet of The Ohio State University checked the identification of conodonts secured by the writer, proofread the manuscript, and offered advice concerning the significance of the conodont faunas. Dr. R. L. Ethington of the University of Missouri also gave valuable information which served to clarify some of the relationships. Dr. R. L. Clark of the University of Wisconsin checked the identification of several of the Canadian conodonts. Drs. W. M. Furnish and B. F. Glenister of the University of Iowa kindly consented to the use of the facilities of the Geology Department at that
institution. Dr. L. L. DeMott of Knox College, Galesburg, Illinois, also discussed Middle Ordovician correlation problems with the writer and made available material from his unpublished thesis.

Dr. John Lemish of the Department of Earth Science, Iowa State University provided laboratory space and facilities and critically read the manuscript. Dr. Harvey Diehl of the Department of Chemistry, Iowa State University, kindly consented to the use of facilities in that department. Dr. E. A. Hicks and Dr. M. J. Ulmer of the Department of Zoology and Entomology, Iowa State University, critically read the manuscript. Dr. Hicks also served as co-chairman on the writer's graduate committee.
STRATIGRAPHIC NOMENCLATURE

During the course of this study, the writer noted many discrepancies in interpretations of the stratigraphic relationships of the Middle Ordovician strata in northern Michigan, suggesting that the presently accepted terminology is in need of revision. These strata are presently known as the Black River and Trenton. These terms bear temporal connotations and are not useful as lithostratigraphic terms in northern Michigan. According to Liberty (1964), the formations of the Black River and Trenton groups of New York cannot be traced across Ontario. The confusion over lithostratigraphic and chronostratigraphic usage of these names has caused Michigan geologists at times to define the Black River-Trenton boundary on a lithologic basis and at other times to locate it on the basis of faunal changes.

Due to the confusion inherent in the usage of these names in this area, the writer urges the abandonment of the terms Black River and Trenton for lithostratigraphic use in northern Michigan and that locally-derived geographic names be substituted in their place.

The Middle Ordovician strata in this area consist of a series of argillaceous limestones that grade upward into less argillaceous limestones and more massive limestones (micrites and biomicrites) or massive dolomites (dismicrites). The contact between the massive carbonates and the argillaceous carbonates which overlie these strata is a sharp, distinct one.
Figure 3  Stratigraphic section for the Escanaba Group (Middle Ordovician) in the Northern Peninsula of Michigan. The stratigraphic nomenclature and subdivision are shown in the columns on the far left. A composite stratigraphic column and paleontological data occupy the middle columns and the portion of the Escanaba Group exposed at the type and reference sections (see figure 1 for locations) are shown diagrammatically in the right-hand column. Lithologic symbols are from LeRoy (1951).
and is the best basis for lithic subdivision of these strata. Five lithologic units can be recognized and are given informal names here. The formational names and approximate thicknesses are:

- Groos Quarry Formation .................. 40' +
- Chandler Falls Formation ........ 30 - 40'
- Trenary Formation ...................... 60 - 70'
- Bony Falls Formation ................. 60'
- McFarland Formation ..................... 60'

Total thickness ........ 250 - 270' +.

These five formations have been placed in a single unit, here referred to as the **Escanaba Group**. These stratigraphic relationships are shown in figure 3. This terminology will be used throughout this report in place of the terms Black River and Trenton, which are confusing because of misinterpretations of the local stratigraphy. These errors will be discussed at greater length elsewhere.
CONODONT-BIOSTRATIGRAPHY

Multielement-Species Nomenclature

Conodont specialists have long recognized that the present biological classification applied to conodonts is unrealistic. Assemblages of conodonts that have been preserved in situ have been described by various writers (for a recent general discussion of the nature of conodonts, see Lindström, 1964, pp. 117-130). Most of the current separation techniques require destruction of the matrix surrounding the conodonts and, as a result, the conodont-elements are recovered separately and given separate zoologic names, as though each part were a discrete animal rather than merely a part of a whole organism. In order to define a biological species to which these parts belonged, it is first necessary to decide which conodont-elements belong to which animal. However, this has not been attempted until recently.

Bergström and Sweet (1966), Webers (1966), and Schopf (1966) all noted that certain conodont-elements were always associated with one another such that, in large samples, the ratio of these elements could be predicted with uncanny accuracy. Kohut (1967) has since tested Bergström and Sweet's empirical analysis statistically and has obtained highly significant results.

The writer has picked conodonts from a number of residues from carbonates of different ages and has usually found a
considerable range in the size of the conodont-elements from a fraction of a millimeter up to two millimeters in size, yet the composition of the fauna from one size grade to another does not appear to differ. It appears, therefore, that Kohut's statistical techniques measure parts that were associated in given proportions in like organisms and not post-mortem sorting by waves and currents. The multielement nomenclature proposed by Bergström and Sweet and supported by Kohut (1967) is adopted in this paper. The writer believes that this is warranted because the same associations reported by Bergström and Sweet (1966) are also found in the northern Michigan strata. Additionally, the strong statistical evidence based upon 250,000 specimens gives greater weight to this classification than any other.

The multielement-species represented in the Escanaba Group include several single-element "form-species" of previous publications. The reader is referred to Bergström and Sweet (1966) for complete synonymies. The multielement-species recognized in this report and the included form-species of Bergström and Sweet are given below:

<table>
<thead>
<tr>
<th>Multielement-species</th>
<th>Included form-species</th>
</tr>
</thead>
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<td>Acontiodus alveolaris</td>
<td>Acontiodus alveolaris</td>
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<tr>
<td>Amorphognathus ordovicica</td>
<td>Ambalodus triangularis</td>
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<tr>
<td>Belodina compressa</td>
<td>Belodina compressa</td>
</tr>
<tr>
<td></td>
<td>Eobelodina fornicala</td>
</tr>
<tr>
<td><strong>Multielement-species</strong></td>
<td><strong>Included form-species</strong></td>
</tr>
<tr>
<td>-------------------------------</td>
<td>-------------------------------------------</td>
</tr>
<tr>
<td>Cyrtoniodus flexuosus</td>
<td>Cyrtoniodus flexuosus Prioniodina-like element</td>
</tr>
<tr>
<td>Distacodus falcatus</td>
<td>Distacodus falcatus</td>
</tr>
</tbody>
</table>
| Drepanodus suberectus         | Drepanodus homocurvatus
|                               | Drepanodus suberectus
|                               | Oistodus inclinatus                        |
| Oistodus venustus             | Oistodus venustus                          |
| Oulodus oregonia              | Cordylopus excavatus
|                               | Oulodus casteri
|                               | Prioniodina oregonia                       |
| Ozarkodina obliqua            | Dichognathus-like element
|                               | Ozarkodina obliqua
|                               | Prioniodina robusta                        |
| Ozarkodina concinna           | Ozarkodina concinna                        |
| Panderodus gracilis           | Panderodus compressus
|                               | Panderodus gracilis                        |
| Periodon grandis              | Falodus-like element
|                               | Ligonodina-like element
|                               | Periodon-like element
|                               | Prioniodina-like element                   |
| Phragmodus undatus            | Dichognathus brevis
|                               | Dichognathus typica
|                               | Oistodus abundans
|                               | Phragmodus undatus                         |
| Plectodina aculeata           | Cordylopus aculeatus
|                               | Trichonodella recurva
|                               | Zygognathus illustris                      |
| Plectodina furcata            | Cordylopus delicatus
|                               | Prioniodina furcata
|                               | Trichonodella angulata
|                               | Zygognathus mira                           |
| Pravognathus idónea           | Pravognathus idonea                        |
|                               | Pravognathus simplex                       |
Multielement-species Included form-species
Scandodus? dissimilis Scandodus? dissimilari
Scolopodus insculptus Scolopodus insculptus
Tetraprioniodus delicatus Hibardella gracilis
Scolopodus insculptus Ligonodina delicata
Tetraprioniodus superbus

Conodont Faunas

The conodont fauna recovered from the Middle Ordovician strata in northern Michigan is similar to Champlainian conodont faunas from the stable interior of North America described by other writers (Bergström and Sweet, 1966; Schopf, 1966; Webers, 1966). The northern Michigan fauna, as the others, consists of forms typical of both the "Midcontinent fauna" and the "European fauna."

Midcontinent fauna

The Midcontinent fauna probably originated in North America, for this is the region of its principal development. This fauna is rather peculiar because of the presence in it of the so-called "fibrous" conodonts. These forms differ in general appearance (color, luster, white matter, basal cavity) from the more typical "lamellar" forms. Current studies indicate that they are limited in stratigraphic range to the Champlainian. Typical "fibrous" form-species represented in the Escanaba Group include Erismodus symmetricus, E. asymmetricus, E. gracilis, Polycaulodus bidentatus, Curtognathus typa, Cardiodella tumidus and Trucheroagnathus distorta.
The remaining conodont-elements of the Midcontinent fauna are "lamellar" forms referred to the multielement-species *Drepanodus suberectus*, *Panderodus gracilis*, *Plectodina aculeata*, *P. furcata*, *Phragmodus undatus*, *Cyrtoniodus flexuosus*, and *Belodina compressa* and to the form-species *Acontiodus alveolaris*, *Distacodus falcatus*, and *Ozarkodina concinna*.

**European fauna**

The European fauna occurs principally in the Ordovician geosynclinal sediments of the Caledonian Orogenic Belt of the British Isles and Scandinavia and of the Appalachian, Cordilleran and Ouachita orogenic belts of North America. A few conodont-elements from the Midcontinent fauna are represented in the Appalachian fauna and the reverse is also true. European forms appear in the strata of the stable interior at certain horizons.

Multielement-species and form-species of the European fauna represented in northern Michigan include *Amorphognathus ordovicica*, *Scandodus? dissimilaris*, *Scolopodus insculptus*, *Periodon grandis*, and *Tetraprioniodus delicatus*.

**Discussion**

The "fibrous" conodonts have been used as guide fossils in the Champlainian strata of New York and Ontario. Schopf (1966) and Barnes (1964) have found that these forms, which are abundant in the Chaumont Formation (Upper Black River Group) diminish markedly or disappear completely at the
contact between the Chaumont and the overlying Rockland Formation (Lower Trenton Group). Schopf has found that the fibrous forms are very rare in the Rockland and Kirkfield formations (Late Wilderness) and in the lower beds of the overlying Shoreham Formation (Early Barneveld).

Webers (1966) and Guldenzopf (1964) have found that the abundant and varied "fibrous" fauna, described by Stauffer (1935a) from the Glenwood Shale of Minnesota and Iowa, is absent in the overlying Pecatonica Dolomite (Lower Platteville Formation) that was deposited during Early Wilderness time. The writer has recovered a few "fibrous" forms from the overlying McGregor Limestone Member of the Platteville Formation while W. C. Sweet (private communication)* reports finding a few "fibrous" conodonts in the Pecatonica, McGregor, and all the members of the Decorah Formation. The Platteville Formation has been correlated with the Upper Black River Group of New York (Early Wilderness) and the overlying Decorah Formation with the Lower Trenton Group (Late Wilderness). DeMott (private communication)** supports this correlation on the basis of trilobite distribution in the Champlainian strata of New York-Ontario and Illinois-Wisconsin. It appears, therefore,

*W. C. Sweet, Department of Geology, The Ohio State University, Columbus, Ohio. Data from reference collections. Private communication, 1967.

that one must accept one of two conclusions. Either past
biostratigraphic correlations are incorrect and the Platte-
ville is of Late Wilderness age or the "fibrous" conodont-
bearing species dwindled in numbers at an earlier time in the
Upper Mississippi Valley than in New York-Ontario. The latter
is probably the case. Sweet (private communication)* has
often expressed the belief that the "fibrous" conodonts are
provincial in distribution and sporadic in stratigraphic
occurrence. They occur most abundantly in the stable interior
and in strata deposited in Early Wilderness (Blackriveran)
time, although they have been found in geosynclinal sediments
as well.

European forms also appear in Champlainian strata at
dissimilar times. Bergström and Sweet (1966) have found that
European conodonts are present in the Lower Lexington Lime-
stone (deposited in Late Wilderness or Nealmontian time) where
they account for 7.5 percent of the total fauna. These forms
appear only 10 feet or so above the peak zone for the "fibrous"
forms. A somewhat similar pattern was found in the Trenton
Group of New York and Ontario (Schopf, 1966). European cono-
donts appear in the lowermost Rockland while the "fibrous"
forms, which are present in great abundance in the upper Chau-
mont, are greatly reduced in numbers. The European forms,

*W. C. Sweet, Department of Geology, The Ohio State University,
Columbus, Ohio. Data from biostratigraphic studies.
Private communication, 1967.
however, have not been found in the Upper Rockland or the Kirkfield formations, but reappear in greater abundance in the Shoreham Formation.

Webers (1966) did not find any of the European forms in the Decorah Formation in Minnesota. The multielement-species Periodon grandis first appears in the Cummingsville Member of the Galena Formation (Minnesota terminology) and the other European forms 125 feet higher in the Stewartville Member of the Galena Formation. The Cummingsville is generally regarded as having been deposited during latest Wilderness (Late Neal-montian) time and the Stewartville during Barneveld (Late Shermanian) time, so it appears that, again, the distribution of these conodonts is sporadic in time and space.

The problem of such "disjunct distribution" has been commented upon by Schopf (1966, p. 22) who postulated that various ecologic factors and shifting current patterns may have been responsible for the appearance and disappearance of conodonts at different times in different areas. Webers (1966 pp. 18-19) and Sweet (private communication)* have suggested that climatic belts may have affected the distribution of conodonts.

Bergström and Sweet (1966, pp. 286-291) indicate that the composition of the conodont faunas in the Trenton Group of New

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*W. C. Sweet, Department of Geology, The Ohio State University, Columbus, Ohio. Data from biostratigraphic studies. Private communication, 1967.
York-Ontario and the Lexington Limestone of the Cincinnati region are similar, while differences in composition, abundance and range of conodont species in these areas and Minnesota are noted. The writer has found (as will be noted in greater detail later) a striking similarity between the northern Michigan Champlainian conodonts and those of Minnesota. Such a distribution pattern of similar faunas may be taken to suggest climatic belts during Ordovician time. This interpretation has also been advanced to explain the Champlainian and Cincinnatian nautiloid "Arctic fauna" (Nelson, 1959) of the Arctic Archipelago and the northern Rocky Mountains, which differs from the nautiloid faunas found in strata of the same age in the Upper Mississippi Valley.

Conodont distribution in the Escanaba Group

The Middle Ordovician strata of northern Michigan contain a typical Champlainian conodont suite. The distribution of conodonts in these strata is summarized in figure 4. All the formations contain representatives of relatively long-ranging multielement-species such as Panderodus gracilis, Belodina compressa, Drepanodus suberectus, and Ozarkodina concinna.

The "fibrous" conodonts dominate the fauna in the McFarland and Bony Falls formations. However, occasional "fibrous" conodonts are found up the section, as high as the Chandler Falls Formation. They disappear very abruptly at the Bony Falls-Trenary contact and have not been recovered from the
The multielement-species Phragmodus undatus appears in the Trenary Formation and is represented only rarely in strata at a higher level in the Escanaba Group. Representatives of this species have been recovered from the Upper Bill's Creek Beds within 10 feet of the contact between the Bill's Creek and the Stonington Formation. Significantly, the beds in which Phragmodus undatus occurs are highly argillaceous and this suggests some environmental control in the distribution of this species.

European forms such as Scolopodus insculptus, Periodon grandis, and Amorphognathus ordovicica are represented in the Chandler Falls and Groos Quarry formations. The European fauna has not been found in the Trenary Formation, but a few elements of Periodon grandis and Scolopodus insculptus have been found in the Bony Falls Formation. This is somewhat surprising, for the European forms have not been reported from strata deposited earlier than Late Wilderness (Nealmontian) to latest Early Wilderness (Blackriveran) time in the stable interior before.

Scolopodus insculptus appears again (and in greater abundance) two feet above the Trenary-Chandler Falls contact and is very abundantly represented in the Chandler Falls Formation. This species is of minor importance, however, in the Groos Quarry Formation although it is present throughout this unit.
Elements of *Periodon grandis* are also abundant in the Chandler Falls Formation, but they diminish markedly in numbers in the Groos Quarry Formation. Specimens of *Amorphognathus ordovicica* are present throughout the Chandler Falls Formation but they constitute a small percentage of the fauna. In the Groos Quarry Formation, where they account for as much as 25 percent of the total fauna, representatives of this species are especially abundant. Specimens of another European species, *Tetraprioniodus delicatus*, have been found only in the Groos Quarry Formation. This multielement-species is represented by four specimens from the lowermost and middle strata of this formation.

*Oulodus oregonia*, a distinctive Midcontinent multielement-species typical of the Nashville Basin (Bergström and Sweet, p. 293) is present in the upper part of the Chandler Falls Formation where it accounts for about five percent of the total fauna.

The conodont faunas from both the Chandler Falls and Groos Quarry formations are dominated by specimens of *Panderodus gracilis*, whereas only three specimens of *Phragmodus undatus* were found in the entire collection from this interval. Elements of the persistent *Ozarkodina concinna* are also quite common in these formations.

Many of the forms reported by Webers (1966), Schopf (1966), and Bergström and Sweet (1966) have not been found in
Figure 4  Range chart of Champlainian conodonts in the Escanaba Group in northern Michigan. Thick lines denote intervals in which specimens are common to abundant (10 or more specimens). Thin lines indicate intervals in which species are present but rare (less than 10 specimens). Broken lines indicate intervals of discontinuous distribution or absence of species found at higher and lower levels. Miscellaneous fibrous conodonts denoted by asterisk include the form-species Curtognathus limitaris, C. typa, Cardio-della tumidus, Polycaulodus bidentatus, P. inclinatus, and Trucheronognathus distorta.
Canadian forms

Misc. Fibrous forms

Erismodus symmetricus, E. asymmetricus

Erismodus gracilis

Plectodina furcata

Ozarkodina concinna

Panderodus gracilis

Belodina compressa

Phragmodus undatus

Scolepodus insculptus

Peridon grandis

Tetraproniodus delicatus

Amorphognathus ordovicica
the Middle Ordovician strata of northern Michigan. The sample size for this study consists of approximately 6,000 conodonts, whereas the other studies were based on 35,000, 55,000, and 250,000, respectively. Thus, many of these forms may be present and would appear in larger samples.

Correlation

The northern Michigan conodont fauna most strongly resembles the Minnesota fauna described by Webers (1966) in several respects. The most obvious resemblance is the dominance of Panderodus gracilis and Belodina compressa in the Chandler Falls and Groos Quarry formations and the paucity of Phragmodus undatus in the same interval. Panderodus gracilis and Belodina compressa dominate the conodont fauna of the Upper Galena Formation of Minnesota and Phragmodus undatus is very rare in those strata. Phragmodus undatus is abundant in the Upper Piatteville Formation, the Decorah Formation, and the Cummingsville Member of the Galena Formation in Minnesota. Similarly, this species is abundant in the Trenary Formation in northern Michigan and is present in the Chandler Falls Formation, which is equivalent to the Cummingsville.

The European forms appear in the Middle Ordovician of Minnesota at the base of the Galena Formation (Cummingsville Member). Periodon grandis ranges from the base of the Galena to the top of the Dubuque Formation (Minnesota terminology) while Scolopodus insculptus ranges throughout the Stewartville
Member of the Galena Formation. Amorphognathus ordovicica and Tetraprioniodus delicatus appear in the uppermost Stewartville and Icriodella superba appears in the Dubuque Formation.

However, most of the European forms appeared much earlier in northern Michigan. Scolpodus insculptus, Periodon grandis, and Amorphognathus ordovicica all appear in strata that are correlated with the Cummingsville, and Tetraprioniodus delicatus in strata correlated with the Prosser and the Lower Stewartville members (see figure 4). Icriodella superba has not been found in the Escanaba Group.

The European fauna is found at the base of the Rockland Formation (lowest Trenton Group) in New York, but disappears and then reappears in the middle of the Shoreham Formation. With the exception of the brief appearance of these forms in the Rockland, then, the distribution of these conodonts in the Trenton Group is very similar to their occurrence in the Minnesota and Michigan faunas.

The northern Michigan fauna is somewhat similar to the New York-Ontario faunas in the distribution of the "fibrous" conodonts as well. The "fibrous" forms nearly disappear at the Bony Falls-Trenary contact in northern Michigan and, though they are abundant throughout the Black River Group in New York, these forms disappear rather abruptly within a few feet of the contact between the Chaumont Formation (Upper Black River Group) and the Rockland Formation (Lower Trenton Group).
They diminish abruptly at the Glenwood-Platteville boundary in Minnesota (Webers, 1966) and Iowa (Guldzenzopf, 1964). So this change occurs much earlier in the Upper Mississippi Valley than in northern Michigan and New York-Ontario. In the Cincinnati region (Bergström and Sweet, 1966), the "fibrous" conodonts persist into strata which are correlated with the Decorah Formation of Minnesota and the Upper Ternary Formation of northern Michigan.

Phragmodus undatus is abundant throughout the Trenton Group of New York-Ontario (Schopf, 1966) and throughout the Lexington Limestone of the Cincinnati region (Bergström and Sweet, 1966). The northern Michigan and Minnesota faunas are most dissimilar to those from the eastern areas in this respect and they are very much like one another in that Phragmodus undatus is restricted to strata deposited in Late Wilderness to earliest Barneveld time in these areas.

The northern Michigan conodont fauna, then, is most closely related to the Minnesota fauna but it is also comparable with the New York-Ontario fauna. The New-York-Ontario conodonts compare most closely with the Cincinnati area conodonts described by Bergström and Sweet (1966).

In spite of the fact that the number of conodonts recovered in this study was relatively small, the writer was able to correlate the Upper Middle Ordovician strata of northern Michigan with those of New York-Ontario, the Cincinnati region,
and Minnesota by means of relative-abundance analysis developed by Bergström and Sweet (1966, pp. 286-291). This technique is simply a measure of the percentage of certain long-ranging species (in this case, Phragmodus undatus and Panderodus gracilis-Belodina compressa) that make up the total fauna. This percentage is then plotted as a log, which is compared visually with other sections and correlated on the basis of important "peaks" and "troughs."

Relative-abundance logs for northern Michigan Champlainian conodonts reveal a rather remarkable (and unexpected) correspondence with those presented by Bergström and Sweet (1966). A comparison of the Michigan relative-abundance log to the Minnesota log is shown diagramatically in figure 5. On this basis, the Trenary Formation is correlated with the Decorah Formation and the lower part of the Cummingsville Member of the Galena Formation of Minnesota. The Chandler Falls-Groos Quarry formational boundary is probably isochronous with the Cummingsville-Prosser boundary in Minnesota.

The Groos Quarry Formation is correlated with the Prosser Member and the lower part of the Stewartville Member of the Galena Formation. Analysis of cores from the Escanaba region indicates that very little limestone has been eroded from the top of this unit, so it appears that during the time the upper part of the Stewartville Member of the Galena Formation and the Dubuque Formation were being deposited in Minnesota, the carbonaceous to calcareous shales of the Bill's Creek Beds were being deposited in northern Michigan. The Trenary,
Figure 5 Relative-abundance log of *Phragmodus undatus* and *Panderodus gracilis*-*Belodina compressa* in New York-Ontario, Minnesota, and northern Michigan. The light shading represents the *Phragmodus undatus* percentage. Zero percent is on the left and 100 percent is on the right. The dark shading indicates the *Panderodus gracilis* and *Belodina compressa* percentages. In these logs, zero percent is on the right and 100 percent is on the left.

The New York-Ontario and Minnesota logs are from Bergström and Sweet (1966), based on data presented in Schopf (1966) and Webers (1966). The reader is referred to Bergström and Sweet (1966, p. 292) for a comparison of the RA logs from the Lexington Limestone of the Cincinnati region and for the original RA logs. The Minnesota and Michigan logs have the same vertical scale, but the Michigan section is enlarged because it is only about half as thick as the Minnesota section. Bergström and Sweet (1966) expanded the Minnesota log, since that section is only four-fifths as thick as those of the Cincinnati region and New York-Ontario.
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Chandler Falls, and Groos Quarry formations may be correlated with the formations of the Trenton Group of New York–Ontario by comparison to relative-abundance logs presented in Bergström and Sweet (1966). The Trenary Formation is correlated with the Rockland Formation and the Lower Kirkfield Formation, while the Chandler Falls is correlated with the Upper Kirkfield and Lower Shoreham formations. The Groos Quarry is correlated with the Upper Shoreham Formation and the Denmark Formation of New York. The contact between the Groos Quarry and the overlying Bill's Creek shales is probably very nearly equivalent to the Denmark-Cobourg formational boundary. These interpretations are shown in figure 6.

It is much more difficult to correlate the McFarland and Bony Falls formations since the distribution of conodonts in strata of equivalent age in New York and elsewhere is incompletely known. The most recent publications dealing with strata deposited during Early Wilderness time are by Barnes (in press) and Andrews (1967). Barnes' paper deals with conodonts from the Chaumont Formation of Ontario and New York while Andrews' publication discusses the distribution of conodonts in the Joachim Formation of Missouri. Both of these units, as is also true of the McFarland and Bony Falls formations, contain abundant "fibrous" conodonts as well as several of the long-ranging lamellar forms.

The "fibrous" conodonts from northern Michigan are most similar to those found in the Glenwood of Minnesota by Webers
(1966) and the Chaumont by Barnes (in press). The most important of these forms from the standpoint of correlation is Erismodus (Ptiloconus) gracilis. In his analysis of the form-genus Erismodus, Andrews (1967, pp. 890-891; text-fig. 3) noted an apparent symmetry transition with time in the erismodus-like conodonts from the Dutchtown, Joachim, and Plattin formations (in ascending order) of Missouri. Erismodus-like conodonts from the Dutchtown tend to be symmetrical (Erismodus typus and E. symmetricus) whereas those from the Joachim are symmetrical to asymmetrical (E. symmetricus and E. asymmetricus). However, almost all the Plattin erismodus-like forms are highly asymmetrical. Erismodus gracilis belongs to this group.

Most of the erismodus-like conodonts recovered from the McFarland and Bony Falls formations in northern Michigan are of the Erismodus asymmetricus-E. gracilis type, so it is inferred that both of these formations are younger than the Joachim. It is not possible to correlate the McFarland and Bony Falls with the Glenwood and Platteville of the Upper Mississippi Valley on the basis of conodonts because the "fibrous" forms are very rare in the Platteville, which is underlain by the unfossiliferous St. Peter Sandstone. On the basis of lithologic identity alone, the upper part of the Bony Falls resembles the Quimbys Mill Member of the Platteville Formation, whereas the Lower Bony Falls resembles the McGregor Member of the Platteville (Mifflin, Grand Detour and
Nachusa formations of the Illinois Geological Survey). The upper dolomites of the McFarland Formation are grossly similar to the Pecatonica Member of the Platteville, but the thick, arenaceous dolomites and thin-bedded argillaceous limestones of the lower McFarland Formation have no lithologic counterparts in the Upper Mississippi Valley. The conodonts from the lowermost McFarland are very similar to the Glenwood fauna of the Minneapolis area (Webers, 1966) and the Dixon, Illinois, and McGregor, Iowa, areas (Guldenzopf, 1964). This suggests that these strata may not be much older than the Glenwood at the localities mentioned.

Exact correlation of the McFarland and Bony Falls formations with the New York-Ontario type area is not possible either, for the Pamelia and Lowville formations of the Black River Group have not been studied yet, even though conodont studies on these units is now in progress (Barnes, private communication)*. However, some inferences may be drawn from incomplete evidence. The writer has recovered specimens of Isotelus gigas from the Lower Bony Falls Formation. This trilobite has not been found in strata lower than the Chaumont Formation in New York, so it is inferred that the Bony Falls, at least, is no older than the Chaumont.

*C. R. Barnes, Department of Earth Sciences, University of Waterloo, Waterloo, Ontario. Data from biostratigraphic studies. Private communication, 1967.
Figure 6 Correlation chart of the Escanaba Group with strata in other midcontinent areas.
The conodont faunas of the Bony Falls and the lowermost McFarland formations are very similar to the Chaumont fauna described by Barnes (in press) so these units may be of nearly the same age. It is suggested, therefore, that the McFarland Formation may be entirely or in part of the same age as the Chaumont or of the same age as some part of the underlying Lowville Formation. It does not appear that any part of the northern Michigan Early Wilderness strata was deposited at the same time as sediments comprising the Pamelia Formation. Much more work will need to be done on strata of Early Wilderness age before general correlations of this type can be made.
SYSTEMATIC DESCRIPTIONS

The conodont-elements from the Escanaba Group have been classified in two different ways. All forms that have been classified by Bergström and Sweet (1966) as multielement-species have been treated in the same manner here. The writer is convinced of the soundness of this classification due to the size (250,000 specimens) of the sample and the statistical evidence that strongly supports these empirical interpretations (Kohut, 1967).

Other forms, particularly the "fibrous" conodonts, are treated as "residual form-species." To date, no studies of very large samples containing these conodonts have been undertaken. The largest sample, reported by Andrews (1967), consists of approximately 1,000 "fibrous" conodont-elements from several samples at 11 localities. The writer is confident that these forms, too, will be found to be parts of a few biological species when enough specimens have been recovered for statistical treatment. For the purpose of this report, however, the classification of Andrews (1967) is used for the Neurodontiformes or "fibrous" conodonts.

All of the type specimens and figured specimens have been stored at the paleontological repository at the University of Iowa, Iowa City, Iowa. The museum catalog number is preceeded by the abbreviation "S. U. I."
Multielement-species

Genus AMORPHOGNATHUS Branson and Mehl, 1933

Type species: Amorphognathus ordovicica Branson and Mehl, 1933

Amorphognathus ordovicica Branson and Mehl

Plate 2, Figures 1, 4, 6, 7, 14

1933 Amorphognathus ordovicica Branson and Mehl, Univ. Missouri Studies, vol. 8, p. 127, pl. 10, fig. 38.

1933 Ambalodus triangularis Branson and Mehl, idem, pp. 127-128, pl. 10, figs. 35-37.


Remarks: This multielement-species is represented in the Chandler Falls Formation and is abundant to common throughout the Groos Quarry Formation. Amorphognathus ordovicica also occurs in the Perkins #2 core between 148 and 183 feet in the Bony Falls Formation.

The amorphognathus-like element is the most numerous in the Michigan samples. The ratio between it and the ambalodus-like element for all samples is 7.2:4 while the ratio for the lower Groos Quarry Formation, where this species is especially abundant, is 6.4:4. Bergström and Sweet (1966) record 6,074 amorphognathus-like elements and 3,922 ambalodus-like elements for a ratio of 6.2:4. Schopf (1966) arrived at a ratio of 4.2:2 (8.4:4) for this species in the Trenton Group of New
York. Data from Webers (1966) indicate an average ratio for the entire Middle and Upper Ordovician of Minnesota to be 14.4:4 but the ratios for intervals in which *Amorphognathus ordovicica* is abundant are 12.8:4 and 10.8:4.

It can be seen that Webers' ratios are significantly different from the ratios in the other studies. There may be several reasons for this: 1) post-mortem sorting; 2) differential durability; 3) evolutionary change; 4) homeomorphism; 5) identification; 6) biased data due to small sample size.

The first four points were raised and discussed by Webers (1966, p. 6) and will not be repeated here. The writer believes that the greater source of error will stem from the fifth and sixth possibilities. Individual judgement concerning morphological features varies, and the disarray of conodont nomenclature reflects this. Moreover, many of the form-species grade into one another and different workers may choose different means of subdividing forms which are morphologically similar.

In a relatively small sample, the most abundant element (the amorphognathus-like element) is more likely to be recovered. Thus, in a fauna represented by many small samples, there will tend to be a statistical bias in favor of the more abundant element. It can be seen that the average ratios for the entire fauna in this study and that of Webers (1966) are higher than the ratios for the shorter, more abundant intervals.
It should also follow that Webers' average ratio is based upon a larger percentage of small samples. Inspection of the tables in Webers (1966), Schopf (1966), and Bergström and Sweet (1966) shows that Webers' collection contains more samples consisting of fewer than 50 specimens than in the other studies. In order to arrive at ratios between elements of a multielement-species, then, it seems apparent that samples containing large numbers of the species in question are most suitable for statistical purposes.

Genus BELODINA Ethington, 1959

Type species: Belodus compressus Branson and Mehl, 1933

Belodina compressa (Branson and Mehl)
Plate 2, Figures 2, 24

1933 Belodus compressus Branson and Mehl, Univ. Missouri Studies, vol. 8, p. 114, pl. 9, figs. 15, 16.

1935 Oistodus fornicalis Stauffer, Jour. Paleontology, vol. 9, p. 510, pl. 75, figs. 3-6.

1966 Belodina compressa (Branson and Mehl), Bergström and Sweet, Bull. Amer. Paleontology, vol. 50, no. 229, pp. 312-315, pl. 31, figs. 12-19 (includes synonymy to 1966).

Remarks: The Escanaba collection contains 97 elements of the form-species Belodina compressa and 14 specimens of Eobelodina fornicala. The ratio of one form to another is approximately 14:2. When only large samples are considered, however, the ratio between the belodina-like and eobelodina-like elements is closer to those computed from figures presented in Schopf.
(1966) and Bergström and Sweet (1966). The ratio between these elements for the entire Middle and Upper Ordovician of Minnesota is close to 12:2 (see Webers, 1966, pl. 1) but ratios for intervals where this species is abundant (and therefore statistically significant) are 7.5:2 and 7:2, somewhat closer to the 9.5:2 ratio in Bergström and Sweet (1966) and 9.6:2 in Schopf (1966). One sample from the Escanaba Group contained 17 belodina-like and 4 ecbelodina-like elements out of a total fauna of over 700 specimens. The ratio, then, is 8.5:2, nearer the figure calculated from data presented in Bergström and Sweet (1966).

This species ranges throughout the Escanaba Group.

Genus CYRTONIODUS Stauffer, 1935

Type species: Cyrtoniodus flexuosus (Branson and Mehl), 1933

Cyrtoniodus flexuosus (Branson and Mehl)

Plate 1, Figures 9, 10

1933 Prioniodus? flexuosus Branson and Mehl, Univ. Missouri Studies, vol. 8, p. 130, pl. 10, fig. 16.

1966 Cyrtoniodus flexuosus (Branson and Mehl), Bergström and Sweet, Bull. Amer. Paleontology, vol. 50, no. 229, pp. 324-327, pl. 32, figs. 9-11 (includes synonymy to 1966).

Remarks: This species ranges throughout the Escanaba Group. The bulk of these specimens are of the cytoniodus-like variety, but a few specimens of the prioniodina-like element have also been found. Cyrtoniodus flexuosus ranges throughout the
Trenton Group, the Lexington Limestone, and the Middle and Upper Ordovician formations of Minnesota.

Genus DREPANODUS Pander, 1856.

Type species: Drepanodus arcuatus Pander, 1856

Drepanodus suberectus (Branson and Mehl)

Plate 1, Figures 2, 8; Plate 2, Figures 5, 8

1933 Oistodus suberectus Branson and Mehl, Univ. Missouri Studies, vol. 8, p. 111, pl. 9, fig. 7.

1933 Oistodus inclinatus Branson and Mehl, idem, p. 110, pl. 9, fig. 8.

1933 Oistodus curvatus Branson and Mehl, idem, p. 110, pl. 111, figs. 4, 10, 12.

1955 Drepanodus suberectus (Branson and Mehl), Lindström, Geologiska Förenings (Stockholm) Förhandlinger, bd. 76, p. 568, pl. 2, figs. 21-22.

1955 Drepanodus homocurvatus Lindström, idem, p. 563, pl. 2, figs. 23-24, 39.


Remarks: This long-ranging Champlainian and Cincinnati species is present throughout the Escanaba Group. Drepanodus suberectus is especially abundant in the more argillaceous strata, in which it accounts for 25-50 percent of the total fauna. This species, however, makes up only 10 percent or less of the total fauna in the less argillaceous limestone. Would this suggest environmental control of D. suberectus? This explanation cannot account for this distribution entirely,
however, for about half of the specimens from the argillaceous strata are blackened and abraded forms that appear to be reworked. Due to the large size of the forms in this species, it may be that they have been concentrated as a "lag" deposit by intermittent currents.

Genus OULODUS Branson and Mehl, 1933

Type species: **Oulodus mediocris** Branson and Mehl, 1933

This genus, as revised by Bergström and Sweet (1966, p. 342) includes oulodus-like elements, cordylodus-like elements, and prioniodina-like elements. The oulodus-like elements include forms previously referred to the form-genera Oulodus Branson and Mehl, 1933, and **Gyrognathus** Stauffer, 1935.

**Oulodus oregonia** (Branson, Mehl and Branson)

Plate 2, Figures 15, 25, 29; Plate 3, Figures 12, 15, 19

1951 Prioniodina oregonia Branson, Mehl and Branson, Jour. Paleontology, vol. 25, pp. 15-16, pl. 3, fig. 18, pl. 4, figs. 26-32.

1959 Cordylodus excavatus Sweet et al., Jour. Paleontology, vol. 33, pp. 1054-1056, pl. 133, fig. 5.

1960 Oulodus casteri Pulse and Sweet, Jour. Paleontology, vol. 34, pl. 36, figs. 1, 8, 12.

1966 **Oulodus oregonia** (Branson, Mehl and Branson), Bergström and Sweet, Bull. Amer. Paleontology, vol. 50, no. 229, pp. 342-347, pl. 32, figs. 20-21, pl. 33, fig. 5, pl. 34, figs. 13-16, fig. 9G-L (includes synonymy to 1966).

Remarks: Thirty-eight specimens of this species were recovered from one sample from the Chandler Falls Formation.
Bergström and Sweet (1966) found representatives of this species in strata that are correlated with the Groos Quarry Formation but did not find these forms at a lower level. Webers (1966) recovered *Cordylocus serratus* (=*Cordylocus excavatus*) and *Oulodus primus* (=*Oulodus casteri?*) from strata correlated with the Bony Falls and Trenary formations, but he did not recover specimens of *Oulodus oregonia* (?) from underlying or overlying strata.

Elements of *Oulodus oregonia* are known to occur in strata as low as the Plattin Formation of Missouri (according to Bergström and Sweet, 1966, p. 344) and as high as the Arnheim Formation of the Cincinnati region (Branson, Mehl and Branson, 1951).

Genus *OZARKODINA* Branson and Mehl, 1933

Type species: *Ozarkodina typica* Branson and Mehl, 1933

*Ozarkodina obliqua* (Stauffer)

Plate 3, Figures 3, 5

1930 *Prioniodus obliquus* Stauffer, Jour. Paleontology, vol. 4, p. 123, pl. 10, figs. 3-4.


1966 *Ozarkodina? obliqua* (Stauffer), Bergström and Sweet, Bull. Amer. Paleontology, vol. 50, no. 229, pp. 348-351, pl. 33, figs. 6-9, pl. 34, figs. 7-8, fig. 10A-F (includes synonymy to 1966).

Remarks: Three specimens of the ozarkodina-like element and one specimen of the dichognathus-like element of this species
were found in a sample near the top of the Chandler Falls Formation. No prioniodina-like elements were recovered from the Escanaba Group.

**Genus PANDERODUS Ethington, 1959**

**Type species:** *Paltodus unicostatus* Branson and Mehl, 1933

*Panderodus gracilis* (Branson and Mehl)

**Plate 1, Figure 3; Plate 2, Figure 12**

1933 *Paltodus gracilis* Branson and Mehl, Univ. Missouri Studies, vol. 8, pl. 8, figs. 20-21.

1933 *Paltodus compressus* Branson and Mehl, *idem*, p. 109, pl. 8, fig. 19.


**Remarks:** This common species is represented abundantly throughout the Escanaba Group. *Panderodus gracilis* accounts for over 50 percent of all the specimens recovered in this study.

**Genus PERIODON Hadding, 1913**

**Type species:** *Periodon aculeatus* Hadding, 1913

Bergström and Sweet (1966, pp. 361-363) have emended the definition of this genus to include form-genera formerly assigned to *Periodon* Hadding, 1913, *Loxognathus*, Graves and Ellison, 1941, *Falodus* Lindström, 1955, and some forms referred to *Prioniodina* Bassler 1925.
Periodon grandis (Ethington)

Plate 1, Figures 13-16

1941 Oistodus prodentatus Graves and Ellison, Missouri School of Mines and Metallurgy, Tech. Ser., vol. 14, pp. 13-14, pl. 2, figs. 6, 22-23, 28.

?1941 Phragmodus undatus Branson and Mehl, Graves and Ellison (part?), idem, pp. 5-6, pl. 2, fig. 26.

?1941 Loxognathus flabellata Graves and Ellison, idem, pp. 12, pl. 2, figs. 29, 31-32.


1959 Balodus prodentatus (Graves and Ellison), Ethington, idem, pp. 277-278, pl. 39, fig. 18.

1959 Loxognathus grandis Ethington, idem, p. 281, pl. 40, fig. 6.

1959 Ozarkodina macrodontata Graves and Ellison, Ethington, idem, pl. 41, fig. 14.

1959 Trichonodella insolita, Ethington, idem, pp. 289-290, pl. 14, fig.


Remarks: Periodon grandis is present throughout the Chandler Falls and Groos Quarry formations and is also present in the Bony Falls Formation in the Perkins #2 core between 153 and 183 feet. This species is most abundant in the Chandler Falls Formation and of lesser importance in the Groos Quarry Formation.
Genus PHRAGMODUS Branson and Mehl, 1933

Type species: Phragmodus primus Branson and Mehl, 1933

Bergström and Sweet (1966, pp. 366-369) have emended this genus to include paired forms referred to the genera Phragmodus Branson and Mehl, 1933, Dichognathus Branson and Mehl, 1933, with associated oistodus-like forms in some species.

Phragmodus undatus Branson and Mehl

Plate 1, Figure 6; Plate 2, Figures 18, 19, 23, 26

1933 Phragmodus undatus Branson and Mehl, Univ. Missouri Studies, vol. 8, pp. 115-116; pl. 8, figs. 22-26.

1933 Dichognathus brevis Branson and Mehl, idem, p. 113, pl. 19, figs. 24-26.

1933 Dichognathus typica Branson and Mehl, idem, pp. 113-114, pl. 9, figs. 27-29.

1933 Oistodus abundans Branson and Mehl, idem, p. 109, pl. 9, figs. 11, 17.

1933 Oistodus breviconus Branson and Mehl, idem, p. 109, pl. 9, figs. 13-14.


Remarks: Phragmodus undatus is absent in the McFarland and Bony Falls formations. It appears abruptly at the base of the Ternary Formation and is common in this unit. It is extremely rare in the Chandler Falls and Groos Quarry formations. This species becomes very abundant toward the top of the Bill's Creek Beds.
Genus PLECTODINA Stauffer, 1935

Type species: Plectodina aculeata (Stauffer), 1930

As emended by Bergström and Sweet (1966, pp. 372-373), this genus includes form-species formerly referred to the form-genera Cordyloodus, Subcordyloodus, Trichonodella, Zygo- gnathus, and Plectodina. A detailed discussion of the nomenclature for this genus is presented in Bergström and Sweet (1966).

Plectodina aculeata (Stauffer)

Plate 1, Figures 7, 11, 12; Plate 2, Figures 3, 22

1930 Prioniodus aculeatus Stauffer, Jour. Paleontology, vol. 4, p. 126, pl. 10, fig. 12.

1933 Trichognathus recurva Branson and Mehl, Univ. Missouri Studies, vol. 8, p. 119, pl. 10, fig. 6.


1966 Plectodina aculeata (Stauffer), Bergström and Sweet, Bull. Amer. Paleontology, vol. 50, no. 229, pp. 373-377, pl. 32, figs. 15-16, pl. 33, figs. 22-23, pl. 34, figs. 5-6, fig. 9A-F (includes synonymy to 1966).

Remarks: This species is common in the McFarland Formation and in the Bony Falls Formation. Only a few specimens of Plectodina aculeata have been recovered from the Trenary Formation and it is very rare in the remaining formations of the Escanaba Group.
**Plectodina furcata** (Hinde), 1879

Plate 1, Figure 5; Plate 2, Figures 21, 28; Plate 3, Figure 15


1933 *Phragmodus mirus* Branson and Mehl, *idem*, p. 123, pl. 10, fig. 12.

1959 *Trichonodella ancgulata* Sweet et al., *Jour. Paleontology*, vol. 33, pp. 1044-1045, pl. 132, figs. 12, 14, 17.

1966 *Plectodina furcata* (Hinde), Bergström and Sweet, *Bull. Amer. Paleontology*, vol. 50, no. 229, pp. 377-382, pl. 32, figs. 17-19, pl. 33, figs. 1-4, 14-21, pl. 34, figs. 9-12 (includes synonymy to 1966).

Remarks: Specimens of *Plectodina furcata* have not been found in the McFarland Formation. This species is present in the Bony Falls Formation and is common to abundant in the Trenary, Chandler Falls, and Groos Quarry formations.

**Genus PRAVOGNATHUS** Stauffer, 1936

Type species: *Pravognathus idoneus* (Stauffer), 1935

*Pravognathus idonea* (Stauffer)

Plate 2, Figure 10


1935 *Heterognathus idoneus* Stauffer, *idem*, p. 607, pl. 72, figs. 9, 14, 15, 20, 26, 29, 32.

1935 *Heterognathus simplex* Stauffer, *idem*, p. 607, pl. 72, figs. 21-22, 31.
1966  Pravognathus idonea (Stauffer), Webers, Minnesota Geol. Survey Spec. Publ. SP-4, p. 45, pl. 10, fig. 8, pl. 11, figs. 4-9 (includes synonymy to 1966).

Remarks: Two broken and twisted specimens from the Upper Chandler Falls Formation have been referred to this multi-element-species. The region about the main cusp is arched and twisted, as in the description of Webers (1966).

Genus TETRAPRIONIODUS Lindström, 1955

Type species: Tetraprioniodus robustus Lindström, 1955

Tetraprioniodus delicatus (Branson and Mehl)

Plate 2, Figures 9, 11

1933  Phragmodus delicatus Branson and Mehl, Univ. Missouri Studies, vol. 8, p. 123, pl. 10, fig. 22.


1959  Keislognathus simplex Ethington, Jour. Paleontology, vol. 33, p. 280, pl. 40, figs. 9-10


Remarks: Conodont-elements belonging to the form-species Tetraprioniodus superbus, Ligonodina delicata, and Keislognathus simplex have been recovered from the Groos Quarry Formation. Only four specimens of this multiplelement-species have been found.
Residual Form-species

Genus ACONTIODUS Pander, 1856

Type species: Acontiodus latus Pander, 1856

Acontiodus alveolaris Stauffer

Plate 1, Figure 1

1935 Acontiodus alveolaris Stauffer, Jour. Paleontology, vol. 9, pp. 601-602, pl. 74, fig. 44.


Remarks: Only four specimens of this species have been recovered from the Escanaba Group. These conodonts were found in the Chandler Falls Formation. This species is represented in strata deposited from Early Wilderness (Nealmontian) to Late Barneveld (Pictonian) time in Minnesota (Webers, 1966).

Genus CARDIODELLA (Branson and Mehl), 1933

Type species: Cardiodus tumidus Branson and Mehl, 1933

Cardiodella tumidus (Branson and Mehl)

Plate 3, Figures 1, 16

1967 Cardiodella tumidus (Branson and Mehl), Andrews, Jour. Paleontology, vol. 41, pp. 886-887, pl. 112, fig. 12, pl. 114, figs. 1-2, 6 (includes synonymy to 1967).

Remarks: This revised form-species includes all of the species assigned to the genus Cardiodus by Branson and Mehl (1933). Andrews found a wide range of variability within this
conodont-element but no single, objective criterion by which it could be subdivided into two or more morphologic species.

**Genus CURTOGNATHUS** Branson and Mehl, 1933

**Type species:** *Curtognathus typa* Branson and Mehl, 1933

*Curtognathus limitaris* Branson and Mehl

Plate 3, Figure 17


Remarks: Andrews (1967) included in this form-species all forms of *Curtognathus* Branson and Mehl in which the denticles are distributed in an asymmetrical manner about the crest of the arched bar.

*Curtognathus typa* Branson and Mehl

Plate 3, Figure 2

1967 *Curtognathus typa* Branson and Mehl, Andrews, *Jour. Paleontology*, vol. 41, pp. 887-888, pl. 113, figs. 4, 21, pl. 114, fig. 22 (includes synonymy to 1967).

Remarks: All forms of *Curtognathus* that are nearly symmetrical about the arched bar were included in *C. typa* by Andrews (1967).
Genus DISTACODUS Hinde, 1879

Type species: Machairodus incurvus Pander, 1856

Distacodus falcatus Stauffer

Plate 1, Figure 4

1935 Distacodus falcatus Stauffer, Geol. Soc. Amer., Bull., vol. 46, p. 142, pl. 12, fig. 16.


Remarks: This species is rare in the McFarland, Dony Falls and Trenary formations. Although it consistently accounts for less than two percent of the fauna in samples from the Chandler Falls and Groos Quarry formations, it is remarkably persistent. Distacodus falcatus is present in every abundant sample from these units.

Genus ERISMODUS Branson and Mehl, 1933

Type species: Erismodus typus Branson and Mehl, 1933

This form-genus has been emended by Andrews (1967, pp. 890-891) to include forms formerly referred to the genera Erismodus Branson and Mehl, 1933, Microcoelodus Branson and Mehl, 1933, and Ptiloconus Sweet, 1955.

Erismodus asymmetricus (Branson and Mehl)

Plate 3, Figure 7

1967 Erismodus asymmetricus (Branson and Mehl), Andrews, Jour. Paleontology, vol. 41, pp. 893-894, pl. 112, figs. 1, 3, 6-7, 14, 17, pl. 113, fig. 1, pl. 114, figs. 7, 9, 13 (includes synonymy to 1967).
Remarks: Andrews included in this form-species conodonts formerly referred to several form-species in the form-genera *Erismodus*, *Microcoelodus*, *Ptiloconus*, and *Curtognathus*. Andrews (1967) distinguished *Erismodus symmetricus* from *E. asymmetricus* by the growth axis of the cusp. This axis is asymmetrical in the latter form-species. *E. asymmetricus* differs from *E. gracilis* in possessing lateral processes in Andrews' analysis.

Specimens of *E. asymmetricus* and *E. gracilis* from the Escanaba Group appear to show a complete transition between forms lacking lateral processes and those possessing long, distinct lateral processes. This fauna, consisting of only 60 specimens, is very small, and the writer has attempted to group them according to Andrews' analysis. However, several specimens are difficult to place.

*Erismodus asymmetricus* is common in the McFarland and Lower Bony Falls formations and is rare to absent in the Upper Bony Falls Formation.

*Erismodus gracilis* (Branson and Mehl)

Plate 3, Figures 4, 8, 11

1933 *Pteroconus gracilis* Branson and Mehl, Univ. Missouri Studies, vol. 8, p. 111; pl. 8, figs. 30, 32.

1955 *Ptiloconus gracilis* (Branson and Mehl), Sweet, Jour. Paleontology, vol. 29, p. 246, pl. 28, figs. 6, 20.

Remarks: Andrews (1967) assigned the nerodontiform conodonts referred to the genus *Ptiloconus* Sweet, 1955, to *Erismodus* since the only basis for this separation appears to be the symmetry of the denticles about the main cusp.

This form-species was not found in the Lower McFarland Formation, but is very common in the Upper McFarland and the Bony Falls formations. *Erismodus gracilis* is the only form of *Erismodus* to occur in the Upper Bony Falls Formation and also in the Upper Chandler Falls Formation.

**Erismodus symmetricus** Branson and Mehl

Plate 2, Figures 17, 27

1967 *Erismodus symmetricus* Branson and Mehl, Andrews, *Jour. Paleontology*, vol. 41, pp. 892-893, pl. 112, figs. 4-5, pl. 113, fig. 7, pl. 114, figs. 4, 18, 24 (includes synonymy to 1967).

Remarks: The growth axis of this form-species is symmetrical, unlike that of *E. asymmetricus* (Andrews, 1967). *Erismodus symmetricus* is common in the McFarland Formation and the Lower Bony Falls Formation but is absent in the Upper Bony Falls.

**Erismodus typus** Branson and Mehl

1967 *Erismodus typus* Branson and Mehl, Andrews, *Jour. Paleontology*, vol. 41, pp. 891-892, pl. 112, figs. 9-11, 18, pl. 114, fig. 21 (includes synonymy to 1967).

Remarks: One doubtful specimen of this form-species has been found in the Lower Bony Falls Formation. It is a blackened, rounded, and pitted "reworked" form that may not actually be *Erismodus typus*.
Genus **OISTODUS** Pander, 1856

Type species: **Oistodus lanceolatus** Pander, 1856

**Oistodus venustus** Stauffer

Plate 3, Figure 14


Remarks: Only four specimens of this species have been recovered from the Escanaba Group. Two of the specimens are from the Chandler Falls Formation and the other two are from the Groos Quarry Formation. *Oistodus venustus* is quite rare in most Champlainian and Cincinnatian Midcontinent faunas, but it may be abundant in some samples (see Webers, 1966, pl. 1).

Genus **OZARKODINA** Branson and Mehl, 1933

Type species: **Ozarkodina typica** Branson and Mehl, 1933

**Ozarkodina concinna** Stauffer

Plate 3, Figure 18


1966 *Ozarkodina concinna* Stauffer, Webers, Minnesota Geol. Survey, Spec. Publ. SP-4, pp. 35-36, pl. 9, figs. 9-12 (includes synonymy to 1966).

Remarks: Most of the ozarkodina-like elements from the Escanaba Group resemble *Ozarkodina concinna* more closely than any of the other forms (i.e. *O. tenuis*, *O. polita*) described by
Schopf (1966) and Bergström and Sweet (1966).

Representatives of this species are common throughout the Escanaba Group. In many of the northern Michigan samples, *Ozarkodina concinna* accounts for 10-25 percent of the total fauna.

Genus *POLYCAULODUS* Branson and Mehl, 1933
Type species: *Polycaulodus inclinatus* Branson and Mehl, 1933

*Polycaulodus bidentatus* Branson and Mehl

Plate 3, Figure 6


Remarks: As emended by Andrews (1967), this form-species includes conodonts referred to several species by Branson and Mehl (1933). These forms are *Polycaulodus bidentatus*, *P. peculiaris*, *P. resupinatus*, and *P. tridentatus*.

*Polycaulodus inclinatus* Branson and Mehl

Plate 3, Figure 10

1967 *Polycaulodus inclinatus* Branson and Mehl, Andrews, *Jour. Paleontology*, vol. 41, p. 898, pl. 113, fig. 24, pl. 114, fig. 11 (includes synonymy to 1967).

Remarks: Andrews (1967) included Branson and Mehl's *Polycaulodus abortivus*, *P. cornulatus*, *P. inclinatus*, *P. normalis*, and several questionable forms in this revised form-species.
Genus SCANDODUS Lindström, 1955

Type species: Scandodus furnishi Lindström, 1955

Scandodus? dissimilaris (Branson and Mehl)

Plate 2, Figure 20

1933 Phragmodus dissimilaris Branson and Mehl (part), Univ. Missouri Studies, vol. 8, pp. 123-124, pl. 10, fig. 29.

1966 Paltodus dissimilaris (Branson and Mehl), Schopf, New York State Museum, Bull. 405, p. 64, pl. 23, figs. 24-25.

1966 Scandodus sp. cf. S. dissimilaris (Branson and Mehl), Bergström and Sweet, Bull. Amer. Paleontology, vol. 50, no. 229, pp. 396-397, p. 34, figs. 24-25, fig. 13D.

Remarks: Scandodus? dissimilaris is quite common in the Chandler Falls and Groos Quarry formations and is always associated with Scolopodus insculptus. This form is similar to S. insculptus in form and ornamentation except that only one side of the cusp bears lateral costae. Lateral costae are found on both sides of the cusp of S. insculptus. Scandodus? dissimilaris and Scolopodus insculptus, as Bergström and Sweet (1966) pointed out, may be part of the same biological apparatus.

Genus SCOLOPODUS Pander, 1856

Type species: Scolopodus sublaevis Pander, 1856

Scolopodus insculptus (Branson and Mehl)

Plate 2, Figures 13, 16
1933 *Phragmodus insculptus* Branson and Mehl, *Univ. Missouri Studies*, vol. 8, p. 124, pl. 10, figs. 32-34.

1966 *Scolopodus insculptus* (Branson and Mehl), Bergström and Sweet, *Bull. Amer. Paleontology*, vol. 50, no. 229, pp. 395-400, pl. 34, figs. 26-27, fig. 13B (includes synonymy to 1966).

**Remarks:** This species is abundant in the Chandler Falls Formation and is common in the Groos Quarry Formation. A few specimens of *Scolopodus insculptus* have been recovered from the Bony Falls Formation in the Perkins #2 core between 153 and 163 feet.

**Genus TRUCHEROGNATHUS** Branson and Mehl, 1933

**Type species:** *Trucherognathus distorta* Branson and Mehl, 1933

*Trucherognathus distorta* Branson and Mehl

Plate 3, Figure 9


**Remarks:** Andrews (1967) included all of Branson and Mehl's (1933) species of *Trucherognathus* in this revised form-species.
REFERENCES CITED

PART I

Andrews, H. E.

Barnes, C. R.

Bassler, R. S.

Bergström, S. M. and W. C. Sweet

Branson, E. B. and M. G. Mehl

Branson, E. B., M. G. Mehl and C. C. Branson

Case, E. C. and W. I. Robinson

Cohee, G. V.

Darby, D. G. and E. C. Stumm
Ethington, R. L.

Fenneman, N. M.

Graves, R. W. and S. P. Ellison

Guldenzopf, E. C.
1964 The conodont fauna and stratigraphy of the Pecatonica Member of the Platteville Formation. Unpublished M. S. thesis, University of Iowa, Iowa City, Iowa.

Hadding, A. R.
1913 Undre dicellograptusskiffern i Skåne jämte några därmed ekvivalenta bildningar. Lunds Universitets Årskriften, afd. 2, bd. 9, nr. 15, pp. 1-90, pls. 1-8.

Hall, James

Hinde, G. J.

Hussey, R. C.

Hussey, R. C.
Hussey, R. C.

Kesling, R. V.

Kesling, R. V.

Kesling, R. V.

Kesling, R. V.


Kohut, J. J.
1967 Quantitative analysis, taxonomy, and distribution of Middle and Upper Ordovician conodonts from the Cincinnati region. Unpublished Ph. D. dissertation, The Ohio State University, Columbus, Ohio.
LeRoy, L. W., ed.

Leverett, Frank

Liberty, B. A.

Lindström, Maurits

Lindström, Maurits

Nelson, S. J.

Pander, C. H.

Pulse, R. R. and W. C. Sweet

Rhodes, F. H. T.
Rominger, Carl  
1873  

Schopf, T. J. M.  
1966  

Sinclair, W. C.  
1960  

Stauffer, C. R.  
1930  

Stauffer, C. R.  
1935a  

Stauffer, C. R.  
1935b  

Stauffer, C. R.  
1936  

Stone, G. L. and W. M. Furnish  
1959  

Stumm, E. C.  
1963  

Stumm, E. C. and E. G. Kauffman  
1958  
Sweet, W. C.

Sweet, W. C., C. A. Turco, Earl Warner and L. C. Wilkie

Templeton, J. S. and H. B. Willman

Thwaites, F. T.

Vanlier, K. E.

Vanlier, K. E.

Webers, G. F.
EXPLANATION OF PLATE 1

Figure 1 Acontiodus alveolaris Stauffer. Posterior view of a specimen from the Chandler Falls section, sample CF-9. X120. S. U. I. - 32487.


Figure 3 Panderodas gracilis (Branson and Mehl). Lateral view of a specimen of the form-species Panderodus compressus from the Chandler Falls section, sample CF9. X120. S. U. I. - 32520.

Figure 4 Distacodus falcatus Stauffer. Lateral view of a specimen from the Groos Quarry section, sample GQts-11. X120. S. U. I. - 32499.

Figure 5 Plectodina furcata (Hinde). Posterior view of a specimen of the form-species Trichonodella angulata from the Groos Quarry Formation at Maplewood, Delta County, Michigan, sample MPaq-6. X120. S. U. I. - 32538.

Figure 6 Phragmodus undatus Branson and Mehl. Lateral view of a specimen of the form-species Dichoqnathus brevis from the Trenary Formation south of Trenary, Alger County, Michigan, sample TRhb-2. X120. S. U. I. - 32526.

Figures 9, 10

*Cyrtoniodus flexuosus* (Branson and Mehl).
10. Lateral view of a specimen of the prioniodina-like element from the Chandler Falls section, sample CFts-0. X120. S. U. I. - 32498.

Figures 13-16

*Periodon grandis* (Ethington)
16. Lateral view of a specimen of the form-species *Licronodina tortilis* from the Chandler Falls section, sample CFts-0. X120. S. U. I. - 32523.
Figures 1, 4, 6, 7, 14

Amorphognathus ordovicica Branson and Mehl.
1, 4, 6, 7. Upper (1, 6) and lower (4, 7) views of two specimens of the form-species Amorphognathus ordovicica from the Groos Quarry section, sample GQts-2, and from the Groos Quarry Formation at Rapid River Falls, Delta County, Michigan, sample RPwf-1. X60. S. U. I. - 32489, and S. U. I. - 32490, respectively.

Figures 2, 24

Belodina compressa (Branson and Mehl).
2. Lateral view of a specimen of the form-species Belodina compressa from the Chandler Falls Formation near Bark River, Delta County, Michigan, sample BRre-3. X60. S. U. I. - 32491.

Figures 3, 22

Plectodina aculeata (Stauffer). Posterior views of growth stages of the form-species Trichonodella recurva. Figure 22, from the Trenary Formation in the Perkins #2 core (sample P2-133), represents an early growth stage while figure 3, from the Chandler Falls section (sample CF9), represents a later stage. X120. S. U. I. - 32534, and S. U. I. - 32535, respectively.

Figures 5, 8

Drepanodus suberectus (Branson and Mehl).
5. Lateral view of a specimen of the form-species Drepanodus suberectus from the Chandler Falls Formation near Cornell, Delta County, Michigan, sample Corb-1. X60. S. U. I. - 32501.
Figures 9, 11

*Tetraprioniodus delicatus* (Branson and Mehl).


Figure 10


Figure 12


Figures 13, 16

*Scolopodus insculptus* (Branson and Mehl). Lateral views of specimens from the Chandler Falls section, samples CFts-3 and CF9, respectively. X60. S. U. I. - 32545, and S. U. I. - 32544, respectively.

Figures 15, 25, 29

*Oulodus oregonia* (Branson, Mehl and Branson)


Figures 17, 27

*Eucrymodus symmetricus* Branson and Mehl. Anterior views of specimens from the Bony Falls Formation in the Perkins #2 core (sample P2-165), and the McFarland Formation near Traunik, Alger County, Michigan (sample JCpl-3). X60. S. U. I. - 32509, and S. U. I. - 32508, respectively.
Figures 18, 19, 23, 26

Phragmodus undatus Branson and Mehl.
18, 23, 26. Lateral views of specimens of the form-species Phragmodus undatus from the Bill's Creek Beds near Stonington, Delta County, Michigan (sample PPbc-6), and the Trenary Formation north of Trenary, Alger County, Michigan (sample DXre-2). X120. S. U. I. - 32530, S. U. I. - 32538, and S. U. I. - 32539, respectively.

Figure 20


Figures 21, 28

Plectodina furcata (Hinde).
Figures 1, 16

Figure 2 Curtognathus typa Branson and Mehl. Lateral view of a specimen from the Bony Falls section, sample Bfts-20. X60. S. U. I. - 32496.

Figures 3, 5
Ozarkodina obliqua (Stauffer).
3. Lateral view of a specimen of the form-species Ozarkodina obliqua from the Chandler Falls section, sample CF9. X120. S. U. I. - 32519.

Figures 4, 8, 11

Figure 6 Polycaulodus bidentatus Branson and Mehl. Lateral view of a specimen from the McFarland Formation near Traunik, Alger County, Michigan, sample GE-1820. X120. S. U. I. - 32541.

Figure 7 Brismodus asymmetricus (Branson and Mehl). Lateral view of a specimen from the Bony Falls section, sample Bfts-11. X120. S. U. I. - 32504.

Figure 9 Truchernognathus distorta Branson and Mehl. Lateral view of a specimen from the Bony Falls section, sample Bfts-11. X120. S. U. I. - 32548.

Figure 10 Polycaulodus inclinatus Branson and Mehl. Lateral view of a specimen from the Bony Falls section, sample Bfts-11. X120. S. U. I. - 32542.
Figures 12, 15, 19

Figure 13

Figure 14

Figure 17

Figure 18
PART II

STRATIGRAPHIC RELATIONSHIPS OF MIDDLE ORDOVICIAN STRATA IN NORTHERN MICHIGAN
INTRODUCTION

The Middle Ordovician strata in northern Michigan consist of alternating layers of thin-bedded argillaceous limestone and thick-bedded limestones and dolomites with one-eighth to three-inch partings of shale. They are best exposed in the bed of the Escanaba River from Wells to Bony Falls on the Delta-Marquette County line. A relatively continuous outcrop occurs along the lower four miles of the Escanaba River south of Chandler Falls (Locality 4). However, strata are exposed discontinuously in the bed of the Escanaba River between Chandler Falls and Bony Falls. The thickest significant exposure in this area is at the Bony Falls hydroelectric dam (Locality 5). Numerous smaller exposures of Middle Ordovician strata are scattered throughout Delta, Alger, Marquette, and Menominee counties. The important exposures will be dealt with in this report.

Previous Work

Michigan geologists presently recognize two Middle Ordovician formations in northern Michigan, the Black River and the Trenton. These names were first applied by James Hall (1851) and later by Rominger (1873) and Hussey (1936, 1950, 1952).

Hussey estimated the entire sequence to be approximately 120 feet thick and designated the "lowermost" dolomites and argillaceous limestones at Bony Falls the Bony Falls Member.
of the "Black River" [Formation]. He believed these to be the lowermost Middle Ordovician strata exposed in this area and did not specify a lower contact for the Bony Falls. Also, he (1952, p. 19) placed the top of the "Black River" just below the horizon at which the brachiopod *Zygospira recurvirostra* first appears at Bony Falls, and just below the *Prasopora* zone at Chandler Falls. This same *Prasopora* horizon is not present in the upper strata at Bony Falls, though. Both the lowest *Z. recurvirostra* zone at Bony Falls and the *Prasopora* zone at Chandler Falls are underlain by a one-inch layer of orange claystone that Hussey took to be a single, continuous metabentonite layer.

The strata above the "metabentonite" at Bony Falls and at Chandler Falls were assigned to the "Trenton" [Formation] by Hussey. He subdivided the "Trenton" into three members. The type section of the lowest unit is at dam #3 near Chandler Falls and is termed the Chandler Falls Member. The base of this member is the *Prasopora* zone and the top was defined as the "chief Maclurites zone" (Hussey, 1952) which forms the uppermost ledge 37 feet above the *Prasopora* zone at this locality.

The strata overlying the Chandler Falls are best exposed in the abandoned Bichler Quarry at Groos, about two miles downstream from Chandler Falls. The contact between the Chandler Falls Member and these strata is not exposed here,
but Hussey believed that it is only a few feet beneath the floor of the quarry. The upper contact of this formation is not exposed at this quarry either. Hussey designated the strata exposed here as the **Groos Quarry Member** of the Trenton.

A series of shales lies stratigraphically above the Groos Quarry Member. Hussey (1952, p. 34) believed that these shales are not more than three or four feet above the top of the ledges at Groos Quarry. These shales are not exposed on the western side of Little Bay de Noc (see figure 1), but are found on the east shore of the Bay and in tributary streams to the Whitefish River north of Rapid River. The exposure that is stratigraphically lowest is found on Haymeadow Creek (Locality 9). It consists of five feet of black, fissile, carbonaceous shale and another seven feet of thin-bedded calcareous shale. The lower beds were named the **Haymeadow Creek Member** by Hussey. He correlated them with the Collingwood Formation of Ontario on a lithologic basis and included this unit in the "Trenton." He further designated the calcareous shales that overlie his Haymeadow Creek Member the **Bill's Creek Beds**, the lowest unit of the "Richmond" [Formation]. These relationships are shown graphically in figure 7.

Subdivision of the "Black River" and "Trenton" formations was based largely on faunal changes while a minimal reliance was placed on lithologic criteria. Hussey (1952) stated:

"These members make up a composite section since they are not all found at the same locality. However no great gaps are in the stratigraphic succession. The members are divided on the basis of faunal associations but changes in lithology are also important..."
Figure 7 Stratigraphic relationships in Middle Ordovician strata in northern Michigan according to Hussey (1952). See text for explanation and compare to figure 3. Lithologic symbols from LeRoy (1951).
"...From bottom to top of the complete section certain genera and species of fossils are observed to disappear while other forms appear."

Acknowledgments

Many people have aided and encouraged the writer in the preparation of this report. Special thanks are due Drs. K. M. Hussey and C. F. Vondra of Iowa State University for their advice and support. Mr. A. K. Slaughter, State Geologist, and Dr. G. E. Eddy, Director, of the Michigan Geological Survey were very cooperative and helpful in providing information and facilities for the writer's use. Mr. Slaughter and the Michigan Basin Geological Society kindly invited the writer to present many of the ideas presented in this report at their annual meeting in 1967.

Valuable suggestions concerning Ordovician nomenclature and correlation were also offered by Dr. M. E. Ostrom of the Wisconsin Geological and Natural History Survey; Dr. B. A. Liberty of the University of Guelph, Ontario; Dr. T. C. Bushbach of the Illinois State Geological Survey; Dr. C. E. Prouty of Michigan State University; Dr. W. C. Sweet of The Ohio State University; and Dr. L. L. DeWitt of Knox College, Galesburg, Illinois.
STRATIGRAPHIC PROBLEMS

The writer has undertaken a study of the conodont faunas of the Champlainian strata of northern Michigan in order to correlate these beds with strata of a similar age in the stable interior of North America. Discrepancies in Hussey's interpretations became apparent as work progressed.

1) If Hussey's thicknesses at the various type localities are added together, the cumulative thickness is approximately 120 feet, but cores indicate that these strata are 250 to 300 feet thick (Hamblin, 1958; Templeton and Willman, 1963) and conodonts of Champlainian age have been recovered from 250 feet of core material.

2) The writer has secured large numbers of conodonts from the upper strata at Bony Falls which are identical to forms abundant in the Chaumont Formation (Upper Black River Group) of New York-Ontario (Barnes, 1964; Schopf, 1966) and the Plattin and Joachim of Missouri (Branson and Mehl, 1933; Andrews, 1967). These conodonts are very rare in the Rockland Formation (Lower Trenton Group) which overlies the Chaumont and in the Decorah and Kimmswick formations of Missouri which overlie the Plattin Formation. In addition, conodonts recovered from the lower strata at Chandler Falls are like those found in the Shoreham Formation (Lower Trenton Group) of New York and the Cummingsville and Prosser members of the Galena Formation of the Upper Mississippi Valley (Ethington, 1959; Webers, 1966). In short, the "Trenton" beds at Bony Falls
contain a Blackriveran fauna and the "Black River" beds at Chandler Falls contain a Trentonian fauna.

3) This ambiguity is also apparent by inspection of the faunal lists for these localities given by Hussey (1952, pp. 18-20, 26-27). The upper beds at Bony Falls were considered by him to be lateral equivalents of the Prasopora zone at Chandler Falls and therefore of Trentonian age. These strata, however, contain fossils found in beds no younger than the Blackriveran at the type locality. He (Hussey, 1952, p. 19) noted one of these occurrences as follows:

"Ulrich identified Lambeophyllum profundum from the upper beds at Bony Falls. This is a Black River coral. However, the form from Bony Falls is apparently a new species."

Kesling et al. (1960), noting that Hussey identified the ostracod Eoleperditia fabulites in the upper strata at Bony Falls, stated that, if this identification were correct, then these strata must be of Blackriveran age, since this fossil has not been reported from younger strata in the type area.

The lowermost strata at Chandler Falls contain species of the bryozoan genus Prasopora (Hussey, 1952). The lowermost stratigraphic horizon at which this genus has been found in the Upper Mississippi Valley is the Ion Member of the Decorah Formation. Prasopora is abundant in the Lower Member of the Verulam Formation (=Upper Kirkfield Formation) in the Lake Simcoe, Ontario, region (Liberty, 1964, pp. 20-21). This genus is not present in underlying formations.
In addition to this, none of the diagnostic Black River fossils such as Lambeophyllum profundum, Tetradium cellulosum, and Bathyurus extans have been found in the lower strata at Chandler Falls.

4) Correlation based on similar conodonts and samples with lithologies of the outcrops and cores reveals that approximately a 90 foot interval lies between the upper strata at Bony Falls and the lowermost strata at Chandler Falls. This might not be suspected immediately, for the outcrop lithology is superficially similar. The lower argillaceous limestone beds at Chandler Falls are succeeded by relatively thicker-bedded, less argillaceous strata. The same general sequence is to be found at Bony Falls, and one might conclude that they are lateral equivalents. Evidence from cores drilled in the Escanaba area indicates that this stratigraphic sequence is repeated five times in the interval between the underlying Lower Ordovician strata and the overlying shales.

Besides these discrepancies in local correlation, the writer objects to the use of the terms "Black River" and "Trenton" in this area on the following grounds:

1) These terms have been carried far from the New York type areas in which they were first used. Although the northern Michigan Middle Ordovician strata appear to resemble the Black River and Trenton (they are carbonates) they differ in detail. Numerous modern studies of carbonate rocks have resulted in the recognition of greater lithologic variation
than was appreciated in the time of Hall or that of Hussey. Carbonates in the stable interior show a considerable variation in sequence, argillaceous content, accessory minerals, etc.

The Black River-Trenton terminology was once applied to central Ontario as well, but Liberty (1955, 1963, 1964) recognized lithologic changes that do not correspond to the standard New York section. The Trentonian strata are characterized by a much larger percentage of shale beds to carbonate beds than are found in New York and eastern Ontario. Liberty found it expedient to redefine the lithostratigraphic nomenclature in central Ontario (see figure 8).

2) The Black River and Trenton groups of New York have been designated by various writers as standard chronostratigraphic units in North America (Blackriveran Stage, Trentonian Stage). Ideally, a chronostratigraphic unit should consist of lithostratigraphic units that are characterized by distinctive faunal assemblages. Even in the New York type area, however, the Black River and Trenton groups are defined in some places on the basis of faunal changes where lithologic changes are not obvious. Kay (1937, p. 251) states:

"...Within some part of its distribution, each formation and member is believed to be lithologically distinct; traced laterally, the differences may become obscure and faunal evidence may be the useful basis of recognition. Lateral changes alter the rank of certain synchronous units from one part of the region to another; the units have been given the
rank that seems most useful within each outcrop area."

Changes in the character of the fauna that occur at lithostratigraphic boundaries in the type area are found to occur in the middle of distinctive lithostratigraphic units elsewhere. In central Ontario, typical Blackriveran forms disappear and typical Trentonian forms appear in the middle of the Bobcaygeon Formation (Liberty, 1955) and on Manitoulin Island, the change takes place in the middle of the "Cloche Island Beds."

Similar difficulties are encountered in defining the boundary between the Trentonian and Edenian stages, both in the type areas and elsewhere. In New York, the Utica Shale which overlies the Trenton, is supposedly Edenian in age while the subjacent Trenton formations have all been considered to be of Trentonian age. In eastern Ontario, however, the Hillier Member of the Cobourg Formation (Upper Trenton Group) contains a megafauna of Edenian affinities (Sinclair, 1958). The entire Cobourg Formation of New York contains a conodont fauna that is also like the conodont fauna of the Eden (Schopf, 1966) suggesting that a part, if not all, of the Cobourg is Edenian in age.

Bergström and Sweet (1966), through comparison of relative-abundance logs for the conodont faunas of the Lexington-Kope interval of the Cincinnati region and that of the Trenton Group of New York—Ontario, have concluded that the Barneveld
Stage of Fisher (1962) or the Pictonian Stage of Kay (1960) overlap with the Edenian Stage. The Pictonian Stage, they assert (Bergström and Sweet, 1966), is not succeeded by the Edenian, but the Pictonian embraces all of the Edenian Stage and may also include portions of the Maysvillian Stage. In terms of the New York section, this means that most, if not all of the Cobourg Formation was laid down during Edenian time.

The lithostratigraphic boundary between the Verulam and Lindsay formations (Liberty, 1955) was considered to be nearly equivalent to the Hallowell-Hillier boundary within the Cobourg Formation (Schopf, 1966). The Verulam was formerly considered to be the lateral equivalent to the "Sherman Fall" (=Shoreham Formation and Denmark Formation of New York) and the Lindsay was formerly termed the "Cobourg Beds" (Liberty, 1964, pp. 20-21). Comparison of the Michigan relative-abundance log to those for the Cincinnati region, New York-Ontario, and Minnesota by Bergström and Sweet (1966, pp. 292, 295) suggests that the uppermost beds of the Groos Quarry Formation sampled by the writer are equivalent to the Denmark Formation of New York, which is of Shermanian age. This means that the stage boundary between the Middle and Upper Ordovician in northern Michigan is stratigraphically higher, probably somewhere in the Bill's Creek Beds. The exposures at Groos Quarry have been considered by various writers (Kay, 1937; Hussey,
1952) to be lateral equivalents of the Upper Cobourg.

If palaeontologic criteria are to be preferred over lithologic criteria in temporal correlation outside of the type area (American Commission on Stratigraphic Nomenclature, 1961, Article 28, Remarks a, b, p. 658) it appears that one must accept the fact that facies changes occur within these chronostratigraphic units. Conversely, one must accept the conclusion that the lithostratigraphic units are not isochronous as has been assumed in the past.

The writer has already noted that the northern Michigan strata are lithologically dissimilar to those of the Black River and Trenton groups of New York. These terms are not valid as lithologic terms in this area, then, and the terms Blackriveran and Trentonian, which are chronostratigraphic names, is the only sense in which these names can be used. The boundary between these stages (Nealmontian and Blackriveran of Kay (1960)) in northern Michigan should be defined on the basis of faunal contrasts, not on the basis of lithologic boundaries.

3) The northern Michigan outcrop area occupies the northwestern margin of the Michigan Basin while the New York type area lies within the northern part of the Allegheny Synclinorium. The two regions were divided by the Findlay Arch (the Cincinnati-Algonquin Line of Kay (1948)), a northeast-southwest trending positive tectonic element, during Cham-
plainian time. The Findlay Arch was elevated during Croixan (Late Cambrian) and Canadian (Early Ordovician) time (Cohee, 1948). The tectonic histories of subsidence and uplift of the Michigan Basin and the northern part of the Allegheny Synclinorium were probably not synchronous. These factors have apparently resulted in facies changes within chronostratigraphic units due to changes in regimen of the two areas at different times.

4) Good exposures of Middle Ordovician strata are either completely absent or of very poor quality in areas immediately outside of the Escanaba region. The bedrock is buried under glacial and post-glacial deposits or is subaqueous. In addition, subsurface control in these areas is insufficient for detailed stratigraphic work. Middle Ordovician exposures of 30-40 or more feet do not occur within a 100-mile radius of the principal northern Michigan exposures. The nearest outcrops of appreciable thickness are found near Green Bay, Wisconsin, approximately 110 miles south of Escanaba. Middle Ordovician strata are buried under glacial deposits east of Escanaba and reappear on the surface 150 miles away on islands in the St. Mary's River south of Sault Ste. Marie and on St. Joseph Island, Ontario. Relatively thick Middle Ordovician exposures occur 100 miles farther east on Manitoulin Island, Ontario, and near Lake Simcoe, Ontario, which is 150 miles southeast of Manitoulin Island. In between these areas, the
bedrock is submerged beneath the waters of Georgian Bay.

Extension of lithostratigraphic terms over long distances with so little control is logically imprecise. Until much more subsurface information becomes available for study, it seems inadvisable to extend lithostratigraphic terminology from any other area into the Escanaba region.

Because of these difficulties, the writer believes that lithostratigraphic names taken from the immediate vicinity should be applied to the Middle Ordovician succession in northern Michigan. This type of nomenclature would have at least two advantages. First, such locally-defined units would be mappable. Their boundaries would be objective and would not be based on lithologic relationships in other areas that may not persist laterally. Secondly, the abandonment of the old nomenclature would clarify the chronostratigraphic relationships. The boundary between the Black River and Trenton, as is now used in the Michigan Basin, has sometimes been defined on the basis of faunal changes and sometimes on the basis of lithologic breaks. The retention of this nomenclature in both the lithostratigraphic and the chronostratigraphic senses will result in a perpetual argument over boundary relationships between the two units. If these names are used only to delineate chronostratigraphic horizons, this difficulty would be avoided.
The writer tentatively subdivides and describes the Middle Ordovician strata in the Escanaba area in terms of their physical properties and boundary relationships. The names for stratigraphic units described in this report are intended to be classified as informal terms. The writer believes that a complete petrographic analysis should accompany a formal proposal for new stratigraphic terms and such an analysis is not within the scope of this study. These informal stratigraphic names reflect the writer's interpretation of evidence obtained from surface exposures, cores, and conodont biostratigraphy. Should a petrographic analysis support these views, a formal proposal should be made for the stratigraphic nomenclature suggested here.
Figure 8 Correlations of Middle Ordovician strata in northern Michigan, central Ontario, and Wisconsin.
DESCRIPTION OF LITHOLOGIC UNITS

As previously mentioned, the same general sequence of lithologies is repeated five times in northern Michigan. Lower, argillaceous, wavy-bedded and thin-bedded carbonates (micrites and biomicrites) with thin shale partings give way vertically to more dense, wavy- and more thickly-bedded carbonates (dismicrites, micrites, biomicrites and biosparites) containing relatively fewer and more widely-spaced shale partings. Some of the upper, less argillaceous beds also contain a higher percentage of bioclastic material than the lower, argillaceous beds. Whole fossils are much more common in the argillaceous beds than in the upper beds. At several horizons, these upper beds have been strongly dolomitized and most of the fossils, bedding, and other primary features have been obscured. The lower argillaceous beds probably represent an intermittently agitated environment (Type II₃ of Plumley et al. 1962) while the upper beds were probably deposited in a moderately agitated environment (Type IV₃ of Plumley et al. 1962). This may indicate that sea level fluctuated slightly during Champlainian time.

The transition between the lower argillaceous strata and the upper beds is a gradual one in which the shale partings become fewer in number and more widely spaced. The boundary between the argillaceous strata and the thicker underlying beds, by contrast, is always a sharp, distinct contact.
Greater lithologic contrast may be seen at these boundaries than at any place in the entire lithologic sequence. In addition to this, the upper surface of the underlying, thick-bedded dismicrites frequently contains abundant pyrite, some glauconite, and small vugs. These features, taken together, have often been cited as evidences of unconformable relationships between strata (Krumbein, 1942; Prokopovich, 1955; Jaanusson, 1961). These "cycles," then, are the most logical, locally usable, and mappable stratigraphic units. Therefore, each "cycle" is here given formational rank. The entire sequence of Middle Ordovician carbonates is distinctly different from the underlying Lower Ordovician sandstones and carbonates and from the overlying Upper Ordovician shales. It is practical, therefore, to describe this unit as a group, herein named the Escanaba Group.

**Escanaba Group**

The Escanaba Group is described here as including all of the carbonates overlying the Lower Ordovician Prairie du Chien Group and underlying the Haymeadow Creek and Bill's Creek shales. The type area of the Escanaba Group is the bed of the Escanaba River between Wells and Bony Falls in Delta County, Michigan, and quarries and exposures along streams near McFarland, Marquette County, Michigan, and Trenary, Alger County, Michigan.
The term Escanaba Group is proposed informally to describe a natural lithologic subdivision of the Paleozoic sequence in this area and may be used in place of the term "Black River-Trenton" which is now used for these same strata. This term may have utility in the deeper parts of the Michigan Basin since both areas are a part of the same tectonic province.

This term is applied to strata occupying the interval that has been named the Ottawa Megagroup (Swann and Willman, 1961), Simcoe Group (Liberty, 1955, 1963, 1964), and Sinipee Group (Ostrom, 1965). The term "Ottawa Megagroup" was taken from the Ottawa River Valley in Ontario and used for strata in the Upper Mississippi Valley. The name "Ottawa" in the Upper Mississippi Valley is usually associated with the Ottawa, Illinois, silica sandstone (the St. Peter Sandstone of Ordovician age) and another silica sandstone at Ottawa, Minnesota (from the Jordan Sandstone of Cambrian age). Because of these objections, Ostrom (1965, p. 53) proposed the name Sinipee Group for Platteville, Decorah, and Galena strata exposed on Sinipee Creek in Grant County, Wisconsin.

The writer does not believe that this term is adequate for use in northern Michigan for several reasons: 1) Several of the lithologic boundaries recognized in Wisconsin are not apparent in northern Michigan. The lithologic boundaries recognized in northern Michigan would fall in the middle of
some formations in Wisconsin. For instance, the boundary between the McFarland and Bony Falls formations most nearly corresponds to the break between the Pecatonica and McGregor members of the Platteville Formation. 2) Some strata that make up the Sinipee Group are not present in the Escanaba Group in northern Michigan. Strata corresponding to the Upper Stewartville and the Dubuque are not present in the Escanaba Group and the strata comprising the Groos Quarry and Chandler Falls formations (as described here) are lithologically dissimilar to the Galena units in Wisconsin and Minnesota. In addition, lithic equivalents of the lowermost Middle Ordovician strata in northern Michigan appear to be absent in Wisconsin. 3) The subsurface data that has been presented to date is not adequate for extension of these lithologic names into northern Michigan. Ostrom (1967) has traced the "Galena-Platteville" from southern Wisconsin into Alger County, Michigan, from 19 cores. The "Galena-Platteville" is not divided in his report and there are several important gaps, especially in northern Wisconsin and Michigan. Until more detailed studies have established lithologic equivalence of Middle Ordovician strata in the two areas, it does not seem advisable to apply Wisconsin terminology to the northern Michigan area.

The name Simcoe Group was proposed by Liberty (1955) for localities in the vicinity of Lake Simcoe, Ontario. The formational boundaries of this group (Gull River, Bobcaygeon, Verulam, and Lindsay) do not appear to coincide with most of
the stratigraphic boundaries in northern Michigan. In addition to this, all of the stratigraphic units of central Ontario contain considerably more shale than the strata in northern Michigan, thus the term Simcoe Group seems inappropriate in that area.

Grabau (in Lane, 1910) first suggested the use of the name "Escanaba Limestone" in the sense that it is suggested here, but Lane (1910) stated that:

"While Escanaba Limestone, suggested by Grabau is a euphonious term, my impression is that it would be better to use Trenton, the old widely used term in a broad sense and introduce Escanaba as applicable to some accurately defined subdivision..."

This was never done.

Hussey (1950) proposed the name Escanaba River Group for the Middle Ordovician strata along the Escanaba River in a field guidebook. In a later publication (Hussey, 1952) that essentially repeated the earlier work, no further reference was made to this suggestion.

McFarland Formation

The lowermost unit is here termed the McFarland Formation for exposures in the abandoned quarry one-half mile west of McFarland, Marquette County, Michigan, in the center of Sec. 25, T. 44 N., R. 24 W. The quarry is reputed to be about 25 feet deep, but it is water-filled and the upper five feet of thick-bedded calcareous to arenaceous dolomite is all that is available for inspection. Argillaceous limestone from below
these dolomites are piled about the edges of the quarry.

TYPE SECTION OF THE MC FARLAND FORMATION AT THE ABANDONED QUARRY ONE-HALF MILE WEST OF MC FARLAND, MICHIGAN IN THE CENTER OF SEC. 25, T. 44 N., R. 24 W., MARQUETTE COUNTY, MICHIGAN.

ESCANABA GROUP
MC FARLAND FORMATION
Dolomite, calcareous: Buff (10YR 7/2) to blue-gray (53 6/1); thick-bedded (6-inch to 1-foot layers); finely crystalline; fair intergranular porosity and permeability; sparsely fossiliferous (some brachiopod fragments are recognizable); Several layers contain a significant amount of discrete quartz particles that are subrounded and frosted.

Water level - The same lithology persists approximately six feet below water level. One sample was obtained three feet below water level.

Limestone, argillaceous: Blue-gray (5B 6/1); finely crystalline; thin-bedded (½-1 inch layers); low porosity and permeability; sparsely fossiliferous (some poor brachiopod fragments and crinoid stem fragments are contained in this rock); This lithology is not readily accessible in place. Large blocks with drill holes penetrating them are found piled about the edge of the quarry, so they are presumed to be from the quarry itself and not transported from elsewhere by glaciers.

The conodont fauna from these strata is Blackriveran or Early Wilderness in age. This exposure is probably very close to the limit of the Middle Ordovician outcrop belt in this area and is correlated with a part of the interval between 236 feet and 183 feet in the Perkins #2 core (Sec. 25, T. 44 N., R. 22 W., Delta County, Michigan) which contains a similar conodont fauna and occupies the same stratigraphic position.
The writer is well aware that a section so poorly exposed is not the best type section. Unfortunately, it is the best surface exposure available. Since such a small portion of this interval is exposed on the surface, the Perkins #2 core, kept by the Geological Survey Division of the Michigan Department of Conservation, is described as a reference section for the McFarland Formation. The following description is taken from a study of this core.

**PRINCIPAL REFERENCE SECTION FOR THE McFARLAND FORMATION FROM THE PERKINS #2 CORE, DRILLED IN THE SW\(^1\)/4, SEC. 25, T. 42 N., R. 22 W., DELTA COUNTY, MICHIGAN.**

<table>
<thead>
<tr>
<th>Vertical Depth (Feet)</th>
<th>Thickness (Feet)</th>
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<tbody>
<tr>
<td>170.1</td>
<td>12.9</td>
</tr>
<tr>
<td>183.0</td>
<td>3.0</td>
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<td>186.0</td>
<td>13.0</td>
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**ESCANABA GROUP**

**BONY FALLS FORMATION**

Interbedded argillaceous limestone and calcareous shale; Limestone, argillaceous; gray (N7); finely crystalline; thin-bedded; low porosity and permeability; moderately fossiliferous.

**MC FARLAND FORMATION**

* Dolomite, calcareous; buff (5YR 5/4); finely crystalline; medium-bedded; low porosity and permeability; recrystallized fossil outlines (fossil ghosts) such as brachiopods and crinoid stems. 183.0 3.0

* Dolomite, calcareous and argillaceous; buff (10YR 6/2); finely to coarsely crystalline; thin, wavy beds with wavy and contorted argillaceous streaks; low porosity and permeability; moderately fossiliferous (gastropods especially notable). 186.0 13.0
<table>
<thead>
<tr>
<th>Vertical Depth (Feet)</th>
<th>Thickness (Feet)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dolomite, calcareous; buff (10YR 6/2); medium-grained crystals; low porosity and permeability; unfossiliferous; recrystallized, vuggy.</td>
<td>199.0</td>
</tr>
<tr>
<td>Dolomite; buff (10YR 6/2); medium-grained crystals; low intergranular porosity with high vuggy porosity, low permeability; pencil-thin argillaceous streaks; massive.</td>
<td>205.0</td>
</tr>
<tr>
<td>Dolomite, calcareous and argillaceous; buff (10YR 6/2); green shale (5G 4/2) streaks about ° inch or less in thickness; finely crystalline; thin-bedded; low porosity and permeability; fossil ghosts of white sparry calcite; some discrete subrounded and frosted quartz grains (floating quartz).</td>
<td>212.0</td>
</tr>
<tr>
<td>Dolomite, calcareous; buff (10YR 6/2) to gray (N6); finely crystalline to medium-sized crystals (salt-and-pepper texture); thin-bedded; low intergranular porosity but high vuggy porosity, low permeability; recrystallized brachiopod outlines (fossil ghosts) of white sparry calcite.</td>
<td>216.0</td>
</tr>
<tr>
<td>Dolomite, buff (5R 6/2); finely crystalline; medium-bedded; low intergranular porosity with some vuggy porosity (vugs 1 mm. in diameter), low permeability; streaked pink and gray bands; mottled.</td>
<td>220.0</td>
</tr>
<tr>
<td>Limestone, argillaceous; gray (N6); finely crystalline; thin-bedded; low porosity and permeability; fossiliferous (brachiopods, ostracodes?): This unit contains pencil-thin wavy argillaceous seams.</td>
<td>231.0</td>
</tr>
</tbody>
</table>

Total McFarland Formation 53.0
PRAIRIE DU CHIEN GROUP

HERMANSVILLE FORMATION

Dolomite, calcareous; buff (10YR 6/4); finely crystalline; medium-bedded; low intergranular porosity but very high vuggy porosity in places (dolomite crystals line vugs).

Dolomite, buff (10YR 6/2) to gray (N6); finely crystalline; medium-grained; low intergranular porosity but high vuggy and fracture porosity; fair permeability; unfossiliferous; some pyrite and glauconite are present and abundant floating quartz is present.

Sandstone; white (N8); medium-grained; massive; friable; high porosity and permeability; round to subrounded and frosted quartz grains.

Dolomite; buff (10YR 7/1); medium-grained; contains oolites (1/2 mm, in diameter); abundant discrete, sand-sized quartz grains.

The underlying Lower Ordovician rocks are equivalent in age to the Shakopee Formation of Minnesota, Iowa, and Wisconsin (Guldenzopf, 1967). The contact between this unit and the McFarland Formation is an unconformable one. The Shakopee equivalent is a fine-grained dolomite that is brecciated and fractured. It has high vugular porosity and contains pyrite, abundant quartz grains that are discrete, subrounded, sand-sized and frosted (referred to here as "floating quartz") and a trace of glauconite. The overlying McFarland, on the other hand, is an argillaceous limestone that contains thin, gray...
shale partings. Between 231 and 183 feet of the Perkins #2 core, the McFarland Formation consists of interbedded calcareous, argillaceous, arenaceous, and pure dolomite. Several layers contain strophomenid and orthid brachiopods.

**Bony Falls Formation**

The term "Bony Falls" was proposed by Hussey (1952) for those strata exposed at the hydroelectric dam at Bony Falls on the Escanaba River in the NE 4, Sec. 2, T. 41 N., R. 24 W., Delta County, Michigan. The Bony Falls was defined by Hussey as those strata which underlay the "Chandler Falls Member" and extend an unknown distance below the bed of the river. The assignment of the upper beds at Bony Falls to the "Trenton" is in error, as the previous discussion indicates.

The exposure at Bony Falls is the most typical of this stratigraphic interval. The writer restricts the term Bony Falls to those strata that overlie Hussey's unit 2 at Bony Falls (Hussey, 1952). Due to the stratigraphic position and the thickness of the succeeding limestone, the writer believes that the calcareous dolomite that forms the base of the Bony Falls section is the uppermost part of the McFarland Formation. The contact between the dolomites of the McFarland and the overlying argillaceous, wavy- and thin-bedded limestones of the Bony Falls is a sharp one. The evidence of an erosion surface found at this contact is equivocal, for although the upper surface of the McFarland is pitted, this could easily
be accounted for by solution and abrasion from recent fluvial processes. In fact, all rock surfaces at this locality that have been subjected to erosion by the Escanaba River in recent time are similarly pitted.

TYPE SECTION OF THE BONY FALLS FORMATION AT THE BONY FALLS HYDROELECTRIC DAM ON THE ESCANABA RIVER IN THE NE¼, SEC. 2, T. 41 N., R. 24 W., DELTA COUNTY, MICHIGAN.

<table>
<thead>
<tr>
<th>Thickness (Feet)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.0</td>
</tr>
<tr>
<td>4.0</td>
</tr>
<tr>
<td>2.0</td>
</tr>
<tr>
<td>3.0</td>
</tr>
<tr>
<td>2.0</td>
</tr>
</tbody>
</table>

ESCANABA GROUP

BONY FALLS FORMATION

Limestone, dolomitic; buff (10YR 6/2); finely crystalline; medium-bedded; massive; low porosity and permeability; fossil ghosts of brachiopod valves filled with sparry calcite and iron oxide stain; fine ripple-marks apparent.

Limestone; buff (10YR 6/2); finely crystalline; medium-bedded; low porosity and permeability; fossiliferous (brachiopods, crinoid stem fragments, gastropod molds, burrows, and small cephalopods).

Limestone; buff (10YR 6/2) to gray (N6); finely crystalline; thin-bedded (¼-1 inch beds); low porosity and permeability; very fossiliferous (Strophomena filitexta?, Hesperorthis triceraria); some secondary dolomite replacement.

Limestone; buff (10YR 6/2); finely crystalline; thin-bedded; low porosity and permeability; very fossiliferous (Hesperorthis triceraria, Strophomena filitexta?, Lambeophyllum profundum, other brachiopods and bryozoa, crinoid stem fragments).

Limestone; buff (10YR 6/2) to blue-gray (5B 6/1); finely crystalline; thin, wavy beds; low porosity and permeability; moderately fossiliferous (contains ostracodes, possibly Eoleperditia fabulites); fine-grained fucoidal beds.
Limestone; blue-gray (5B 5/1) to buff (10YR 6/2); medium-grained; thin, wavy, and nodular beds separated by ½-1/8 inch shale partings; low porosity and permeability; massive; fossiliferous (ostracodes, packed bioclastic debris of brachiopod valves and crinoid stem fragments).

Limestone, argillaceous; buff (10 YR 6/2) to blugray (5B 6/1); finely crystalline; thin-bedded; low porosity and permeability; fossiliferous (ostracodes, brachiopods including Strophomena filitexta?, crinoid stem fragments); fucoidal.

Limestone, argillaceous; blue-gray (5B 5/1) to buff (10YR 6/2); finely crystalline; thin-bedded; low porosity and permeability; moderately fossiliferous (brachiopods, crinoid stem fragments).

MC FARLAND FORMATION
Limestone, dolomitic; buff (10YR 6/1); finely crystalline; medium-bedded; low porosity and permeability.

Dolomite, calcareous; buff (10YR 6/2); finely crystalline; thick-bedded; good intergranular and vuggy porosity with secondary dolomitization. Vugs have been formed around old brachiopod sites; good permeability; unfossiliferous, but there is evidence that fossils were present in this unit; some pyrite and floating, sand-sized quartz grains.

Total thickness of the section 38.0

The top of the Bony Falls Formation is not exposed at the type locality. The type section is correlated with the interval between 183 and 155 feet in the Perkins #2 core. In addition to the type section, seven feet of interbedded argillaceous limestone and dolomite and 27 feet of argillaceous dolomite and pure dolomite in the core are included in this...
unit. The Bony Falls Formation, thus described, is 62 feet thick. The upper contact between the Bony Falls Formation and the overlying Trenary Formation is exposed in the bed of the West Branch Whitefish River south of Trenary, Alger County, Michigan.

PRINCIPAL REFERENCE SECTION FOR THE BONY FALLS FORMATION FROM THE PERKINS #2 CORE DRILLED IN THE SW¼, SEC. 25, T. 42 N., R. 22 W., DELTA COUNTY, MICHIGAN.

Vertical Depth Thickness
(Feet) (Feet)

ESCANABA GROUP
TRENARY FORMATION
Limestone, argillaceous; gray (N5); finely crystalline; thin, wavy beds with interbedded shale layers; low porosity and permeability; fossiliferous (brachiopods, bryozoa). 100.5 22.5

BONY FALLS FORMATION
Dolomite, calcareous; buff (10YR 6/2); fine to medium-sized crystals; medium-bedded; massive; contains occasional floating sand-sized quartz grains; abundant pyrite near upper contact; argillaceous toward base. 123.0 17.0

Limestone, argillaceous; gray (N5); very finely crystalline; thin-bedded; low porosity and permeability; moderately fossiliferous (brachiopods including Hesperorthis truncaria, bryozoa, planispirally-coiled gastropods, ostromacodes) with rod-like calcite growths filling brachiopod shells; This unit contains black, thinly-laminated shale. 140.0 13.0

Limestone, dolomitic and argillaceous; gray (N5); fine to medium-sized crystals (salt-and-pepper texture); thin-bedded; low porosity and permeability; very sparingly fossiliferous. In this unit, white dolomite crystals are surrounded by a darker argillaceous limestone matrix. 153.0 3.5
Limestone, argillaceous; gray (N7) to dark gray (N5 to 6B 5/1 or 5YR 6/1); finely crystalline; thin-bedded; low porosity and permeability; fossiliferous (Brachiopods and crinoid stem fragments).

Interbedded argillaceous limestone and calcareous shale; Limestone, argillaceous; gray (N7); finely crystalline; thin-bedded (\(\frac{3}{4}-1\) inch layers); low porosity and permeability; moderately fossiliferous (brachiopod and crinoid stem fragments).

**Thickness of the Bony Falls Formation** 60.0

<table>
<thead>
<tr>
<th>Depth</th>
<th>Thickness</th>
</tr>
</thead>
<tbody>
<tr>
<td>156.5</td>
<td>13.6</td>
</tr>
<tr>
<td>170.1</td>
<td>12.9</td>
</tr>
</tbody>
</table>

**MCFARLAND FORMATION**

Dolomite, calcareous; buff (5YR 5/4); finely crystalline; medium-bedded; low porosity and permeability; fossil ghosts (brachiopod and crinoid stem fragments).

**Trenary Formation**

This unit is named for exposures south of Trenary, Alger County, Michigan. The type section of the Trenary is here designated as those exposures in the bed of the West Branch Whitefish River just east of U.S. Highway 41 bridge in the NW\(^1\)/4, NE\(^3\)/4, Sec. 30, T. 44 N., R. 21 W., Alger County, Michigan. At this locality, 20 feet of argillaceous, dark blue-gray, thin-bedded limestone with thin shale partings is exposed. These strata rest upon a medium- to thick-bedded calcareous dolomite that forms the river bed. These strata are the uppermost beds of the Bony Falls Formation. The contact between these units is sharp, but again, the evidence that it
is an erosion surface is equivocal.

The conodont fauna in the lower dolomites contains several of the so-called "fibrous" form-genera such as Erismodus, Polycaulodus, Trucheronognathus, and Curtognathus. These forms are very rare in the overlying Trenary and younger strata. The lowermost beds of the Trenary contain the Phragmodus undatus assemblage that does not occur in the underlying dolomites.

**TYPE SECTION OF THE TRENARY FORMATION IN THE NE 1/4, NE 1/4, SEC. 30, T. 44 N., R. 21 W., ALGER COUNTY, MICHIGAN, ON THE SOUTH BANK OF THE WEST BRANCH WHITEFISH RIVER JUST EAST OF U.S. HIGHWAY 41.**

<table>
<thead>
<tr>
<th>Thickness (Feet)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ESCANABA GROUP</strong></td>
</tr>
<tr>
<td><strong>TRENARY FORMATION</strong></td>
</tr>
<tr>
<td>Limestone, argillaceous; buff (10YR 5/2) to gray (N7); thin, wavy beds with thin shale partings; low porosity and permeability; sparsely fossiliferous.</td>
</tr>
<tr>
<td>Limestone, argillaceous; blue-gray (5B 4/1-5/1) to dark blue gray (5PB 5/2-6/2); very finely to finely crystalline; thin-bedded (1/4-1 inch) with 1/4-1/2 inch shale partings; low porosity and permeability; some layers are very fossiliferous, containing Hesperorthis trincenaria, Strophomena filiformis, and other brachiopods, Craniops, and other trilobite fragments, bryozoa (Rhynocephalus?), and crinoid stem fragments.</td>
</tr>
<tr>
<td>Total Trenary Formation</td>
</tr>
</tbody>
</table>

| **BONY FALLS FORMATION** |
| Dolomite, calcareous; buff (10YR 6/2) to dark blue gray (5PB 6/2); finely to coarsely crystalline; medium-bedded; low porosity and permeability with some vuggy porosity; some thin, argillaceous partings but generally massive in appearance; some fossil ghosts with sparry filling; abundant pyrite. | 2.0 |
| Total thickness of the section | 19.0 |
The Bony Falls-Trenary contact is also exposed along the West Branch Whitefish River in the NE\(^1\), SE\(^1\), Sec. 21, T. 44 N., R. 21 W., Alger County, Michigan, about 1,000 yards north of the Delta County line. This locality is included as a reference section. Seven feet of calcareous dolomite are overlain by five feet of argillaceous limestone. Again, the contact is a sharp one and the change from the "fibrous" conodont fauna in the dolomite to the Phragmodus undatus fauna in the limestone is abrupt and occurs at the contact.

In the summer of 1966, a natural gas pipeline was laid across the Whitefish River at this locality and a trench excavated in the south valley wall exposed a 65-foot sequence of argillaceous limestones. Loose rock from the trench piled over the pipe as fill serves as evidence of the section below.

**PRINCIPAL REFERENCE SECTION FOR THE TRENARY FORMATION IN THE VALLEY OF THE WEST BRANCH WHITEFISH RIVER 1,000 YARDS NORTH OF THE DELTA-ALGER COUNTY LINE IN THE NE\(^1\), SE\(^1\), SEC. 31, T. 44 N., R. 21 W., ALGER COUNTY, MICHIGAN**

<table>
<thead>
<tr>
<th>Thickness (Feet)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ESCANABA GROUP</strong></td>
</tr>
<tr>
<td><strong>TRENARY FORMATION</strong></td>
</tr>
<tr>
<td>Limestone, argillaceous; buff (10YR 6/2) to dark blue-gray (5PB 6/2); finely crystalline; thin-bedded with thin, gray, wavy shale partings; sparsely fossiliferous.</td>
</tr>
<tr>
<td>Limestone, argillaceous; dark blue-gray (5PB 6/2); finely crystalline; thin-bedded (1/4-1 inch layers) separated by thin, wavy calcareous blue shale partings; low porosity and permeability; moderately to abundantly fossiliferous (brachiopods, bryozoans, crinoid stem fragments); This unit is very shaly at the</td>
</tr>
</tbody>
</table>
base and becomes less shaly upward. The blue shale gives the rock an over-all blue cast which causes local residents to refer to it as the "blue rock."

Total Trenary Formation

<table>
<thead>
<tr>
<th>Thickness (Feet)</th>
</tr>
</thead>
<tbody>
<tr>
<td>61.0</td>
</tr>
</tbody>
</table>

**BONY FALLS FORMATION**

Dolomite, calcareous; dark blue-gray (5PB 6/2); fine to medium-sized crystals; medium-bedded (1-6 inch beds) with some wavy argillaceous partings; low intergranular porosity, but there are numerous small vugs at the upper contact, low permeability; sparingly fossiliferous (orthocerid cephalopods are very abundant in a layer 2-3 feet below river level.

Total thickness of the section

<table>
<thead>
<tr>
<th>Thickness (Feet)</th>
</tr>
</thead>
<tbody>
<tr>
<td>79.0</td>
</tr>
</tbody>
</table>

The majority of this section was exposed by trenching operations during the laying of a natural gas pipeline across the river at this point. It is now largely covered over, but loose blocks may be seen piled about the edge of the stream and uphill on both banks of the stream.

The upper contact of the Trenary Formation with the overlying Chandler Falls Formation is not exposed at any of these localities. In order to study the upper contact relationships, one must consult the Perkins #2 core that is kept by the Geological Survey Division of the Michigan Department of Conservation.

This contact, like the previous two, consists of a sharp break between a lower medium- to thick-bedded dolomite and an upper thin-bedded, argillaceous limestone with thin shale partings. This lithologic change occurs at a depth of 55 feet near Perkins, Delta County, Michigan, but the contact has not been identified at the surface. The lower contact between the Bony Falls and the Trenary formations occurs at a depth of
123 feet near Perkins. The exposures in the Trenary region are thus correlated with the interval between 123 feet and 55 feet in the Perkins #2 core on the basis of lithologic similarity, stratigraphic position, and faunal content. There is an abrupt change from the "fibrous" forms to the Phragmodus undatus fauna at 123 feet in the core also. The lower part of the Trenary is composed of argillaceous limestones with thin shale partings, argillaceous dolomites and one thin sandstone bed at 83-83.5 feet. The upper beds of the Trenary are composed of alternating beds of limestones and medium- to thick-bedded dolomites. The uppermost unit of the Trenary is composed of six feet of fine-grained, poorly-bedded dolomite with vuggy porosity. This dolomite is overlain by more argillaceous limestone and shale.

PRINCIPAL REFERENCE SECTION FOR THE TRENAKY FORMATION FROM THE PERKINS #2 CORE DRILLED IN THE SW¹/₄, SEC. 25, T. 42 N., R. 22 W., DELTA COUNTY, MICHIGAN.

<table>
<thead>
<tr>
<th>Vertical Thickness</th>
<th>Depth (Feet)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ESCANABA GROUP</td>
<td></td>
</tr>
<tr>
<td>CHANDLER FALLS FORMATION</td>
<td></td>
</tr>
<tr>
<td>Limestone; greenish-gray (5GY 6/1); finely crystalline; thin-bedded; low porosity and permeability; fossiliferous; abundant sulfide mineralization; rose quartz fragments are abundant.</td>
<td>53.0 2.0</td>
</tr>
</tbody>
</table>

<p>| TRENARY FORMATION | |
| Dolomite, calcareous and argillaceous; gray (N5); medium to coarse crystals; fair vuggy porosity (some vugs are 5 mm. long and 0.5 mm. wide and lined by dolomite crystals); fair permeability; cut by thin argillaceous bands; unfossiliferous. | 55.0 6.0 |</p>
<table>
<thead>
<tr>
<th>Description</th>
<th>Depth</th>
<th>Thickness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Limestone, argillaceous; greenish-gray (5GY 6/2); finely crystalline; thin-bedded; low porosity and permeability; fossiliferous (brachiopod, crinoid stem and fish plate? fragments).</td>
<td>61.0</td>
<td>4.5</td>
</tr>
<tr>
<td>Dolomite, calcareous; buff (10YR 6/2); medium-sized crystals; fair intergranular porosity, low permeability; massive.</td>
<td>65.5</td>
<td>2.5</td>
</tr>
<tr>
<td>Limestone, argillaceous; gray (N7); finely-crystalline; low porosity and permeability; thin, wavy shale partings, thin, wavy beds (½-1 inch); recrystallized fossil ghosts with sparry filling; some pyrite present.</td>
<td>68.0</td>
<td>4.0</td>
</tr>
<tr>
<td>Dolomite, argillaceous; gray (N5); medium-sized crystals; thin-bedded; low porosity and permeability; some fossil ghosts with thin argillaceous wavy streaks.</td>
<td>72.0</td>
<td>1.0</td>
</tr>
<tr>
<td>Limestone, argillaceous; greenish-gray (5GY 6/2); finely crystalline; thin-bedded; low porosity, fair permeability; fossiliferous (brachiopods and bryozoa); Cut by thin argillaceous wavy bands with lineation of platy shale particles.</td>
<td>73.0</td>
<td>4.5</td>
</tr>
<tr>
<td>Dolomite, calcareous and argillaceous; gray (N5); medium to coarse crystals; vuggy porosity (with vugs up to 10 mm. in diameter); some brachiopod fragments and subrounded, frosted sand grains.</td>
<td>77.5</td>
<td>1.5</td>
</tr>
<tr>
<td>Shale, calcareous; blue-gray (5B 5/1); low porosity and permeability; some floating, subrounded and frosted sand-sized quartz particles.</td>
<td>79.0</td>
<td>1.5</td>
</tr>
</tbody>
</table>
Limestone, argillaceous; greenish-gray (5GY 6/2); finely crystalline; thin-bedded; low porosity and permeability.

Dolomite; buff (10YR 6/2); finely crystalline; medium-bedded; low porosity and permeability.

Sandstone, calcareous; white (N8); medium-grained; subrounded to subangular; fragmental; good porosity and permeability; Sand-sized quartz grains are frosted; This rock is 99% quartz with minor calcite cement. A few of the sand-sized quartz grains are amethyst.

Dolomite; buff (10YR 6/2); finely crystalline; low porosity and permeability.

Limestone, argillaceous; gray (N6) to bluish-gray (5B 5/1); finely crystalline; thin-bedded (½-1 inch beds); low porosity and permeability; moderately fossiliferous (brachiopods and bryozoa); some beds contain limestone nodules (intraclasts) in a very wavy, contorted argillaceous limestone matrix.

Dolomite, calcareous; gray (N5) with buff (10YR 6/2) nodules; finely crystalline; thin-bedded with some shaly bands; low porosity and permeability.

Limestone, argillaceous; gray (N5); finely crystalline; thin, wavy beds with inter-bedded shale layers; low porosity and permeability; fossiliferous (brachiopods and bryozoa).

Total Ternary Formation 68.0

BONY FALLS FORMATION

Dolomite, calcareous; buff (10YR 6/2); finely crystalline; medium-bedded; massive; contains occasional floating sand-sized quartz grains; abundant pyrite near upper contact.
The Trenary Formation is 68 feet thick near Perkins. It is a distinctive stratigraphic unit due to its color and texture. Although it superficially resembles most of the other argillaceous limestone strata scattered throughout the Escanaba Group, the limestones can be readily distinguished in outcrops from the others. Hussey's correlation of these strata with the "conglomerate zone" at Chandler Falls is erroneous.

Chandler Falls Formation

The term "Chandler Falls member" was proposed by Hussey (1952) for strata exposed at the hydroelectric dam on the Escanaba River near Chandler Falls in the SE¹, NW², Sec. 25, T. 40 N., R. 23 W., Delta County, Michigan. This exposure is the most typical of this interval and is designated as the type section of the Chandler Falls Formation. Unfortunately, neither the top nor the bottom contact is exposed at this locality.

A blue-gray calcareous shale with interbedded thin, fossiliferous limestone comprises the lower strata at this locality. These beds grade upward into thin-bedded argillaceous limestone and thin, wavy shale seams. The upper strata are thin- to medium-bedded with relatively fewer shale seams. Many of the beds contain abundant brachiopod, pelecypod, gastropod, cephalopod, crinoid and bryozoan fossils.

The lower contact of this formation has not been identified in outcrop, but based on the thickness of the exposures
at the type locality and the thickness of the Chandler Falls in the Perkins #2 core, it is probably not far below the level of the river.

TYPE SECTION OF THE CHANDLER FALLS FORMATION IN THE SE$\frac{1}{4}$, NW$\frac{1}{4}$, SEC. 25, T. 40 N., R. 23 W., DELTA COUNTY, MICHIGAN.

Thickness (Feet):

ESCANABA GROUP

CHANDLER FALLS FORMATION

Limestone, argillaceous; buff (10YR 6/2) to gray (6N); finely crystalline; thin, wavy beds (1/2-4 inches); fair porosity and permeability; fossiliferous (Maclurites cuneata, Plectorthis plicatella trentonensis, and crinoid stem fragments are particularly abundant).

Limestone, argillaceous; buff (10YR 6/2) to greenish-gray near base (5GY 6/1) to gray (N6); finely crystalline; thin, wavy beds (1/2-2 inches) but forming a more massive cliff face than the units above or below; medium to low porosity and permeability; fossiliferous (Maclurites sp., Prasopora spp., Sowerbyella sericea, Streptelasma corniculum, other brachiopods, and some ostracodes?); This unit forms a prominent overhang due to the erosion of the more shaly and less resistant bed underlying it.

Limestone, argillaceous; blue-gray (5B 7/1) to gray (N7) or greenish-gray (5GY 6/1); very finely crystalline; thin, wavy beds (1/2-2 inch) separated by thin shale partings; low porosity and permeability; abundantly to moderately fossiliferous (Strophomena filiformis, Plectorthis plicatella trentonensis, other brachiopods, crinoid stem fragments, and nautiloid cephalopods are very abundant).

River level — River levels were rather high during the field seasons that the writer collected this locality. Both Hussey (1952) and Templeton and Willman (1963) have described strata lying stratigraphically lower than those described in this report. The following description is modified from Templeton and Willman (1963, p. 185).
TRENARY FORMATION
Limestone, dolomitic, calcarenitic, conglomeratic, argillaceous and shaly.

Shale, calcareous; blue-green; in very thin, irregular beds; abundant Prasopora oculata Foord, P. selwyni (Nicholson), P. simulatrix Ulrich, and many other bryozoans.

Limestone, very argillaceous and shaly; gray-green; thin-bedded chert band at base.

Total thickness of the section 48.75

The upper contact of the Chandler Falls Formation is exposed about one-half mile south of the type section in a cliff on the west side of the Escanaba River in the SW\(^4\), SW\(^4\), Sec. 25, T. 40 N., R. 23 W. The contact between the Chandler Falls and the overlying Groos Quarry Formation is here taken as the top of a medium- to thick-bedded dolomitic limestone nine feet above the base of the cliff. An argillaceous, sublithographic limestone with thin shale partings succeeds this unit. The sublithographic limestone is an excellent marker bed locally.

PRINCIPAL REFERENCE SECTION FOR THE UPPER CHANDLER FALLS FORMATION AND THE LOWER GROOS QUARRY FORMATION ALONG THE WEST BANK OF THE ESCANABA RIVER ONE-HALF MILE SOUTH OF THE CHANDLER FALLS TYPE SECTION IN THE SW\(^4\), SW\(^4\), SEC. 25, T. 40 N., R. 23 W., DELTA COUNTY, MICHIGAN.

ESCANABA GROUP

GROOS QUARRY FORMATION
Limestone, argillaceous; gray (N7); very finely crystalline (sublithographic); thin, wavy beds (½-1 inch) with thin shale partings; fossiliferous (mainly crinoid stem fragments and small brachiopods); this unit forms a prominent overhang.
CHANDLER FALLS FORMATION
Limestone, dolomitic; buff (10YR 6/2) to blue-gray (5B 6/1); thin- to medium-bedded with some thin shale partings. This layer is generally massive and resistant.

Limestone, argillaceous; blue-gray (5B 6/1) to buff (10YR 6/2); thin-bedded (1/8-1 inch) with wavy shale partings; relatively non-resistant; the uppermost layer contains a packed bioclastic debris (fossil hash). These beds are identical to the upper strata at the Chandler Falls type section.

Total thickness of the section 15.0

About 45-50 feet of strata that are correlated with the Chandler Falls and Groos Quarry formations are exposed on both sides of Delta County Road 535 about one-mile north of the village of Bark River, Delta County, Michigan, in the NW\(^2\), NW\(^4\), Sec. 5, T. 38 N., R. 24 W. It is an excellent reference section for the upper part of the Chandler Falls. The lower part of this roadcut consists of argillaceous limestone with thin, wavy shale partings. This is succeeded by 30 feet of argillaceous limestone with relatively less shale.

PRINCIPAL REFERENCE SECTION FOR THE UPPER CHANDLER FALLS FORMATION AND THE LOWER GROOS QUARRY FORMATION ONE MILE NORTH OF BARK RIVER ALONG DELTA COUNTY ROAD 535 IN THE NW\(^2\), NW\(^4\), Sec. 5 AND THE E\(^4\), NE\(^4\). Sec. 6, T. 38 N., R. 24 W., DELTA COUNTY, MICHIGAN.

ESCANABA GROUP
GROOS QUARRY FORMATION
Limestone; gray (N7-N8); very fine-grained (sub-lithographic); thin, wavy beds (1/4-3 inches); conchoidal fracture; low porosity and permeability; moderately fossiliferous (brachiopod valves and crinoid stem fragments); pyrite.
CHANDLER FALLS FORMATION

Dolomite, calcareous; buff (10YR 6/1); finely crystalline (saccharoidal); medium-bedded (2 inches to 1 foot thick); massive appearance in outcrop; low porosity and permeability; sparingly fossiliferous.

Limestone, argillaceous; buff (10YR 6/1) to gray (N6); finely crystalline; thin, wavy beds with interbedded shale; low porosity and permeability; moderately fossiliferous. This unit becomes increasingly argillaceous toward the base and is generally massive in appearance. Several thin layers (1/2-1 inch) made up of packed bioclastic debris (mainly crinoid stem fragments) occur in this unit.

Limestone, argillaceous; buff (10YR 6/1), gray (N6); or purplish gray (5RP 5/2); finely crystalline; thin-bedded (1-2 inches) with interbedded blue-gray (5B 6/1) shale; low porosity and permeability. This unit is much less resistant to weathering than the overlying unit. The limestone beds are nodular in appearance and are moderately fossiliferous.

Total thickness of the section 46.0

A four-foot calcareous dolomite overlies these strata and they are succeeded in turn by an argillaceous, sublithographic limestone. The top of the dolomitic limestone is here described as the contact between the Chandler Falls and the Groos Quarry formations.

These exposures are correlated with the interval between 55 and 26 feet in the Perkins #2 core. The lower beds of the core are composed of argillaceous limestones, argillaceous and calcareous dolomites and a calcareous dolomite bed between 26-28 feet.
PRINCIPAL REFERENCE SECTION FOR THE CHANDLER FALLS FORMATION
FROM THE PERKINS #2 CORE DILED IN THE SW\(\frac{1}{4}\), SEC. 25, T. 42 N.,
R. 22 W., DELTA COUNTY, MICHIGAN.

<table>
<thead>
<tr>
<th>Vertical Depth (Feet)</th>
<th>Thickness (Feet)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ESCANABA GROUP</td>
<td></td>
</tr>
<tr>
<td>GROOS QUARRY FORMATION</td>
<td></td>
</tr>
<tr>
<td>Limestone, argillaceous; gray (N7); very finely crystalline (sublithographic); thin- to medium-bedded (2 to 6 inches); low porosity and permeability; fossiliferous (brachiopod valve fragments, bryozoans); argillaceous wavy bands at intervals; abundant pyrite.</td>
<td>17.5</td>
</tr>
<tr>
<td>CHANDLER FALLS FORMATION</td>
<td></td>
</tr>
<tr>
<td>Dolomite, slightly calcareous; buff (10YR 7/2); medium-sized crystals; low intergranular porosity but numerous vugs 1 mm. in diameter are present, low permeability; very poorly fossiliferous; recrystallized, several argillaceous seams; some pyrite.</td>
<td>26.0</td>
</tr>
<tr>
<td>Limestone; buff (10YR 6/2); finely crystalline; low intergranular porosity but there is some fracture porosity, low permeability; moderately fossiliferous (brachiopod and crinoid stem fragments); some floating quartz and pyrite.</td>
<td>28.0</td>
</tr>
<tr>
<td>Limestone, argillaceous; buff (10YR 6/2); fine to medium-sized crystals; low porosity and permeability; moderately to abundantly fossiliferous (brachiopods including Strophomena filifera?, bryozoans, ostracods, crinoid stem fragments); This unit is cut by thin, wavy shale partings and is fusoidal.</td>
<td>38.5</td>
</tr>
<tr>
<td>Limestone; greenish-gray (5GY 6/1); finely crystalline; low porosity and permeability; fossiliferous (brachiopods, corals, trilobites?); abundant sulfide mineralization, notably pyrite; fragments of rose quartz are abundant.</td>
<td>53.0</td>
</tr>
<tr>
<td><strong>Total Chandler Falls Formation</strong></td>
<td><strong>29.0</strong></td>
</tr>
</tbody>
</table>
TRENARY FORMATION
Dolomite, calcareous and argillaceous; gray (N5); vuggy porosity; cut by thin argillaceous bands; unfossiliferous.

Vertical Depth Thickness
(Feet) (Feet)

55.0 6.0

Groos Quarry Formation

The term "Groos Quarry member" was proposed by Hussey (1952) for 38 feet of limestone exposed in the abandoned quarry at Groos in Delta County. These strata are designated as the Groos Quarry Formation in this report. The only change made in this report from Hussey's original article is in the designation of a lower contact. The lower 12 feet are composed of sublithographic limestone with thin wavy shale partings. The floor of the sump in the quarry lies just above the top of the Chandler Falls Formation.

The remaining 26 feet are composed of fossiliferous limestone with wavy shale partings and several thin beds composed of packed bioclastic debris (fossil hash). The upper boundary of the Groos Quarry Formation is not exposed in outcrop, but it is known that the uppermost limestone beds are in sharp contact with the overlying shales. More evidence from cores will be needed to determine how much of the Groos Quarry is eroded from the top of the type section.

The strata between 0-26 feet in the Perkins #2 core are correlated with the lower sublithographic limestone beds and the lower part of the succeeding limestones at the type section. A dolomite bed occurs between 12-17.5 feet in the
Perkins core, but equivalent strata at the type section contain only minor amounts of secondary dolomite.

**TYPE SECTION OF THE GROOS QUARRY FORMATION IN THE SW\(_{1/4}\), SEC. 1, T. 39 N., R. 23 W., DELTA COUNTY, MICHIGAN.**

<table>
<thead>
<tr>
<th>Thickness (Feet)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ESCANABA GROUP</strong></td>
</tr>
<tr>
<td><strong>GROOS QUARRY FORMATION</strong></td>
</tr>
<tr>
<td>Limestone; buff (10YR 6/2); thin-bedded (½-6 inch beds) but more regularly bedded and not as &quot;nodular&quot; as underlying units; fossiliferous (packed bioclastic debris of brachiopod and crinoid stem fragments).</td>
</tr>
<tr>
<td>Limestone; buff (10YR 6/2); finely crystalline; thin-bedded (pod- or lens-like bioclastic horizons); low porosity and permeability; The surface of this unit seems quite susceptible to recrystallization with very coarsely crystalline calcite forming on the surface as a crust.</td>
</tr>
<tr>
<td>Limestone; buff (10YR 6/2); finely crystalline; thin-bedded with minute laminations discernable in individual limestone beds; relatively less fossil material than in beds above or below.</td>
</tr>
<tr>
<td>Limestone; buff (10YR 6/2); finely crystalline; medium-bedded (6-inch to 1-foot beds) with wavy surfaces; packed bioclastic debris occurs in lens-like layers which do not persist laterally; At the top of this unit is a persistent layer of bioclastic debris about one inch thick.</td>
</tr>
<tr>
<td>Shale; greenish-gray (5GY 6/1); wavy-bedded.</td>
</tr>
<tr>
<td>Unconformity?</td>
</tr>
<tr>
<td>Limestone; gray (N7-N8); very finely crystalline (sublithographic); conchoidal fracture; thin-bedded with thin shale partings, wavy-bedded; low porosity and permeability; fossiliferous with many small crinoid and brachiopod fragments; The upper surface of this unit may be unconformable since there are features resembling interference ripple marks present. The</td>
</tr>
</tbody>
</table>
unit becomes more shaly toward the base.
Abundant pyrite.

Quarry floor

Total Groos Quarry Formation

Summary

The Escanaba Group is described as the carbonates that overlie the Lower Ordovician Prairie du Chien and underlie the Haymeadow Creek and Bill's Creek shales. Five formations are recognized. They are listed as follows:

**ESCANABA GROUP**
- Groos Quarry Formation ............... 40' +
- Chandler Falls Formation .............. 30-40'
- Trenary Formation .............. 60-70'
- Bony Falls Formation .............. 60'
- McFarland Formation .............. 60'

Total thickness ............... 250-270' +

This subdivision may be more practical for field mapping in the Escanaba area. This new nomenclature or some litho-stratigraphic subdivision should replace the terms "Black River-Trenton" that are now used for strata of this interval because these names have connotations of time in North America and because they cannot be traced from the type area in New York.
REFERENCES CITED

PART II

American Commission on Stratigraphic Nomenclature

Andrews, H. E.

Barnes, C. R.

Bergström, S. M. and W. C. Sweet

Branson, E. B. and M. G. Mehl

Cohee, G. V.

Etherington, R. L.

Fisher, D. W.
1962 Correlation of the Ordovician rocks in New York State. New York State Museum and Science Service, Map and Chart Series, no. 3 (chart and text).

Guldenzopf, E. C.

Hall, James
Hamblin, W. K.  

Hussey, R. C.  
1936 The Trenton and Black River rocks of Michigan.  

Hussey, R. C.  
1950 Ordovician rocks of the Escanaba-Stonington area.  

Hussey, R. C.  
1952 The Middle and Upper Ordovician rocks of Michigan.  

Jaanusson, Valdar  

Kay, G. M.  

Kay, G. M.  

Kay, G. M.  

Kesling, R. V., F. S. Crafts, D. G. Darby, K. E. Shubak and R. N. Smith  
Krumbein, W. C.

Lane, A. C.

LeRoy, L. W., ed.

Liberty, B. A.

Liberty, B. A.

Liberty, B. A.

Ostrom, M. E.

Ostrom, M. E.

Plumley, W. J., G. A. Risley, R. W. Graves, Jr. and M. E. Kaley
Prokopovich, Nicolas

Rominger, Carl

Schopf, T. J. M.

Sinclair, G. W.

Swann, D. H. and H. B. Willman

Templeton, J. S. and H. B. Willman

Webers, G. F.