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DEVONIAN CONODONTS AND STRATIGRAPHY OF SOUTHWESTERN ONTARIO

T.T. UYENO
P.G. TELFORD
B.V. SANFORD

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Institute of Sedimentary and
Petroleum Geology, Calgary

Authors' addresses:

Dr. T.T. Uyeno
Institute of Sedimentary and
Petroleum Geology
3303 - 33rd Street N.W.
Calgary, Alberta T2L 2A7

Dr. P.G. Telford
Ontario Geological Survey
77 Grenville Street
Toronto, Ontario M5S 1B3

Dr. B.V. Sanford
Geological Survey of Canada
601 Booth Street
Ottawa, Ontario K1A 0E8

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Preface

The Devonian rocks of southwestern Ontario have been studied since the mid-nineteenth century. Restricted megafaunas and complex changes in the aspects of the rocks, however, have prevented close correlation with rocks in Europe, and even with those in immediately adjacent New York State, the Devonian reference for eastern North America. Well-controlled conodont zonation and improved understanding of the complex relationship of the various rock units described in this report, have aided in overcoming many of these correlation problems. Such precise dating and correlation are essential for success in the currently renewed active search for petroleum deposits in this area. The study will also help refine calibration of the geological time scale in other parts of the world.

Ottawa, February, 1982

R.A. Price,
Director General,
Geological Survey of Canada.

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DEVONIAN CONODONTS AND STRATIGRAPHY OF SOUTHWESTERN ONTARIO

Abstract

A succession of Devonian strata, ranging in age from Pragian? to Famennian and possibly post-Famennian, occurs in southwestern Ontario. The Lower Devonian sequence comprises the sandstone of the Oriskany Formation (Pragian?), cherty dolomitic limestone of the Bois Blanc Formation (**robustus** Zone, and possibly equivalent to the **serotinus** Zone; Emsian), the bioclastic limestone of the Amherstburg Formation (possibly **serotinus** to **patulus** Zones; Emsian?) and the lithologically variable Lucas Formation. The latter two units form the Detroit River Group. The sandy limestone facies ("Columbus limestone"), developed within the Anderdon Member of the Lucas Formation, contains conodonts of the **patulus** Zone (undivided). Pending the final decision, the Lower-Middle Devonian boundary lies very close to the **patulus** Zone, and therefore to the Anderdon Member. In the Niagara Peninsula, New York nomenclature is applicable, and parts of the Onondaga Formation are recognized (in ascending order): Edgecliff, Clarence, and Moorehouse Members. The true relationship of the Onondaga and the Detroit River is still not entirely known.

At the base of the Middle Devonian sequence is the fossiliferous, micritic limestone of the Dundee Formation which lies disconformably on the Detroit River strata. Dundee conodonts are assignable to the **costatus costatus, australis** and **kockelianus** Zones, of Eifelian age. The overlying Hamilton Group, studied only in outcrop sections, includes the upper part of the Arkona Formation (shale), and the Hungry Hollow (shale and limestone), Widder (shale), and Ipperwash (limestone) Formations. The conodonts of this upper part of the Hamilton belong to the Lower **varcus** Subzone of Givetian age. The lower part of the Hamilton may possibly contain conodonts of the **ensensis** Zone, which straddles the Eifelian-Givetian boundary.

The Upper Devonian black shales of the Kettle Point Formation lie disconformably on the Ipperwash Formation. Kettle Point conodonts are assignable to the Middle **asymmetricus** Zone to possibly the **costatus** Zone (Winder, 1966), thus demonstrating that almost the entire Upper Devonian (ranging in age from early Frasnian to late Famennian) is represented in the subsurface.

The Devonian conodonts of southwestern Ontario were among the earliest to be studied in North America (Hinde, 1879; see also Bergström and Hansen, 1979). In the present study, one new species, **Icriodus hankae**, is introduced.

Résumé

Dans le sud-ouest de l'Ontario se trouve une succession de strates du Dévonien, allant du Pragien? au Famennien et peut-être jusqu'au post-Famennien. La succession du Dévonien Inférieur comprend le grès de la Formation d'Oriskany (Pragien?), le calcaire dolomitique à silex de la Formation de Bois Blanc (Zone **robustus** qui équivaut peut-être à la Zone **serotinus** – Emsien), le calcaire bioclastique de la Formation d'Amherstburg (probablement de la Zone **serotinus** à celle **patulus**; Emsien?) et la Formation de Lucas dont la lithologie est variable. Les deux dernières unités forment le Groupe de Detroit River. Le faciès de calcaire sableux ("calcaire de Columbus") qui s'est développé à l'intérieur du niveau d'Anderdon de la Formation de Lucas, contient des conodontes de la Zone **patulus** (non divisée). En attendant la décision finale, on pense que la limite entre le Dévonien Inférieur et Moyen est très proche de la Zone **patulus** et donc du niveau d'Anderdon. Dans la péninsule du Niagara, on peut appliquer la nomenclature de New-York et y reconnaître (par ordre ascendant), certaines parties de la Formation d'Onondaga: les niveaux d'Edgecliff, Clarence et Moorehouse. On ne connaît pas encore la relation exacte entre les formations d'Onondaga et de Detroit River.

À la base de la succession de roches du Dévonien Moyen se trouve le calcaire micritique à fossiles de la Formation de Dundee qui repose en discordance sur la strate de Detroit River. Les conodontes de Dundee appartiennent aux Zones **costatus costatus, australis** et **kockelianus** de l'Eifélien. Le Groupe d'Hamilton qui le recouvre n'a été étudié que dans les affleurements et comprend la partie supérieure de la Formation d'Arkona (schiste argileux) et les Formations de Hungry Hollow (schiste argileux et calcaire), de Widder (schiste argileux) et d'Ipperwash (calcaire). Les conodontes de cette partie supérieure du Hamilton appartiennent à la Sous-zone Inférieure **varcus** du Givétien. La partie inférieure du Hamilton contient peut-être des conodontes de la Zone **ensensis** qui chevauche la limite Eifélien-Givétien.

Les schistes argileux noirs du Dévonien Supérieur de La Formation de Kettle Point reposent en discordance sur la Formation d'Ipperwash. Les conodontes de Kettle Point retirés d'un puits, appartiennent à la Zone Moyenne **asymmetricus** et peut-être à la Zone **costatus** (Winder, 1966) ce qui démontre que presque tout le Dévonien Supérieur (du début du Frasnien à la fin du Famennien) est représenté dans le sous-sol.

Les conodontes du Dévonien de l'Ontario du sud-ouest sont parmi les premiers à être étudiés en Amérique du Nord (Hinde, 1879; voir aussi Bergström et Hansen, 1979). Dans cette étude, on a présenté une nouvelle espèce: **Icriodus hankae.**

DEVONIAN CONODONTS AND STRATIGRAPHY OF SOUTHWESTERN ONTARIO

INTRODUCTION

History of Previous Work

A detailed summary of the history of previous geological investigations of Devonian strata of southwestern Ontario was made by Best (1953, p. 4-12) in an unpublished thesis. Some of the more important aspects are mentioned below and also, where appropriate, throughout the text.

The geology of southwestern Ontario was initially described by Murray (1845, 1850, 1852). When dividing the Devonian, he applied the terms already in use by the State Geological Survey of New York. He recognized the following Devonian succession (in ascending order): Oriskany sandstone, Corniferous limestones, Hamilton group, and Portage and Chemung group.

Commencing in 1858, Billings (1858a, b, 1859, 1874, among others) described several fossils, many of which were illustrated by pencil drawings, from the Devonian of southwestern Ontario. The strata included the Oriskany sandstone, Onondaga and Corniferous limestones, and the Hamilton formation. Additional Devonian fossils were described and illustrated by Nicholson (1875, among others).

Murray's classification was followed by Logan (1863, p. 359-389), with additional detailed description and age assignment of each stratigraphic unit. Typical fossils from some of these units were illustrated. In Logan's usage, the Oriskany formation of Ontario encompassed the Oriskany sandstone, Caudagalli [Esopus] grit, and Schoharie grit of New York. The Onondaga limestone and Corniferous formation were grouped together under the name Corniferous formation. The Hamilton formation included the Marcellus shale, Hamilton group, and Tully limestone of New York. The Portage and Chemung group comprised the Genesee slates, Portage or Nunda group, and Chemung group; of these, only the Genesee was noted to have extended into Ontario. This unit is presently called the Kettle Point Formation.

Nattress (1902, 1912, among others) discussed the stratigraphy of Corniferous (Dundee) and the underlying Detroit River strata (referred to as Anderdon beds, Dolomitic limestone and Dolomite beds) in the Detroit River area. This initiated the introduction of Michigan stratigraphic terms into Ontario. In a footnote, Nattress (1912, p. 281) noted the correlation of the Corniferous formation of Ontario with the Dundee limestone of Michigan, Jeffersonville limestone of Indiana, Columbus limestone of Ohio, and the Onondaga limestone of New York.

The term Monroe formation of Michigan was introduced by Lane et al. (1909). The upper part of this unit, above the Sylvania sandstone, also termed the "Detroit River series" in the original definition, was considered to be late Silurian by Sherzer and Grabau (1909). The age of the "upper Monroe" was later revised to Devonian by Nattress (1912, p. 282) and subsequently by Stauffer (1916). Because the term Monroe spanned the Siluro-Devonian boundary, Williams (1919, p. 22) later adopted the alternate term "Detroit River" for the Devonian part of the sequence.

A series of summary reports and a paper by Stauffer (1911, 1912a, b, 1914) culminated in his important and extensive memoir published in 1915. As discussed under stratigraphy, Stauffer (1912b; 1915, p. 7) noted a basic age difference in clastic deposits of similar appearance, and subsequently distinguished them as the Oriskany and Springvale sandstones. Another important contribution made by Stauffer (1915, p. 8, 9) is the recognition of the Delaware [=Dundee] limestone, as a separate and distinct unit from the Onondaga limestone and the Hamilton group.

Stauffer and Williams (in Parks et al., 1913) presented descriptions of the Oriskany sandstone, Springvale sandstone, Onondaga limestone, and the Hamilton formation. Sites included in their guidebook were described in detail, accompanied with extensive faunal lists.

The stratigraphy and paleontology of the Dundee limestone, in its type area in southeastern Michigan, were described in detail by Bassett (1935). He concluded that the beds formerly designated as Onondaga in the quarry at Amherstburg (Station 29 herein), were more correctly assignable to the Dundee.

Caley (1940 to 1946), in a series of memoirs, presented a thorough documentation on the stratigraphy, age and paleontology, economic significance, and correlation of the Devonian strata in southwestern Ontario. He (1941, p. 49) introduced the term Norfolk formation, and later pre-Norfolk (1946, p. 33), which together encompassed the entire pre-Hamilton Devonian rocks. Following a study made by Landes et al. (1945), in which the term "Bois Blanc" was introduced, Caley (1947) revised the Ontario Devonian nomenclature and suggested that the succession is similar to that in the Mackinac Straits region of Michigan. The pre-Hamilton sequence thus read (in ascending order): Oriskany sandstone, lower Onondaga limestone (Bois Blanc formation), Detroit River limestone, and Dundee limestone.

Best (1953) essentially adopted the succession in Michigan, with the addition of the Columbus limestone. This name, with its origin in central Ohio, had already been introduced into Ontario by Ehlers and Stumm (1951) for the sandy limestone in the Ingersoll area (Station 13 herein). The unit is now known to be more correctly identified as a facies development within the Anderdon Member of the Lucas Formation.

Most of the key references published since 1953 are noted under Stratigraphy. These include the updating of the Paleozoic geology of the Windsor-Sarnia area by Sanford and Brady (1955). Hewitt (1960) and Hewitt and Vos (1972) published information on the economic value and briefly on the geology of the Devonian rocks of southwestern Ontario. Fagerstrom (1961a, b) documented the stratigraphy and fossils of the Formosa Reef Limestone, a reefal development in the Formosa area. Oliver (1966, 1976a) continued his studies on the stratigraphy and coral fossils of the Bois Blanc Formation and Onondaga Limestone in New York and adjacent parts of the Niagara Peninsula. The Devonian geology of Michigan and southwestern Ontario was concisely summarized by Sanford (1968), followed by an updated geological map that included the present study area (1969).

Liberty and Bolton (1971) studied the stratigraphy of Devonian rocks in the northern parts of the present area. They presented Best's (1953) nomenclature on the facies of the Detroit River Formation, and the lower and upper members of the Dundee Formation. The Ontario Geological

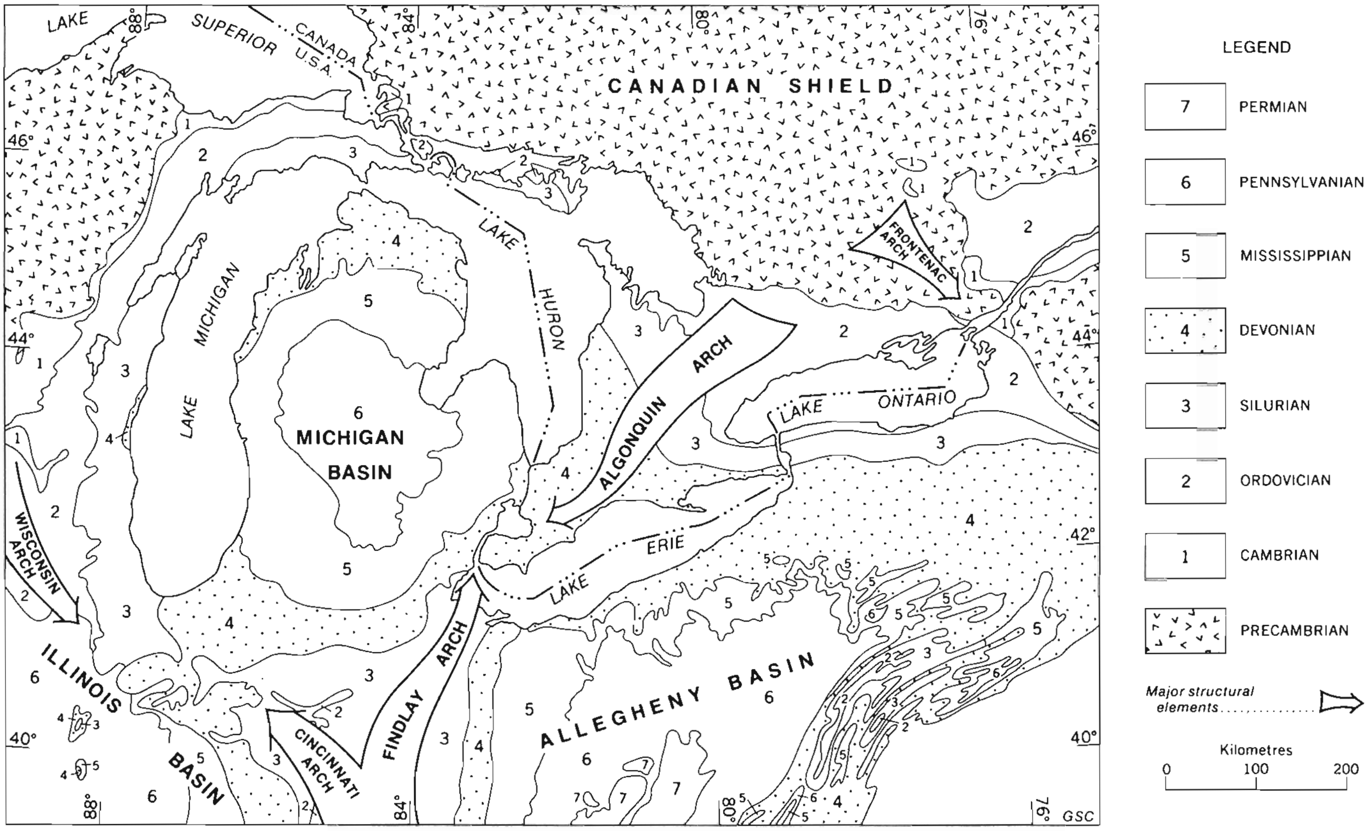

Figure 2. *Geological map of Great Lakes region of Canada and the United States.*

Survey initiated a detailed mapping project of the Devonian strata of southwestern Ontario, and two map-sheets have been published (Telford and Tarrant, 1975a, b).

Present Work

This study is the result of an extensive field program of collecting and mapping. Samples of Devonian rocks of southwestern Ontario were collected for conodonts by TTU in June 1966 (in company of BVS) and in June and July 1972. BVS has mapped the study area, and studied and documented numerous wells over a period of several years (Sanford, 1958, 1964, 1969). The accompanying geological map by BVS (Fig. 1 in pocket) is the updated synthesis of these earlier efforts. PGT has also mapped parts of the Niagara Peninsula on 1:50 000 sheets (Telford and Tarrant, 1975a, b), and is continuing the detailed mapping project.

TTU is responsible for all aspects of the conodont study, including biostratigraphy and systematic paleontology, the introduction, and for the overall coordination of the project. PGT wrote the part on regional and economic geology, and on physical stratigraphy. BVS provided the geological map and, in a combined effort with PGT, the regional correlation chart (Fig. 4).

Acknowledgments

Gratitude is expressed to the operators of the several active quarries that were visited during the course of field work. Special thanks are offered to J.A. Pearce of Allied Chemical Canada, Ltd. of Amherstburg, and to J.M. Plyley of Ridgemount Quarries Ltd., Stevensville. Mr. and Mrs. Keith Schweyer of Cheapside offered kind hospitality to TTU while collecting on their property.

A.R. Ormiston of Amoco Production Co., Tulsa, and A.E.H. Pedder of the Geological Survey of Canada, Calgary, identified some megafossils. L.R. Snowdon, also of the Geological Survey, conducted a carbon analysis of a sample from the Dundee Formation. B. Taylor, formerly of the University of Calgary, identified a few palynomorphs from some samples. C.G. Winder of the University of Western Ontario, London, made arrangements for the shipping of some conodont samples to Calgary.

P.H. von Bitter of the Royal Ontario Museum, Toronto, kindly provided TTU with facilities for examining the Telford et al. (1977) collections stored in that institution. C.B. Rexroad, Indiana Geological Survey, Bloomington, A.S. Horowitz, Indiana University, Bloomington, and S.M. Bergström, Ohio State University, Columbus, arranged for the loan of some specimens. W.C. Sweet, also of the Ohio State University, kindly loaned his copy of a thesis written under his supervision.

We have benefited greatly from reviews by A.W. Norris, Geological Survey of Canada, Calgary, and G. Klapper, University of Iowa, Iowa City. The latter also provided the use of a manuscript scheduled for publication prior to this paper. Discussions with J.G. Johnson, Oregon State University, Corvallis, D.C. McGregor, Geological Survey of Canada, Ottawa, and L.V. Rickard, New York State Museum and Science Service, Albany, have been helpful. Finally, TTU is deeply grateful to his wife, Anna, for assistance in the field in 1972.

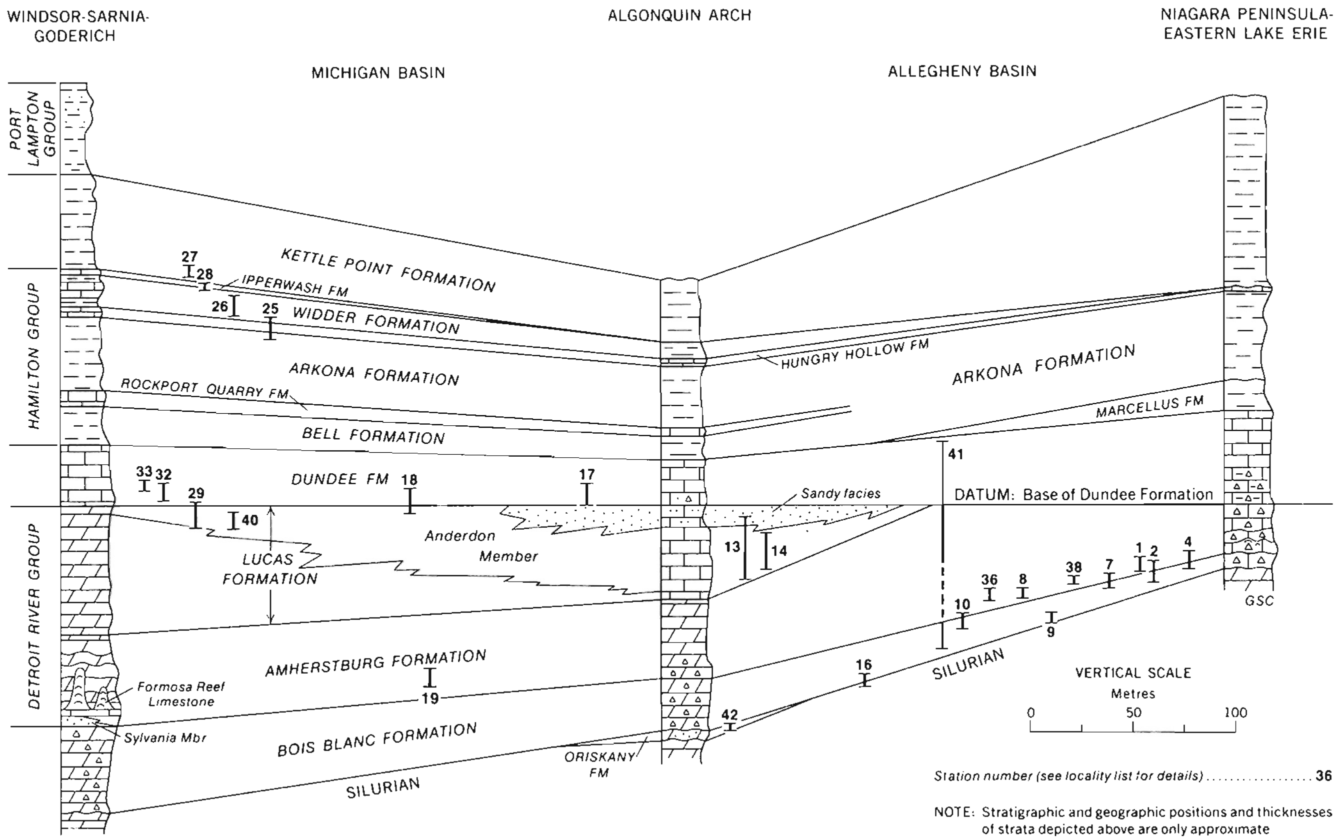

Figure 3. *Devonian succession of southwestern Ontario.*

REGIONAL AND ECONOMIC GEOLOGY

Devonian strata form the bedrock of approximately 40 000 square kilometres of southwestern Ontario (Fig. 1). They underlie the southern margin of the Niagara Peninsula bordering eastern Lake Erie and the entire southern Ontario peninsula southwest of a line extending from Hagersville in the southeast to Port Elgin on Lake Huron. Pelee Island in western Lake Erie is also underlain by Devonian rocks.

The Devonian platform sedimentary rocks of southwestern Ontario consist mainly of limestones and shales with minor dolostone and coarse-grained sandstones. They occupy a somewhat unique position in that the western and northern sequences were deposited on the edges of the Michigan Basin, whereas those in the eastern and southern areas accumulated in the Allegheny Basin (Fig. 2).

A broad Precambrian high, called the Algonquin Arch, trending southwesterly through the centre of the southern Ontario peninsula, separated the basins though it apparently never formed a complete barrier (Fig. 2). The Devonian strata have a gentle dip (5.5 to 8.5 m per km) toward the depocentres of the Michigan and Allegheny Basins. Cross-sections of Paleozoic strata parallel with, and perpendicular to, the Algonquin Arch have been given by Sanford (1969, and in Poole et al., 1970, Fig. 6-21, p. 284). There are numerous local reversals of the general dip that are often associated with bioherms or reefs in the Devonian units or collapse features due to salt solution of underlying Silurian units. Some normal faulting has been identified but it is of minor importance (Brigham, 1972).

Trending northerly and obliquely to the Algonquin Arch is the Findlay Arch, which extends through western Ohio, southeastern Indiana, and the extreme western regions of southern Ontario. In the study area, the two arches meet at right angles. The Chatham Sag, a locally developed broad depression, lies between the two arches, and Devonian strata within this structure are generally horizontal.

In central Michigan, the Devonian strata measure up to 1130 m thick. This thickness decreases to less than 305 m in southwestern Ontario, and then increases again into the Allegheny Basin (Sanford, 1968, p. 973). Around the margins of the basins the Devonian units have been truncated by pre-Pleistocene erosion.

The Devonian limestones and shales of southwestern Ontario are a very important source of raw materials for the construction, steel, and chemical industries. Usage and value of these materials were summarized by Goudge (1938), Hewitt (1960), and Hewitt and Vos (1972). Cherty limestones of the Bois Blanc and Onondaga Formations are quarried for crushed stone at numerous sites in the Niagara Peninsula region between Fort Erie and Hagersville (Hewitt, 1960; Hewitt and Vos, 1972). The Dundee Formation is quarried in the Port Dover area and on Pelee Island for crushed stone and is extracted at St. Marys for the manufacture of lime and portland cement. Near Woodstock, four large quarries extract extremely high purity limestone of the Lucas Formation for the manufacture of high calcium lime. Some of the product is used as a metallurgical flux in the steel industry at Hamilton, Ontario. The Lucas Formation is also quarried near Amherstburg for production of lime that is used locally in the manufacture of soda ash. Shale of the Arkona Formation is quarried at Thedford for the manufacture of brick and tile (Guillet, 1977).

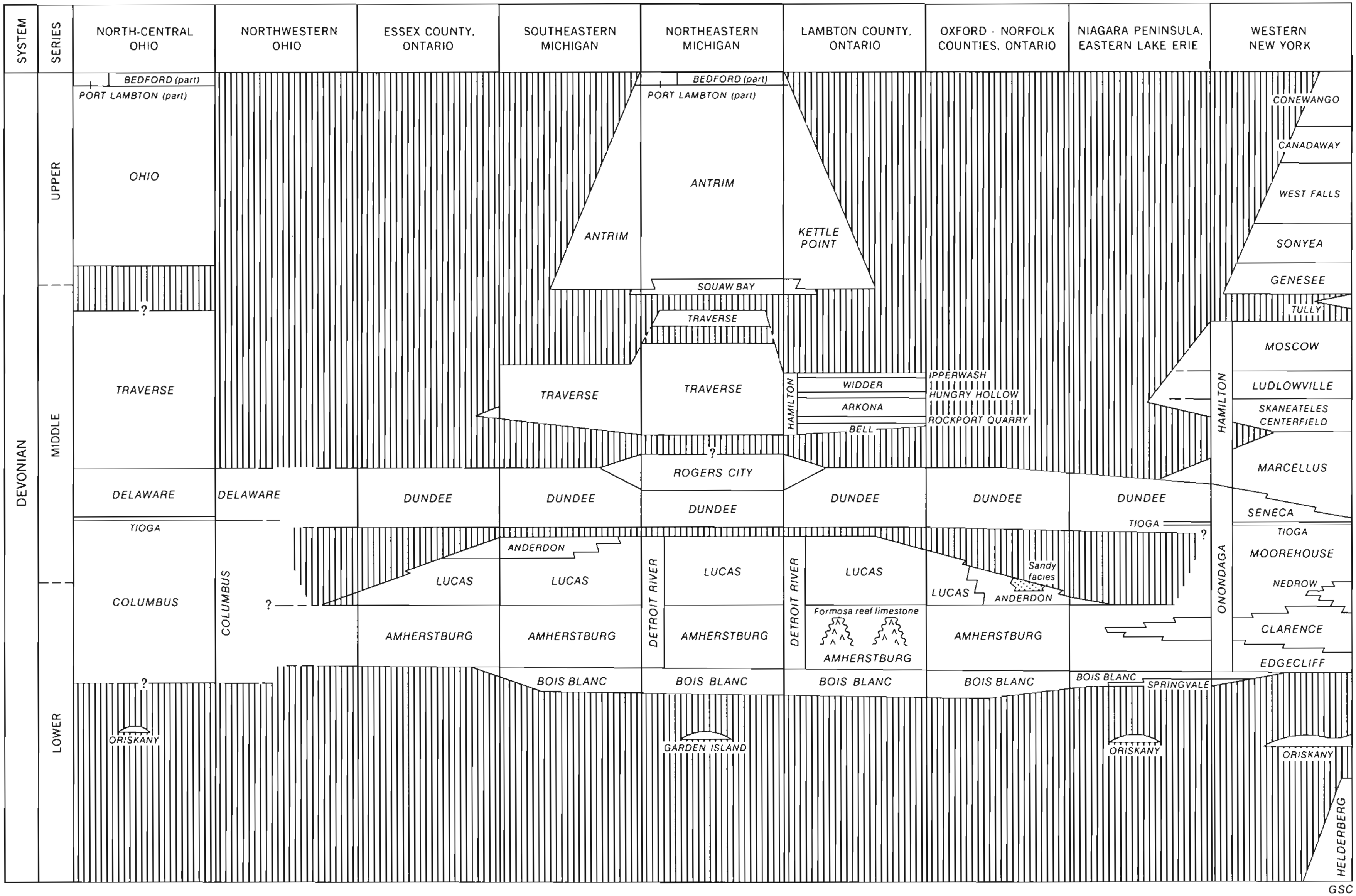

Figure 4. Formational nomenclature and correlation of the Devonian succession in southwestern Ontario and adjoining areas.

The North American petroleum industry began circa 1857 with the extraction of oil from Devonian strata in the Petrolia-Oil Springs area of Lambton County. Initial production was from shallow shafts extended to known oil seepages but, subsequently, many wells were drilled and production has continued to the present day. Since the early 1860's, more than 20 Devonian oil fields have produced over 40 000 000 barrels of 33° API gravity oil. Most of the production has been from locally dolomitized beds of the Lucas and Dundee Formations. Accumulation was apparently controlled by differential subsidence over areas where leaching had removed salt units from the underlying Upper Silurian Salina Formation. Sources and occurrences of oil and gas in southwestern Ontario, as well as in other sedimentary basins of the province, were summarized by Sanford (1962).

In adjoining Michigan, oil and gas production has been and still is being obtained from the Devonian succession of Lucas Formation through the Traverse Group (Matzkanin et al., 1978, Fig. 1), although since 1973 the principal source for both is the underlying Silurian strata (Ells et al., 1979, p. 59, 61). The Oriskany Sandstone has been the target in recent deep drilling programs carried out in Pennsylvania (King, 1979, p. 46).

PHYSICAL STRATIGRAPHY AND BIOSTRATIGRAPHY

Introduction

Strata deposited in the Michigan and Allegheny Basins are separated by a broad high, the Algonquin Arch (Fig. 2). Owing to this bilateral nature of Ontario rocks, problems of formational nomenclature are encountered and, in some cases, "hybrid" terminology is a common practice, e.g., the term Hamilton Group is of New York origin, but some of the formations within this unit, such as Bell and Rockport Quarry, are from Michigan (there, they are units within the Traverse Group). Although in most parts of the study area the stratigraphic terminology of the Michigan Basin is applicable, at least for the lower part of the Devonian succession, in the extreme easterly part, the Niagara Peninsula, New York terms are more appropriate (see Sanford, 1968, Fig. 3; Sanford and Norris, 1975, Fig. 7; Telford and Tarrant, 1975a, b). Winder and Sanford (1972, Figs. 2, and 12) carried the Michigan Basin terms Amherstburg, Lucas, and Dundee Formations throughout southwestern Ontario. One distinct advantage of this practice is that it provides a single uniform set of nomenclature. It is followed in the section dealing with conodont biostratigraphy. Unfortunately, the exact relationships of the two sets of terminology are not totally resolved and some of the problems are discussed under individual formations. The correlation of southwestern Ontario Devonian strata with adjacent areas is shown on Figure 4. The regional correlation of these rocks, based on conodont biostratigraphy, is shown on Figure 5.

The biostratigraphic significance of conodonts is discussed under the heading of individual stratigraphic units, and is summarized in the section on CONODONT STUDY. The sole exception to this is the brief mention at the end of these introductory remarks on the conodonts of the Upper Silurian Bertie Formation.

Tremendous advances have been made, especially in recent years, on conodont-based zonation of Devonian rocks. Many of these zones, established in classic areas including the Franco-Belgian Ardennes, Eifel Hills, Rhenish Schiefergebirge, and the Barrandian sections in Bohemia, are mondial in their applicability. Most of the literature pertaining to North America and Europe has been summarized by Klapper and Ziegler (1979). Some of the more recent studies include Mashkova (1978, 1979), Mashkova and Apekina (1978), and Apekina and Mashkova (1978) in the USSR; Bultynck (1970, 1975), Ziegler et al. (1976), Klapper (1977b), Klapper et al. (1978), and Weddige (1977) in central and western Europe; Klapper (1971, 1977a), Klapper et al. (1978), Sandberg and Poole (1977), Uyeno (1979), and Chatterton (1979) in North America; and Glenister and Klapper (1966) and Telford (1975) in Australia.

The Silurian-Devonian boundary was selected in the stratotype at Klonk near Suchomasty in the Barrandian (see Chlupáč and Kukal, 1977, and final report by McLaren, 1977). The Devonian-Carboniferous boundary, as yet unsettled, is currently under discussion by the Working Group on the Devonian-Carboniferous Boundary of the International Commission on Stratigraphy.

The placements of intra-Devonian boundaries are now being deliberated by the Subcommission on Devonian Stratigraphy, with plans to settle internationally acceptable definitions at the International Geological Congress in Paris in 1980. Some of the more contentious levels for the Lower-Middle and Middle-Upper Devonian boundaries have been summarized by Klapper et al. (1978, p. 107) and House and Ziegler (1977, p. 90, Fig. 4), respectively. For the Lower-Middle Devonian boundary, the three principal alternatives appear to be:

i) base of the **costatus costatus** Zone (near the base of the Choteč Limestone in Barrandian),

ii) base of the upper part of the **patulus** Zone (close to the Lauch-Heisdorf boundary in Eifel Hills), and

iii) base of the **Nowakia holynensis** Zone (close to the base of the **patulus** Zone and approximately near the base of the Couvinian in the Ardennes).

For the Middle-Upper Devonian boundary, the three contending levels are:

i) base of the **Pharciceras lunulicosta** Zone (doIα),

ii) base of the **hermanni-cristatus** Zone, and

iii) base of the Lower **asymmetricus** Zone (which coincides with the base of the Assise de Frasnes (F2) in Belgium).

It should be noted that a fourth alternative exists, the one that has commonly been accepted as the base of the Upper Devonian in western Canada, and that is the base of the **Pandorinellina insita** fauna, and which was regarded as coinciding with the base of the Lowermost **asymmetricus** Zone (see Norris and Uyeno, in press). More recently a new zone, the **dengleri** Zone, has been introduced as the North American equivalent of the European Lowermost **asymmetricus** Zone and, in this scheme, the **insita** fauna is an equivalent of the Upper **dengleri** Subzone (Klapper and Johnson, 1980). With respect to level (i), it should be further noted that in the Tully Limestone of New York, the base of the Upper **varcus** Subzone lies near the first occurrence of **Pharciceras amplexum** (Hall), and which was considered by House (1962, 1973) to indicate the base of the Upper Devonian in this area (Ziegler et al., 1976, p. 114).

As a consequence of the limitations imposed on the intra-Devonian boundaries as outlined above, it follows that in the discussions below and on the accompanying Figure 5 that the serial boundaries are indefinite, and that these boundaries are placed more as a convenient time framework for discussion than as endorsement of any particular level.

Correlation of Devonian strata in southwestern Ontario on the basis of conodonts is shown on Figure 5. The approximate stratigraphic and geographic positions of those sections sampled for conodonts are displayed on Figure 3.

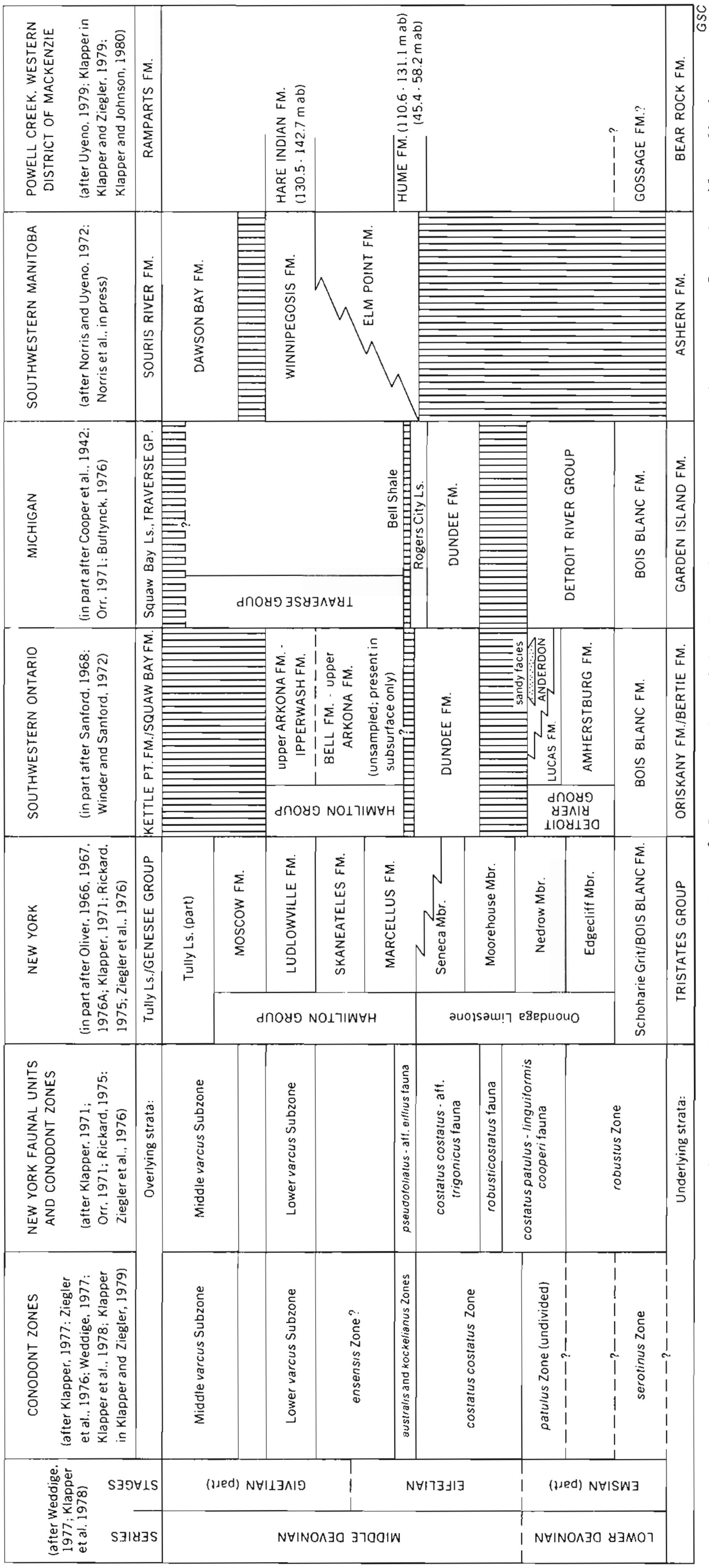

Figure 5. Conodont zonation and conodont-based correlation of Lower and Middle Devonian rocks in southwestern Ontario, New York, Michigan, southwestern Manitoba, and western District of Mackenzie. (ab=above base of formation).

Table 1 contains the summary of distribution of Devonian conodonts in the study area. More detailed information on the conodont distribution is given for each stratigraphic unit on Tables 2 to 8.

Authors' names of taxa are given only at their first mention. The zonal name-givers are quoted by their trivial names only, following the recommendation advocated by Klapper (1977a, p. 37).

The Upper Silurian Bertie Formation is briefly mentioned here as it, and its equivalent, the Bass Islands Formation, constitute the Silurian units on which the entire Devonian strata rest in southwestern Ontario. Only one sample (GSC loc. C-38901; Table 7) was collected from this stratigraphic unit. It yielded **Ozarkodina remscheidensis remscheidensis** (Ziegler), a species which, in central Nevada, spans from the uppermost **eosteinhornensis** Zone (of Klapper and Murphy, 1975, p. 19) of late Pridolian age, to **Ozarkodina** n. sp. D Zone (of Klapper, 1977a, p. 40-41) of Early Devonian age. The age of the Bertie Formation is well established as Late Silurian on other grounds (see, e.g., Sanford in Poole et al., 1970, p. 277).

Description of Formations

Oriskany Formation

Definition and Distribution

Vanuxem (1839) proposed the term Oriskany sandstone for the 6.1 metres (20 ft) of white quartz sandstone exposed at Oriskany Falls, Oneida County, New York. At this locality, the sandstone overlies limestone of the Silurian Manlius Formation. Murray (1845) first noted the sandstone in the Niagara Peninsula of Ontario. Stauffer (1915) showed that two sandstone units of slightly different age were present in Ontario, referring the older one to the Oriskany Formation and defining the younger unit as the Springvale sandstone member of the Onondaga (now partly Bois Blanc) Formation. However, neither Stauffer (1915) nor Caley (1940) was able to separate the sandstone units on their maps, and both showed the Oriskany as present from Fort Erie west to Hagersville. Subsequent studies (Best, 1953; Sanford, 1969; Telford and Tarrant, 1975a) have demonstrated that the Oriskany Formation may be identified with certainty at only one locality in Ontario, where it forms the bedrock of an approximately 600 hectare area, 10 km east of Hagersville. The reference section is in an abandoned quarry, lots 48-49, Concession II, Oneida Township, Haldimand County. Sanford (1968) suggested that the formation may be present elsewhere in the subsurface of southwestern Ontario but positive identification is not possible. Occurrences of the Oriskany Formation in Ontario represent erosional remnants of a unit that has wide distribution in the Allegheny Basin to the southeast, and which had its provenance in the Appalachian Basin. Maps showing the regional distribution of the Oriskany in eastern North America were compiled by Boucot and Johnson (1968b, Fig. 2) and Summerson and Swann (1970, Fig. 5).

TABLE 1

Summary of distribution of conodonts in the Devonian strata of southwestern Ontario

		CONODONTS	*Ozarkodina remscheidensis remscheidensis*	*Icriodus* sp. (a)	*Ozarkodina*? sp.	*Icriodus latericrescens robustus*	*Pandorinellina* ? sp. B	*Belodella* spp.	*Coelocerodontus* spp.	*Panderodus* spp.	cf. *Coelocerodontus* spp.	*Icriodus hankae*	*Icriodus* sp. (b)	*Polygnathus* sp. (a)	*Polygnathus linguiformis linguiformis*	*Icriodus* aff. *I. retrodepressus*	*P. costatus patulus* ⟶ *P. cooperi cooperi*	*Polygnathus costatus costatus*	*Polygnathus* cf. *P. costatus*	*Polygnathus intermedius*	*Polygnathus* aff. *P. trigonicus*	*Polygnathus* sp. (b)	*Parapolygnathus angusticostatus*	*Icriodus angustus*	*Icriodus* cf. *I.* sp. A	*Icriodus* sp. C	*Polygnathus* sp. (c)	*Polygnathus varcus* Group	*Icriodus difficilis*	*Icriodus latericrescens latericrescens*	*Polygnathus timorensis*	*Icriodus brevis*	*Icriodus obliquimarginatus*	*Oulodus* sp.	*Palmatodella quadrantinodosa quadrantinodosa*	*Palmatodella glabra glabra*
GROUP	FORMATION	MEMBER																																		
	KETTLE POINT																																		●	●
HAMILTON	IPPERWASH														●														●	●	●	●		●		
	WIDDER								●						●														●		●	●	●	●		
	HUNGRY HOLLOW							●	●	●	●				●	●												●	●	●						
	ARKONA														●	●											●	●	●	●						
	DUNDEE					●		●	●	●	●				●	●		●	●	●	●	●	●	●	●	●										
DETROIT RIVER	LUCAS	Anderdon (sandy ls.)				●		●								●	●																			
	LUCAS	Anderdon (ls.)													●	●																				
	LUCAS												●	●																						
	AMHERSTBURG	Formosa Reef Ls.							●			●																								
	AMHERSTBURG					●		●	●		●																									
	BOIS BLANC					●	●	●	●	●																										
	ORISKANY			●	●																															
SILURIAN	BERTIE		●																																	

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Lithology, Contacts, and Thickness

The Oriskany Formation consists of massive or thick-bedded, grey to yellowish white, coarse grained, friable sandstone. Quartz is the major detrital mineral; feldspar is a very minor constituent and subangular fragments of dolostone (reworked from underlying Silurian strata) are common in the lower part of the unit. The sand grains are well rounded, poorly sorted, and cemented by iron-rich silica.

The maximum, presently exposed thickness of the Oriskany, is 4.5 m. Stauffer (1915), who examined the sandstone when quarry operations were still active, reported a maximum thickness of about 6 m.

The Oriskany Formation disconformably overlies Silurian dolostone of the Bertie Formation. Sand grains are commonly present in cracks and joints of the upper part of this unit. At its reference locality, the Oriskany forms a shallow lensoidal body with margins disconformably overlapped by cherty limestone of the Bois Blanc Formation.

Fossils, Age, and Correlation

Fossils are abundant at some levels of the Oriskany Formation, preserved mostly as external moulds and steinkerns, with those of large, thick-shelled brachiopods being the most common. Stauffer (1915, p. 249-251) and Best (1953, p. 29, 30) provided detailed faunal lists.

The age of the Oriskany Formation was suggested as definitely Devonian by Stauffer (1915, p. 218), and as Early Devonian by Best (1953, p. 30). Genera of brachiopods in the Oriskany Sandstone occurring regionally in eastern North America were listed by Boucot and Johnson (1968b, Table 1), and were assigned to the **Rensselaeria** faunal unit, of Siegenian age. In terms of the Barrandian sequence, Johnson (1975, Fig. 2; 1979, Fig. 1) dated the Oriskany brachiopods as Pragian, equivalent to Intervals 7 and 8 of the Nevada scheme (Johnson, 1977, p. 21, 22, Fig. 2). Of the genera listed by Boucot and Johnson (op. cit.), the more diagnostic are **Costispirifer**, **Rensselaeria**, **Acrospirifer**, and **Hipparionyx**, according to Winder and Sanford (1972, p. 66). The Oriskany correlates with the Garden Island Formation of northern Michigan (Landes et al., 1945).

The conodont fauna in the Oriskany is sparse and the specimens are highly fragmented and pitted. From samples collected by PGT from the reference section cited earlier (GSC loc. C-80199; Station 42), some 9.7 kg of the sandstone were processed for conodont analysis. The collection includes the following (see also Table 7):

> **Icriodus** sp. (consisting of 6 specimens of I element, including a detached principal process, and 2 specimens of possibly acodinan (S_{2a}) element);
>
> **Ozarkodina**? sp. (consisting of 3 specimens of Pa (spathognathodontan? element) and a single M (neoprioniodontan) element).

Because the specimens are so fragmented, it is extremely difficult to identify them. One almost complete spindle of an I element is present in the collection. The shape of its denticles, the longitudinal spacing of lateral row denticles (more widely spaced apart anteriorly), and the fine interconnecting longitudinal and lateral ridges, as well as the rather short detached principal process, are somewhat like those features exhibited by specimens illustrated by Klapper and Johnson (1980, Pl. 2, figs. 18, 23, 24), and identified by them as **Icriodus** aff. **I. celtibericus** Carls and Gandl. The latter specimens are from the McColley Canyon Formation of Nevada and originate in the **kindlei** Zone of Lane and Ormiston (1979, p. 45).

Bois Blanc Formation

Definition and Distribution

The name Bois Blanc Formation was proposed by Landes and Ehlers (in Landes et al., 1945, p. 80) for a 110-m thick rock unit in northern Michigan which they described as "a Lower or Middle Devonian formation occupying a position between the Lower Devonian Garden Island formation, or the Upper Silurian St. Ignace formation where the Garden Island is absent, and the Lower or Middle Devonian Detroit River group". The type locality was selected on Bois Blanc Island, situated in Lake Huron, about 10 km east of the Straits of Mackinac.

Best (1953) applied the name Bois Blanc to strata in Ontario formerly referred to the lower part of the Onondaga (Stauffer, 1915; Caley, 1940). In the Niagara Peninsula area he used a broad definition of the unit (subsequently used by Hewitt, 1972) and included in it all Devonian strata lying between the Upper Silurian Bertie Formation or, where present, the Lower Devonian Oriskany Formation and the Middle Devonian Dundee Formation (=Best's (1953) Delaware Formation). In eliminating the names Onondaga and Detroit River from the Devonian sequence of the Niagara Peninsula, Best (1953) and Hewitt (1972) added to the confusion surrounding correlation of these Michigan Basin and Allegheny Basin units (see Oliver, 1967, 1976a for a history of this problem).

In western New York and the Niagara Peninsula of Ontario, Oliver (1967) limited the Bois Blanc Formation to the lower part of the interval defined by Best (1953). He suggested correlation of the remaining part of the interval with the Onondaga Limestone. Sanford (1969) also used a restricted definition of the Bois Blanc and correlated the strata lying between the Bois Blanc and Dundee Formations with the Amherstburg Formation of the Michigan Basin. Recent mapping in the Welland and Dunnville areas (Telford and Tarrant, 1975a, b) has confirmed the restricted definition of the Bois Blanc Formation in the Niagara Peninsula area. The designation of the immediately overlying strata is discussed later in this report.

Farther west, towards the Michigan Basin, the definition of the Bois Blanc Formation continues to be imprecise. There is no question that the overlying rock unit is referable to the Detroit River Group, but the boundary with the latter is poorly defined. Between Simcoe at the western end of the Niagara Peninsula and Port Elgin on Lake Huron, outcrops of the Bois Blanc Formation are sparse. Subsurface data provided by petroleum exploration activities are abundant but, as emphasized by Beards (1967), the Bois Blanc/Detroit River contact is difficult to pick lithologically or by using geophysical well logs, and is an unreliable marker horizon.

An additional complication in definition of the Bois Blanc Formation is the presence of sandstone in the lower part of the unit in the Niagara Peninsula and eastern Lake Erie region. Stauffer (in Parks et al., 1913; 1915) proposed the name Springvale Member for these sandstones which have their most extensive development in the Hagersville-Springvale area. However, the distribution of the sandstone or sandy limestones is very irregular and, in this report, they are treated only as an occasional sandy facies within the Bois Blanc Formation.

The Bois Blanc Formation forms the bedrock in a narrow belt extending west from Fort Erie through the southern part of the Niagara Peninsula to the vicinity of Hagersville, and thence northwest through Innerkip, Listowel, and Mildmay to Port Elgin on the shore of Lake Huron. Between Fort Erie and Hagersville the subcrop belt is only 0.5 to 2 km in width but outcrops of the formation are numerous as it forms the caprock of the discontinuous Onondaga Escarpment (Feenstra, 1974). Several quarries in the Hagersville, Dunnville, and Port Colborne areas also provide excellent exposures of the formation (Telford and Tarrant, 1975a, b).

Northwest of Hagersville the subcrop belt broadens gradually to a maximum of 18 km near Port Elgin. However, outcrops of the formation are very sparse and only a few limited sections can be seen near Innerkip, Gorrie, Cargill, and Pinkerton. In the subsurface the formation extends beneath the entire southwestern Ontario peninsula, the northern part of Lake Erie, and southern Lake Huron (Sanford, 1968, Fig. 5a).

Lithology, Contacts, and Thickness

The Bois Blanc Formation disconformably overlies the Bertie Formation or the Oriskany Formation. The nature of this contact was discussed in detail by Kobluk et al. (1977), who, as previously done by Sanford (1968, p. 979), noted two erosional surfaces: pre- and post-Oriskany Formation. With the removal of much of the Oriskany orthoquartzite during the post-Oriskany subaerial erosion, the glauconitic sandstone of the Springvale Member of the Bois Blanc Formation, is commonly found to rest on the dolomite beds of the Bertie Formation.

In the Niagara Peninsula region the formation varies in thickness from less than 3 m to about 15 m. To the west the thickness increases to as much as 50 m. Subsurface records show thickness variation over relatively short distances in the London-Sarnia and Goderich areas and this is attributed to solution effects on the underlying Silurian evaporitic sequences. The basal sandy facies of the Bois Blanc Formation is rarely greater than 3 m in thickness though Sanford (1968) noted subsurface reports in Kent County of local thicknesses in excess of 30 m. These are interpreted as deposits in solution cavities within Upper Silurian strata.

An abundance of chert and diversity of texture and composition characterizes the formation which consists mainly of cherty, dolomitic limestone with shale partings. The limestones are irregularly laminated, medium to thin bedded, greenish grey to light grey-brown, grey weathering, medium to fine grained, argillaceous or cleanly bioclastic. Coquinas of brachiopod and coral debris are developed locally. Light grey or brown chert is abundant as thin beds or nodules. Northwestwards, towards the Michigan Basin the limestones are gradually replaced by grey or grey-brown microsucrosic dolostone, and chert becomes less abundant.

Where developed, the basal sandy facies contains medium to coarse grained, greenish grey or white, poorly fossiliferous, calcareous, quartz sandstone with interbeds of green, glauconitic sandstone, sandy limestone, dolostone, and brown chert.

According to Hixon (1964), the silica in the chert was derived, in part, from quartz sand and silt grains, and siliceous organisms (mainly sponges). The silica was deposited initially around nucleation sites, mainly organic debris, and then enlarged by replacing surrounding carbonate. The formation of chert occurred subsequent to the deposition of the sediments, but prior to the calcite matrix lithification to a brittle solid. In contrast to this view, Liberty (in Liberty and Bolton, 1971, p. 59) suggested that vast quantities of silica were present in the marine waters probably in gel form, and that the deposition of the silica alternated with that of the carbonates. The silica gel was squeezed into fractures, and moved according to the varying conditions of load and slope, replacing fossils and other porous bodies. Where porous units were absent, the gel formed a mass parallel to the bedding. A variation of the latter hypothesis was favoured by Gardner (1974, p. 20, 23, 24), who also presented a summary of literature on the origin of chert in the Bois Blanc Formation in Ontario and Michigan.

The Bois Blanc Formation is an eastward thinning carbonate wedge. It can be considered basically as a Michigan Basin rock unit which spilled over the Algonquin Arch (the eastern margin of the Michigan Basin) and intertongued with clastic and limestone units of the Allegheny Basin. In Ontario, the Bois Blanc Formation disconformably overlies Upper Silurian dolostones of the Bertie and Bass Islands Formations or, where present, the Lower Devonian Oriskany Formation. In the Niagara Peninsula it is succeeded with possible disconformity by the Edgecliff Member of the Onondaga Formation. West of Hagersville it is overlain by the Amherstburg Formation of the Detroit River Group but, as noted earlier, contact relationships with this unit are uncertain.

The Bertie/Bois Blanc disconformity is particularly striking and, at some localities, the contact displays several metres of relief. Algal biohermal masses in the upper Bertie Formation may account for some of the irregular relief. The top of the Bertie Formation is a subaerial erosion surface and Kobluk et al. (1977) compared it with Pleistocene and Recent hardgrounds in the West Indies. They noted the presence of sandy sediments of the Oriskany and Bois Blanc Formations in solution widened joints on the Bertie surface. The occurrences of macroborings (possibly of polychaetes or sipunculids) and microborings (endolithic algae) into the Bertie surface were also described. Thus, the Bertie/Bois Blanc contact represents a long period of subaerial erosion on the shelf separating the Michigan and Allegheny Basins, and the Bois Blanc Formation represents a major marine transgression into this region.

Fossils, Age, and Correlation

Brachiopods and rugose corals are common in the Bois Blanc Formation, less common are tabulate corals, molluscs, and trilobites (Oliver, 1976a, p. 8). A composite floral and faunal list is given in Liberty and Bolton (1971, p. 133-134).

The coral faunas of the Bois Blanc Formation and Onondaga Limestone of New York were outlined by Oliver (1960, 1966, 1967, 1968). The distinctive Bois Blanc forms include **Aemulophyllum exiguum** (Billings) and **Acrophyllum oneidaense** (Billings). Subsequently, the same author (1976a) published a monograph which gives an extensive discussion on the noncystimorph colonial rugose corals of the Bois Blanc and Onondaga rocks in New York and adjacent areas, together with their paleobiogeographic and biostratigraphic significance. Owing to the endemic nature of the coral faunas, belonging to the Appohimchi Province of the Eastern Americas Faunal Realm (Oliver, 1976a, 1977a, b), a definite age assignment, in terms of European nomenclature, could not be made. Correlations are possible within the Realm, however.

The brachiopods of the Bois Blanc Formation of New York were studied by Boucot and Johnson (1968a, b), and were assigned to the **Amphigenia** faunal unit. The authors concluded that the age of these megafossils was Emsian, and possibly early Emsian. According to Oliver (1967, p. A6), the common brachiopods include **Acrospirifer duodenaria** (Hall), **Coelospira camilla** (Hall), **Centronella glansfagea** (Hall), and small specimens of **Amphigenia elongata** (Vanuxem).

Trilobites were found in the Bois Blanc Formation in a quarry near Cayuga (Station 9, GSC loc. C-38850; Table 2). According to A.R. Ormiston (pers. comm., Dec. 1974), these represent "...two articulated specimens of **Otarion (Maurotarion) minuscula** (Hall, 1876), a species which has been reported from decomposed chert boulders (which almost certainly means Bois Blanc) at North Cayuga, Ontario (Hall and Clarke, 1888, p. 142). This species has also been reported by Hall from the Schoharie Formation and Corniferous Limestone in New York State. Thus, its range is apparently not restricted to the Bois Blanc. The two articulated specimens are present side-by-side and suggest a low energy environment of deposition in the sample at hand".

Although agglutinated foraminiferans were found in the Bois Blanc strata at Innerkip (Station 16), the age of this unit was not further refined owing to lack of knowledge of Lower Devonian foraminiferal faunas (Conkin and Conkin, 1973, p. 37).

The Springvale Member at Hagersville, Ontario, is of Bois Blanc age, as indicated by the same distinctive coral fauna as in the overlying carbonates of the Bois Blanc Formation (Oliver, 1976a, p. 8). Boucot and Johnson (1968b, p. 1264) noted the presence of many Oriskany fossils in the Springvale Member, but that unit includes younger sandstones as well.

The distribution of conodonts in the Bois Blanc Formation is given on Tables 2 and 8. The low diversity Bois Blanc conodont fauna consists predominantly of **Icriodus latericrescens robustus** Orr. This is a long-ranging subspecies, and extends up to the Dundee Formation in southwestern Ontario (see Table 1). It has yet to be reported from Europe, and in New York and the Michigan Basin, it has a similar long range (Klapper and Ziegler, 1967; Orr, 1971, Fig. 4). Aside from the ubiquitous cones consisting of **Belodella**, **Coelocerodontus**, cf. **Coelocerodontus**, and **Panderodus**, the formation yielded a single fragmentary

TABLE 2

Distribution of conodonts in the Bois Blanc Formation

STATION NO.	GSC LOC. NO.	*Icriodus latericrescens robustus* (I:s)	*Icriodus latericrescens robustus* (I:i)	*Icriodus latericrescens robustus* (I:a)	*Icriodus latericrescens robustus* (S2)	*Icriodus latericrescens robustus* (M_2)	*Pandorinellina* ? sp. B (Pb)	*Belodella* spp.	*Coelocerodontus* spp.	*Panderodus* spp.	NOTE: *Icriodus latericrescens robustus*: fragmentary specimens that cannot be assigned to the three morphotypes are not listed.	INTERVAL ABOVE BASE OF FM. OR *BELOW TOP OF FM. (m)	WEIGHT (kg)
16	C-38902	5	38	12	17	17		6	8	12		0.0 - 0.30	4.0
	C-38903	7	81	36	2			1	10	1		0.30 - 0.61	4.0
	C-38904	10	109	25	5			17	22	4		0.61 - 1.04	4.0
	C-38905	1	20	7				1	1			1.04 - 1.34	4.0
	C-38906	2	28	5	1				1	1		1.34 - 1.77	4.0
	C-38907	2	55	5				1	1	1		1.77 - 2.23	4.0
	C-38908		38	3					1	1		2.23 - 2.68	4.0
	C-38909		7	1								2.68 - 3.20	4.0
	C-38910	1	12	2				1	2			3.20 - 3.60	4.0
	C-38911	1	5	1	1			1	1			3.60 - 3.90	4.0
4	C-38825		BARREN									0.46 - 0.64	2.0
	C-38826		BARREN									1.43 - 1.62	2.0
	C-38827		BARREN									2.23 - 2.32	1.9
	C-38828	2	2	1	1				1	1		3.08 - 3.23	2.0
	C-38829	4	4					46	1	4		3.87 - 4.02	2.0
2	C-38815		BARREN									0.0 - 0.27	4.0
	C-38816		BARREN									1.31 - 1.49	4.0
	C-38817	10	15	6	9				5	12		2.19 - 2.35	4.0
	C-38818	1	10	4	2					1		2.71 - 2.83	4.0
7	C-38838							1		1?		*1.71 - 1.86	4.0
	C-38839						1	3	1			1.01 - 1.16	4.0
	C-38840		1		2			9		1		0.21 - 0.34	4.0
9	C-38849	31			21			33	55	27		3.60 - 3.78	4.0
	C-38850	1			5	2		7	9	2		4.18 - 4.24	4.0
	C-38851	14			11	7		25	81	2		4.42 - 4.48	4.0
	C-38852	3	1		9	1		2	40	3		5.21 - 5.27	4.0
10	C-38853								1			0.34 - 0.58	4.0
	C-38854					1						1.13 - 1.25	4.0
	C-38855		BARREN									1.74 - 1.95	4.0
	C-38856	12	29	2	25	5		1	23	2		3.41 - 3.60	4.0
	C-38857	6	11	5	18	3			4	9		4.18 - 4.27	4.0
	C-38858	2	53	6	1							4.82 - 4.94	4.0

LEGEND: Simple .... s; Intermediate ...... i; Advanced .... a

GSC

specimen that may possibly be assignable to **Pandorinellina**, such as **P.** n. sp. A of Uyeno and Mason (1975). The Schoharie and Bois Blanc Formations of New York contain, in addition to **I. latericrescens robustus, I. huddlei** (Klapper and Ziegler, 1967, p. 67). That the Bellepoint Member of the Columbus Limestone of central Ohio correlates with the Bois Blanc and Schoharie is suggested by the common occurrence of these two same species (Ramsey, 1969). **Icriodus huddlei**, which is apparently absent in the equivalent strata in Ontario, is restricted to an interval that has been regarded as Lower Devonian elsewhere (Ziegler in Ziegler, ed., 1975, p. 118).

The Bois Blanc fauna is referable to the **robustus** Zone of Orr (1971) (see Rickard, 1975). The **Pandorinellina** n. sp. A fauna of Uyeno (1979), which occurs in the Gossage Formation at Powell Creek, western District of Mackenzie, and the **robustus** Zone, may be equivalent in part to the **serotinus** Zone of Weddige (1977; see Table 3 therein). The correlations of the sequence from the Bois Blanc Formation to the Hamilton Group are shown on Figure 5.

Onondaga Formation

Definition and Distribution

The name Onondaga Limestone was introduced by Hall (1839) and the stratigraphy of the formation now embraced by this name was thoroughly documented by Oliver (1954, 1956). An up-to-date summary of the stratigraphy of the unit was provided by Oliver (1976a).

Oliver (1967, Fig. 1) referred strata of the Niagara Peninsula that lie between the Bois Blanc and Dundee Formations, to part of the Onondaga Limestone of New York. Sanford (1969), in an attempt to maintain a single set of formational nomenclature across southwestern Ontario, assigned them to the Amherstburg Formation. Oliver's interpretation was supported by the mapping of Telford and Tarrant (1975a, b), but the latter authors encountered difficulties in extending the New York names farther west (see below).

In western New York the Onondaga Limestone has been divided into four members, comprising (in ascending order) Edgecliff, Clarence (in part equivalent to the Nedrow of central and eastern New York; Oliver, 1966, p. 39-40), Moorehouse, and Seneca. The Edgecliff, Clarence, and lower part of the Moorehouse Members extend into the Niagara Peninsula of Ontario and can be traced with reasonable confidence as distinct rock units to the vicinity of Selkirk (Telford and Tarrant, 1975a, b). They form the bedrock of a narrow zone, rarely broader than 5 km, that follows the northern shore of Lake Erie from the Niagara to Grand Rivers. Farther west the zone broadens to over 10 km and the three members become less distinct.

Between Selkirk and Port Dover there are outcrops of limestones that can probably be referred to the Onondaga Formation but which cannot be identified more precisely. Subsurface data suggest that west of Port Dover the Onondaga limestones grade laterally into limestones and dolostones of the Detroit River Group.

Lithology, Contacts, and Thickness

i) Edgecliff Member. This unit contains a diversity of limestones that can be grouped into three main facies (Oliver, 1976a, p. 8-10). The most widespread is a biostromal facies consisting of medium bedded, medium to fine grained, dark grey, fossiliferous, bioclastic limestone. Black chert is abundant as nodules or irregular thin beds. The megafauna is dominated by solitary rugose and tabulate corals, large crinoid stems, brachiopods, and trilobites. An estimated average thickness of this facies is 8 to 10 m.

The biostromal limestones commonly surround or overlie reefal and biohermal bodies. The reefal limestones are massive, light grey, very porous, coarse grained, and constructed mainly of colonial rugose corals such as **Acinophyllum stramineum** (Billings) and **A. segregatum** (Simpson). They occur separately or within large biohermal mounds up to 300 m in diameter. Other limestones within these mounds are irregularly bedded, grey, medium to coarse grained, very fossiliferous, and contain abundant black chert nodules. Thickness of the reefal-biohermal facies varies noticeably and sections of 8 to 10 m have been measured (Telford and Tarrant, 1975b).

A third facies of the Edgecliff Member occurs in the Port Colborne area, in the lower part of the unit. It is 3 to 4 m thick and consists of medium bedded, dark greenish grey, very argillaceous, fossiliferous limestone which weathers into thin, soft, shaly beds. Chert is rare. The profuse megafauna includes rugose and tabulate corals, bryozoans, brachiopods, gastropods, trilobites (e.g., **Terataspis**), crinoids, and fragmentary fish remains. As noted by Oliver (1976a, p. 10), the lower 1.2 m of this facies contains colonial rugose corals that are typical of the Bois Blanc Formation.

ii) Clarence Member. This unit consists of thick bedded, dark grey-brown, fine grained, poorly to nonfossiliferous, extremely cherty limestone. The dark grey or dark brown chert constitutes over 50 per cent of the rock and occurs as thin beds and dendritic nodules. Upper and lower contacts of the member are not exposed in the Niagara Peninsula area so that thickness of the unit cannot be determined accurately. Thicknesses of 8 m (Best, 1953) and 5 m (Telford and Tarrant, 1975b) have been recorded.

iii) Moorehouse Member. The most extensive exposures of this unit occur in the Selkirk area of the Niagara Peninsula. The lithology is similar to the biostromal facies of the Edgecliff Member, consisting of medium bedded, dark grey-brown or purplish brown, fine to coarse grained, variably cherty, very fossiliferous, bioclastic limestone. The dark grey or brown chert occurs as thin beds or rounded nodules. The megafauna is dominated by colonial rugose corals; tabulate and solitary rugose corals, bryozoans, and brachiopods are also common. The latter are particularly common in the upper part of the unit where the limestones are more argillaceous. A complete thickness of the unit is nowhere exposed but in the Selkirk area, the Moorehouse is at least 4.5 m thick (Telford and Tarrant, 1975a).

The boundary between the Edgecliff Member and underlying Bois Blanc Formation is generally sharp and may be disconformable. An exception to this situation occurs near Port Colborne where, as noted above, an argillaceous limestone facies contains a typical Bois Blanc fauna in its lower part, and a typical Edgecliff fauna in the upper part, without a noticeable lithological break.

Boundaries between the Edgecliff, Clarence, and Moorehouse are possibly gradational. Bioherms of the Edgecliff Member often protrude into and through the Clarence Member, thus occurring as small inliers or producing noticeable doming of the cherty limestone beds. The contact of the Moorehouse Member with the overlying Dundee Formation is very sharply defined and is well exposed in quarries and creek sections in the Nanticoke-Port Dover area.

Fossils, Age, and Correlation

The rich and diverse fauna of the Onondaga Limestone of New York and adjacent areas, including the Niagara Peninsula of Ontario, has been tabulated by Oliver (1954, 1956, 1968, 1976a). The fauna consists primarily of brachiopods and corals, both tabulate and rugose, but also includes bryozoans, molluscs, trilobites, crinoids, and ostracodes. As already noted above under discussion of the Bois Blanc Formation, although diverse the Onondaga fauna is also highly endemic, belonging to the Eastern Americas Faunal Realm, and correlations with faunas outside of the Realm are difficult (Oliver, 1976a, b). The generalized distribution of this fauna within the formation is given under discussion of individual members.

The Edgecliff Member may be Emsian or Eifelian in age (Oliver, 1976a, p. 19, 21). However, owing to distinct change in the fauna from that of the underlying Bois Blanc-Schoharie units, and taxa that are common in higher units but uncommon or absent in subjacent units, the Edgecliff was tentatively assigned to the Eifelian. In terms of New York stadial terminology, the unit is in the lower part of the upper Onesquethaw.

Discussion on the significance of conodonts of the Onondaga Formation in southwestern Ontario is given under the headings of the Detroit River Group and Dundee Formation.

Detroit River Group

The Detroit River Group consists of the Amherstburg Formation and the overlying Lucas Formation. Since it was first defined by Landes et al. (1909, p. 555), this unit has had a complex nomenclatural history. Detailed accounts of this history have been provided by Briggs (1959) and Fagerstrom (1971).

Amherstburg Formation

Definition and Distribution. The Amherstburg Formation is a poorly defined unit. Its original definition was based on dredgings from the Detroit River opposite Amherstburg, about 20 km south of Windsor (Sherzer and Grabau, 1909). No outcrops are present in the area and elsewhere in southwestern Ontario exposures of this formation are sparse. The upper few metres are present in several quarries between Woodstock and Ingersoll, while farther north in the Formosa-Teeswater area, biohermal limestones and dolostones of the Detroit River Group may be referable to the Amherstburg Formation. In this northern area formational boundaries are less distinct and some workers prefer to discuss the various lithological units as merely facies within the Detroit River Group (e.g., Liberty and Bolton, 1971). Lack of biostratigraphic control also hampers correlation.

As noted previously, the boundary of the Amherstburg Formation with the underlying Bois Blanc Formation is nowhere exposed and cannot be defined with confidence in the subsurface. Similarly, lateral relationships between the Amherstburg and Onondaga Formations are not clear because of lack of outcrops in the critical area between Simcoe and Woodstock. The upper boundary of the Amherstburg Formation with the Lucas Formation is only distinct in the Woodstock-Ingersoll and Douglas Point areas, the latter in a recently excavated site of a nuclear power station.

An additional problem in definition of the formation is the status of the Sylvania Sandstone. This strandline deposit of well sorted, fine to medium grained, orthoquartzitic sandstone (Sanford, 1968) overlies the Bass Islands and Bois Blanc Formations around the western, southern, and southeastern margins of the Michigan Basin. In Essex County, Ontario, the sandstone has a maximum thickness of about 25 m and is referred to as a member of the Amherstburg Formation (Sanford, 1968). This designation has been disputed by other workers (e.g., Fagerstrom, 1971) who prefer to treat the Sylvania Sandstone as a separate formation within the Detroit River Group. No further discussion of the sandstone is included in this report as it does not outcrop in Ontario.

It is probable that the upper part of the type section of the Bois Blanc Formation in northern Michigan is actually equivalent to the Amherstburg Formation.

Lithology, Contacts, and Thickness. In the Woodstock-Ingersoll area the Amherstburg Formation consists of grey brown or dark brown, fine to coarse grained, coral-stromatoporoid bioclastic limestone. It is very bituminous and contains grey chert nodules. In the subsurface of the Saginaw Bay area, central Michigan, the formation is better developed and attains thicknesses of about 100 m (Gardner, 1974, p. 31).

In the easternmost of the three large quarries situated between Ingersoll and Beachville (Station 14), there is about one metre of bituminous, bioclastic limestone that may perhaps be referable to the Amherstburg Formation. The unit is more clearly developed in a quarry located just to the north of these quarries. The Amherstburg-Lucas contact there appears to be conformable, although there is a relatively sharp lithological change from dark coloured, bituminous, coarsely bioclastic limestone to a generally light brown micritic limestone.

Localized reefal development approximately 15 m thick, scattered over an area of about 39 000 hectares in Bruce and Huron Counties, were termed Formosa Reef Limestone by Fagerstrom (1961b, p. 344, 346). Briggs (1959) also illustrated similar carbonate bank development on the northern rim of the basin, in the present Straits of Mackinac area. These reefs and bioherms are the present surface impression of a large platform reef development which characterized the southeastern rim of the Michigan Basin during the time of Amherstburg deposition. The "Huron Biostromes" of Sanford (1968, p. 981) is an integral part of the Formosa Reef Limestone, and probably forms a unit on which the reefal development rests. The type section was selected in a roadcut 4.0 km north of Formosa (Station 19). Stratigraphically the reefs occur within the 61-m interval of dark brown, cherty, bituminous dolostones which are assigned to the Amherstburg and Lucas Formations (Best, 1953, p. 145; Fagerstrom, 1961b, p. 342), or are considered to be restricted to the Amherstburg Formation (Sanford, 1968, p. 981). The latter interpretation is followed herein (Figs. 3, 4). The bioherms or reefs consist of light grey or bluish grey, fine grained, very high purity limestone. Stromatoporoids are the principal reef builders, with subordinate tabulate and rugose corals, in a micritic matrix. Dwellers include brachiopods, molluscs, and trilobites (Stumm, 1969, p. 242). Roper (in Stumm, 1969, p. 242, 244) suggested that the Formosa Reef at its type section may be oriented according to the distribution of stromatoporoids. The south end, with its concentration of stromatoporoids, was on the windward side, and the north end on the leeward side. Most of the **Favosites** colonies, large rugose corals and cephalopods were situated on the windward side. The basal part of the reef was postulated by Roper to have been deposited in a quiet water stage, then the intermediate parts either in rough water or a shallowing stage, and the upper parts in a wave resistant stage.

Two opposing views are held on the influence of the Formosa Reef on the development of the surrounding Amherstburg Formation. One is that the extensive reefs and carbonate banks contributed to the characteristic dark colour and bituminous nature of the Amherstburg strata formed in more basinal environments, by restricting water circulation and creating increasingly more stagnant conditions. The other is that the biohermal and biostromal developments were of high energy origin and the organic rich material washed off these reefs was transported laterally and deposited in adjacent sites of a more quiescent environment.

Fossils, Age, and Correlation. The Detroit River Group of the Michigan Basin is correlative with the lower part of the Onondaga Limestone of New York, with the Amherstburg Formation equating, at least in part, with the Edgecliff Member (Oliver, 1960, Fig. 77.1, 1968, Fig. 1, 1976a, Fig. 3; Fagerstrom, 1966, p. 1237-1238; Sanford, 1968, Fig. 3).

The group has been correlated further, at least in part, with the Columbus Limestone of central Ohio and Jeffersonville Limestone at the Falls of the Ohio area in northern Kentucky and southern Indiana (Fagerstrom, 1971, Fig. 13; Oliver, 1976a, Fig. 3). More detailed correlations are discussed under individual units of the Detroit River.

The brachiopods of the Detroit River Group of southwestern Ontario and neighbouring areas of Michigan and Ohio belong to the Appalachian Province (now termed the Eastern Americas Realm), and were discussed by Fagerstrom (1971). Although the fauna is highly endemic, making intercontinental correlation an impossibility, it is nevertheless distinct from those of the adjacent Bois Blanc and Dundee Formations (Fagerstrom, op. cit., p. 8-9). The entire Detroit River Group was assigned to the **Prosserella** Zone, after its most diagnostic constituent. In the Amherstburg area, each unit of the group is further characterized by a distinctive faunal assemblage, and each assemblage was designated as a separate biostratigraphic subzone: in ascending order, the Amherstburg Formation was assigned to the "coral-mixed brachiopod Subzone", the Lucas Formation to the **Acanthonema holopiforme** Subzone, and the Anderdon Member of the Lucas Formation to the **Amphipora nattressi** Subzone.

A faunal list of the Amherstburg Formation was given by Best (1953, p. 156, 157). The megafauna is dominated by tabular stromatoporoids and large favositid coral colonies. Less abundant constituents are solitary rugose corals, bryozoans, and the bivalve, **Conocardium.** Some Amherstburg colonial rugose corals in the Woodstock area were described and discussed by Oliver (1976a, Table 2, p. 17). He noted the abundant **Heliophyllum** and **Favosites,** and some typical Edgecliff colonial rugose corals. Both the coral and brachiopod faunas are endemic, and belong to the Appohimchi Province of the Eastern Americas Realm (Boucot, 1975, Fig. 2; Oliver, 1977a, Fig. 1A; Oliver and Pedder, 1979, p. 246).

The extensive fauna of the Formosa Reef Limestone was listed by Best (1953, p. 159-162) (the same list was repeated by Liberty and Bolton, 1971, p. 134-135), and described by Fagerstrom (1961a). Oliver (1976a, Table 2, p. 17) described a sparse colonial rugose coral fauna from the reef. Based on megafossils, the Formosa Reef Limestone is considered to be of lower Detroit River age, equivalent to the Amherstburg Formation, which, in turn, is correlated with the Edgecliff Member of the Onondaga Limestone of New York (Fagerstrom, 1971, p. 59).

The low diversity of the Amherstburg conodont fauna is similar to that of the underlying Bois Blanc Formation (see Tables 3 and 8). Again, **Icriodus latericrescens robustus** is essentially the only species present, and represents the **robustus** Zone. (Discussion on the significance of this zone can be found under Bois Blanc Formation.) The Edgecliff Member of the Onondaga Limestone in New York (Klapper and Ziegler, 1967, p. 77) and the Amherstburg Formation of the Detroit River Group in the Michigan Basin (Orr, 1971, p. 103) are similarly impoverished. The Edgecliff was tentatively assigned to the lower part of the **patulus** Zone by Klapper (in Klapper and Ziegler, 1979, Fig. 4), mainly on the basis of its stratigraphic position.

In addition to **I. latericrescens robustus,** the Formosa member yielded a new icriodontan species, **Icriodus hankae.** The conodonts, however, do not add any new information in regards to the age of this member (see discussion under "Previous Investigations"). It appears then, that both the conodonts and the megafauna, as summarized above, of the Amherstburg Formation cannot be used for correlations with faunas outside of the Eastern Americas Realm. The age of the Edgecliff Member, a probable correlative of the Amherstburg, has been discussed earlier in this report.

Lucas Formation

Definition and Distribution. The Lucas Formation is well exposed in southwestern Ontario and forms the bedrock of a broad belt extending northwestward from the Ingersoll area to Lake Huron. It directly underlies part of the Amherstburg-Leamington area bordering Lake Erie, and forms small inliers surrounded by limestones of the Dundee Formation in the Goderich and Grand Bend areas. The latter were identified from oil and gas well drilling records (Sanford, 1964, 1969). Excellent exposures of the Lucas Formation occur in quarries near Amherstburg, Ingersoll, and St. Marys, and along the Maitland River near Goderich. Less extensive sections are exposed along the shore of Lake Huron, near Inverhuron and Douglas Point, and inland towards the Formosa-Teeswater area.

First defined in Ohio by Prosser (1903), the Lucas Formation is a complex unit with a variety of lithologies. In the central Michigan Basin it is basically an evaporitic unit composed of salt and anhydrite interbedded with anhydritic dolostones and limestones (Sanford, 1968). Towards the margins of the basin, such as the Algonquin Arch region of southwestern Ontario, the formation consists of platform carbonate deposits of high purity limestones and dolostones. These are underlain by the Amherstburg Formation and are disconformably overlain by the Dundee Formation.

Various subdivisions of the Lucas Formation have been proposed but, in Ontario, only one unit, the Anderdon Member, has been separately defined. It forms the upper part of the Lucas Formation in the Amherstburg area and encompasses all of the Lucas Formation of the Ingersoll area. In the latter area, a sandy limestone facies occurs in the upper part of the Anderdon Member.

Liberty and Bolton (1971) described a southern, northern, and biohermal facies of the Detroit River Formation, in the manner previously outlined by Best (1953). It is suggested herein that Detroit River should be used only as a group name, with the three facies defined, when possible, as formations or members within the group. As mentioned previously, the biohermal facies is probably referable to the Amherstburg Formation. The southern facies, which Liberty and Bolton (1971, p. 60) noted as being dominantly limestone, may be referred to the Anderdon Member of the Lucas Formation. The northern facies, which is mainly dolostone, can be considered as undifferentiated Lucas Formation. The term northern facies is somewhat of a misnomer as this same rock unit underlies the southern facies or Anderdon Member at Amherstburg. A more realistic interpretation is illustrated in Figure 7a of Sanford (1968) where the evaporitic portion of the Lucas Formation in the central Michigan Basin is, in turn, bounded by a limestone zone. These outer zones are virtually continuous around the margins of the Michigan Basin.

Lithology, Contacts, and Thickness. As implied above, three main lithologies are present in the Lucas Formation of southwestern Ontario and can be discussed as three distinct units.

TABLE 3

Distribution of conodonts in the Amherstburg Formation, Detroit River Group

LEGEND

Simple .... s
Intermediate i
Advanced .... a

STATION NO.	GSC LOC. NO.	*Icriodus latericrescens robustus* (I;s)	*Icriodus latericrescens robustus* (I;i)	*Icriodus latericrescens robustus* (I;a)	*Icriodus latericrescens robustus* (S_2)	*Icriodus latericrescens robustus* (M_2)	*Belodella* spp.	*Coelocerodontus* spp.	*Coelocerodontus* (with lateral denticles)	cf. *Coelocerodontus* spp.	*Panderodus* spp.	NOTE: *Icriodus latericrescens robustus*: fragmentary specimens that cannot be assigned to the three morphotypes are not listed.	INTERVAL ABOVE BASE OF FM. OR *ABOVE BASE OF SECTION (m)	WEIGHT (kg)
4	C-38830	8	6				151	6					0.0 - 0.18	2.2
	C-38831	3	5	3	3?		143	6					0.52 - 0.64	2.1
	C-38832	5			3		482	4			4		1.25 - 1.40	2.4
	C-38833	1	1		1		152	3			1		2.32 - 2.44	2.1
	C-38834	1					42	1					3.14 - 3.44	2.2
	C-38835						7						4.30 - 4.39	2.1
	C-38836						15	1					4.85 - 4.94	2.2
	C-38837	1	3				70	1			1		5.70 - 5.76	2.2
2	C-38819		BARREN										0.0 - 0.18	4.0
	C-38820	2	5				19	7			12		0.79 - 1.01	4.0
	C-38821	36	20		11	1	146	5			6		1.58 - 1.77	4.0
	C-38822	8	7		2		64	9			4		2.13 - 2.29	4.0
	C-38823	4	6	1	3	3	204	6					2.93 - 3.14	4.0
	C-38824	11	11		1	4	103	14			4		4.21 - 4.27	4.0
7	C-38841					2	6	1			2		0.0 - 0.12	4.0
	C-38842	3	4		1	3	16	7			1		0.58 - 0.67	4.0
	C-38843	5	1		2	2	20	5	3				1.58 - 1.68	4.0
10	C-38859	1	8	1			1	1		5			0.21 - 0.40	4.0
36	C-38978		BARREN										*0.15 - 0.43	4.0
	C-38979		2					2					1.22 - 1.37	4.0
	C-38980		4					1					2.04 - 2.13	4.0
	C-38981		BARREN										3.51 - 3.72	4.0
	C-38982		1										4.54 - 4.63	4.0
	C-38983		2			1		1					5.39 - 5.49	4.0

3a

LEGEND

Simple .... s
Intermediate i

FORMATION	STATION NO.	GSC LOC. NO.	*Icriodus latericrescens robustus* (I;s)	*Icriodus latericrescens robustus* (I;i)	*Icriodus latericrescens robustus* (S_2)	*Icriodus latericrescens robustus* (M_2)	*Icriodus hankae* (I)	*Icriodus hankae* (S_2)	*Belodella* spp.	*Coelocerodontus* spp.	*Coelocerodontus* (with lateral denticles)	cf. *Coelocerodontus* spp.	NOTE: *Icriodus latericrescens robustus*: fragmentary specimens that cannot be assigned to the three morphotypes are not listed.	INTERVAL ABOVE BASE OF SECTION (m) *South end of road cut	WEIGHT (kg)
AMHERSTBURG FORMATION	1	C-38806	4	10					2	8				0.43 - 0.58	4.0
		C-38807	3	3	1					13		2		1.22 - 1.52	4.0
		C-38808	11	18	7	6			407	23				1.92 - 2.10	4.0
		C-38809	9	6	4	3			179	14				2.83 - 2.99	4.0
		C-38810	6	11	2				110	9	8	2		3.84 - 4.02	4.0
		C-38811	4	4					127	9				4.33 - 4.57	4.0
		C-38812	1	2					27	3				5.39 - 5.52	4.0
		C-38813	6	3	2	1			143	8				6.43 - 6.58	4.0
		C-38814	2	1	1	2			75	8				7.28 - 7.35	4.0
Formosa Reef Limestone	19	C-38932								1				0.0 - 0.91	7.1
		C-38933		1						5	4			0.91 - 1.83	6.9
		C-38934		1			1			2	2			1.83 - 2.74	7.4
		C-38935					3			3				2.74 - 3.66	6.8
		C-38936	1				6			2	1			3.66 - 4.57	7.2
		C-38937		1							1			4.57 - 5.49	6.6
		C-38938		2							3			5.49 - 6.40	6.4
		C-38939								1				6.40 - 6.92	6.2
		C-38940	2				1			5	4			0.0 - 0.91*	7.0
		73680					1							0.0 - 1.52*	1.6
		C-38941					4	1		7	5			0.91 - 1.83*	6.3

3b

GSC

i) Lucas Formation undifferentiated. In quarries at Amherstburg and St. Marys (Stations 29 and 17, respectively), this unit consists of thin to medium bedded, light brown or grey brown, finely crystalline, poorly fossiliferous dolostone with dark bituminous laminations, minor chert, and local mottling which could be of algal origin. A complete section of the unit is not exposed and thicknesses are difficult to estimate. In the quarry of St. Mary's Cement Company Limited at St. Marys about 3 m of dolostones are exposed. Beards (1967) illustrated a 75 m thickness of the unit in the subsurface of Huron County near Goderich.

ii) Anderdon Member. This unit, which is quarried extensively near Ingersoll and Amherstburg (Hewitt, 1960), is a very high purity limestone. It is comprised of alternating zones of fine grained, sparsely fossiliferous, micritic limestone and thick or massive beds of coarse grained, very fossiliferous, bioclastic limestone. The micritic limestone is generally medium to thick bedded and light brown to dark grey-brown in colour. The bioclastic limestone varies in colour according to its fossil content. Beds and lenses of pseudo-oolitic limestone are present in the exposures near Amherstburg. Near Ingersoll, where several large quarries have exposed a virtually complete section of the unit, the Anderdon Member is about 39.5 m thick.

iii) Sandy limestone facies of the Anderdon Member. In the Steel Company of Canada Limited quarry near Ingersoll (Station 13), the upper 7 m of the Anderdon Member is composed of buff-coloured, thick to massive bedded, medium to coarse grained, fossiliferous, sandy limestone, and lenses of orthoquartzitic sandstone. The relatively friable sandy limestone facies overlie and intertongue with the upper part of the Anderdon Member but it extends only a short distance southwest of the outcrop near Ingersoll. Sanford (1968) noted local developments of the facies in Kent and Essex Counties. Summerson and Swann (1970, p. 481) similarly noted the essentially continuous nature of the sandstone from these areas to as far east as Ingersoll. This, in addition to the lithological similarity of the sandstone to that of the Sylvania, led them to favour a western source.

The disconformable boundary between the Lucas Formation and overlying Dundee Formation is well exposed in the quarries at St. Marys and Amherstburg. The basal 5 to 10 cm of the Dundee Formation is a conglomerate with tabular dolostone clasts in a matrix of micritic limestone. A major disconformity is also suggested by the undulating contact of the Lucas and Dundee exposed along the Maitland River near Goderich (Station 18).

As described earlier, the Lucas Formation in the central part of the

Michigan Basin is a thick evaporitic unit. Concentric dolostone and limestone zones surround the central evaporitic core of the formation. The outer limestone zone (Anderdon Member) thins rapidly towards the margin of the basin. In the Port Dover area of the Niagara Peninsula, the Lucas Formation is not represented in the Devonian sequence, and the Dundee Formation lies directly on the Amherstburg Formation. The reason for the absence of the Lucas in this area is debatable, it could be due to non-deposition or a facies change, or both. Whatever the reason(s), the following must be taken into account: firstly, the occurrence of aeolian sandstone and sandy limestone in the Anderdon Member from the Windsor through Woodstock-Ingersoll areas, and its implication of emergence, deposition of sand, and subsequent submergence (Summerson and Swann, 1970, p. 481). That renewed submergence actually occurred is supported by a major change in the conodont population between the Anderdon Member and the overlying sandy unit. Secondly, if non-deposition is in fact the case, where is the extension of the break into western New York and north-central Ohio? In both places, such a break is yet to be recorded. In this connection, it should be noted that, to the north, in the Moose River and Hudson Bay Basins of the Hudson Platform, a hiatus is present between the Moose River Formation and the overlying Murray Island Formation. This depositional break may possibly correspond to the hiatus between the Detroit River Group and the Dundee Formation in southwestern Ontario (Sanford and Norris, 1975, p. 55, 60, Fig. 7). The accompanying correlation chart (Fig. 4) shows the first of these alternatives.

Fossils, Age, and Correlation. At the type section of the Lucas Formation, fossils are neither abundant nor diverse, according to Fagerstrom (1971, p. 5). As stated earlier, in the Amherstburg area, the fauna of the Lucas (in undifferentiated sense) is assignable to the gastropod **Acanthonema holopiforme** Subzone. Oliver's (1976a, p. 17) study did not include Lucas corals.

The Lucas Formation is equivalent to the Nedrow Member of the Onondaga Limestone of New York. The unit is further correlated, at least in part, with the Detroit River Formation of northern Indiana, with the upper part of the Jeffersonville Limestone of southern Indiana and northern Kentucky, and with Zones E through H of Stauffer (1909) of the Columbus Limestone of central Ohio (Oliver, 1976a, Fig. 3; Doheny et al., 1975, Fig. 3).

A faunal list of the Anderdon Member was provided by Best (1953, p. 155, 156). The megafauna is dominated by tabular and ellipsoidal stromatoporoids, solitary rugose corals, brachiopods, bryozoans, and bivalves (e.g., **Conocardium**). Beds composed mainly of stromatoporoids are usually very light brown or cream, and form distinct, traceable levels. In the McGregor quarry of Allied Chemicals Limited near Amherstburg (Station 40), large gastropods (?**Acanthonema**) are prominent in the upper part of the member.

The gastropod fauna of the Anderdon Member as represented in three quarries located in southwestern Ontario (near Amherstburg; Station 29), southeastern Michigan, and northwestern Ohio was described and discussed by Linsley (1968). Because of the limited biostratigraphic value of gastropods, the dating of the Anderdon was not further refined. They did, however, contribute to the interpretation of paleoecologic setting. In the Amherstburg quarry, he found two kinds of facies, consisting (i) primarily of a biostromal aggregation of corals and gastropods, with small gastropods living in what was interpreted as a sheltered environment, and (ii) of a fine calcilutite, in which comparatively large gastropods were found. The latter was interpreted as a protected back-reef or inter-reef environment.

As stated earlier, Fagerstrom (1971, p. 8) assigned the fauna of the Anderdon Member to the stromatoporoid **Amphipora nattressi** Subzone. Conkin and Conkin (1973, Fig. 1, p. 34) assigned the upper part of the Anderdon Member in the Stelco quarry (Station 13) to the **Amphipora ramosa** Zone, thus correlating it with the uppermost part of the Bellepoint Member (Zone C and the upper part of Zone B of Stauffer, 1909) of the Columbus Limestone of central Ohio, and with the Nedrow Member of the Onondaga Limestone of New York.

The Anderdon Member also carries the one-celled algae, **Leiosphaeridia** sp., at the McGregor Quarry (Station 40) (pers. comm., B. Taylor, 1977).

The Lucas Formation (undifferentiated) was sampled at two localities; one on the south bank of Maitland River near Goderich (Station 18), and the other at St. Marys (Station 17). Both conodont collections are small and the specimens fragmented (see Table 4a).

The Anderdon Member was extensively sampled for this study, at its type section (Station 29) and at the nearby McGregor Quarry (Station 40), as well as the thick sequences in the quarries near Beachville (Stations 13 and 14). A total of 263 kg of this member was processed, yielding a miniscule collection of only four conodont specimens (see Tables 4a, b). These are the Pa element of **Polygnathus linguiformis linguiformis** Hinde (as noted in the Systematic Paleontology section of this report, the nominate subspecies is identical to the gamma morphotype of Bultynck, 1970, and hereafter the subspecies is used in this sense), the I element of **Icriodus** aff. **I. retrodepressus** Bultynck, **Belodella** sp., and an unassigned S_2 element. Both **P. linguiformis linguiformis** and **Icriodus** aff. **I. retrodepressus** are long-ranging in southwestern Ontario (see Table 1) and elsewhere, and are of limited biostratigraphic use.

The sandy limestone facies of the Anderdon Member, exposed at the quarry of the Steel Company of Canada (Station 13), has been erroneously designated "Columbus limestone" in the past (e.g., Ehlers and Stumm, 1951; Sanford, 1958; Fagerstrom, 1971, 1978; Oliver, 1976a) and miscorrelated with Zone H of Stauffer (1909) of the Columbus Limestone of central Ohio, and with the Dundee Formation on Pelee Island. This misinterpretation has been pointed out by Sanford (1968, p. 985) and Conkin and Conkin (1973, p. 34). The latter authors correlated the sandy facies with Zone E of Stauffer (1909) of the Columbus Limestone. The term Columbus, as used in southern Ontario, has been discarded (see Beards, 1967, p. 2).

A.E.H. Pedder (pers. comm., Aug. 1974) in 1959 made the following collection from the sandy limestone facies at the Stelco quarry in Ingersoll:

Favosites hemisphericus Troost
Heterophrentis inflata (Hall)
H. nitida (Hall)
H. sp. nov., exceptionally large for genus
halliid, gen. & sp. nov., related to species of **Aulacophyllum**
Heliophyllum sp. cf. **H. scotiense** Stewart
Eridophyllum seriale M.-Edwards and Haime
Megastrophia sp. cf. **M. hemispherica** (Hall)
"**Spirifer**" sp. cf. "**S.**" **varicosus** Hall, closer to species of **Mucrospirifer** than to any of true **Spirifer**
Conocardium cuneus (Conrad)

According to Pedder,

"In terms of existing knowledge of species' ranges this fauna indicates correlation with, part at least, of the upper 21 feet (6.5 m) of the Jeffersonville Limestone at the Falls of the Ohio, where the formation is 30 feet (9 m) thick, and also, again part at least, of the Delhi Member of the Columbus Limestone of Ohio. According to Stauffer's (1909) figures, the Delhi Member, which is equivalent to his zones E-H, constitutes approximately the upper 57 feet (15.5 m) of the Columbus Limestone. The average thicknesses of all his Columbus zones total 95 feet (29 m).

"Ehlers and Stumm's (1951) faunal list from Ingersoll is larger and includes **Paraspirifer acuminatus** (Conrad). This species is restricted to the top 14 feet (4 m) of the Jeffersonville Limestone (Conkin and Conkin, 1969, p. 72-77) and, in the Columbus Limestone, to Stauffer's Zone H. This is the highest of the Columbus zones and is apparently nowhere more than 16 feet (5 m) thick. **P. acuminatus** has been identified in the Moorehouse Member of the Onondaga Formation of central New York by Oliver (1954, p. 640)."

The upper 21 and 14 feet (6.5 and 4 m) of the Jeffersonville Limestone at the Falls of the Ohio comprise assemblage zones C through F, and D through F, respectively, of Oliver (1976a, Fig. 9, p. 19). According to Oliver's (op. cit., Fig. 3) correlation chart, these zones correlate with Stauffer's (1909) Zones D through H, and F through H, respectively, of the Columbus Limestone of central Ohio.

The Anderdon sandy facies at Ingersoll yielded a relatively rich conodont fauna (Table 4b), including, among others, a transitional form between **P. costatus patulus** Klapper and **P. cooperi cooperi** Klapper. This represents the **P. costatus patulus-P. linguiformis cooperi** fauna of Klapper (1971, p. 60) which occurs in the Nedrow Member and the lower part of the Moorehouse Member of the Onondaga Limestone in New York. There the upper part of the fauna belongs to the **costatus costatus** Zone (of Weddige, 1977) since the index subspecies occurs in the upper part of the Nedrow Member (Klapper in Klapper and Ziegler, 1979, Fig. 4). Because the critical subspecies, **P. costatus partitus** Klapper, Ziegler and Mashkova is absent, the lower part of the fauna can only be assigned to the undivided **patulus** Zone (of Weddige, 1977). However, since a limited interval of strata is involved, Klapper (in Klapper and Ziegler, 1979, p. 207) suggested that the **patulus** Zone in the Nedrow Member may represent the upper part of that zone. In Ontario, **P. c. costatus** occurs in the overlying Dundee Formation which suggests that the **patulus-cooperi** fauna in the sandy facies is assignable to the undivided **patulus** Zone. By analogy with the New York sequence, this, too, may perhaps represent the upper part of the zone. It should be noted that the correlation of the Lucas Formation in general with the middle part of the Onondaga Limestone in New York, as depicted on Figure 5, is principally based on the fauna of the sandy facies of the Anderdon Member. **P. costatus patulus** has not been reported from Michigan, but an equivalent of the **patulus** Zone is presumably represented in the upper part of the Detroit River Group.

In the type Couvinian sequence of the Ardennes, **P. costatus patulus** spans from Co1b to Co2bI (Bultynck, 1970, Pl. 38; Klapper in Ziegler, ed., 1973, p. 349). In the Barrandian sections of Czechoslovakia, the subspecies occurs in the Třebotov and Suchomasty Limestones and the basalmost part of the Choteč Limestone (Klapper, 1977b, Table 1; Klapper et al., 1978, Fig. 2). In the Eifelian Hills, its range is from the base of the Heisdorf Formation to near the top of the overlying Lauch Formation (Weddige, 1977, Table 5). The significance of the **patulus** Zone is discussed in the introductory part of this chapter.

Dundee Formation

Definition and Distribution

The name Dundee Formation was first used by Wadsworth (in Lane, 1893) for rock exposures near Dundee, in southeastern Michigan. The stratigraphy and fauna of the formation at its type area were studied by Bassett (1935). The term was first applied to Ontario rocks by Sherzer and Grabau (1909), although subsequently the term Delaware Formation, originating in central Ohio, and a part equivalent of Dundee, has often been used in Ontario. It is now a generally accepted procedure in Ontario to use the name Dundee Formation for strata lying between the Detroit River and Hamilton Groups (see Beards, 1967, p. 2).

The formation constitutes bedrock of a broad belt extending across southwestern Ontario from central Lake Erie to Lake Huron. It also underlies part of the Windsor-Essex area and forms the bedrock of Pelee Island in Lake Erie. Outcrops of the formation are not plentiful. The most extensive exposures occur in the Selkirk-Port Dover area of the Niagara Peninsula, on Pelee Island, in quarries near Amherstburg, and along the Thames and Maitland Rivers near St. Marys and Goderich. One of the thickest and best known sections is in the quarry of St. Mary's Cement Company Limited at St. Marys.

Lithology, Contacts and Thickness

Except for the strata exposed on Pelee Island, the Dundee Formation has a relatively uniform lithology. It consists of medium to thick bedded, dark brown, fossiliferous, micritic limestone. Bituminous laminations and shale partings are common and lenses of coarse grained, crinoid-brachiopod, bioclastic limestone are present in some sections. Although not particularly abundant, brown chert nodules occur at most localities.

In the Selkirk-Port Dover area, the formation is more thinly bedded and the lower part contains two prominent horizons of black, bituminous limestone with abundant tentaculitids. On Pelee Island, the lower part of the formation consists of massive, light brown, medium to coarse grained, bioclastic limestone. Lenses of pseudo-oolitic limestone enclosing coarse bioclastic debris are occasionally present. Bituminous laminations are present and pockets of bituminous material are generally concentrated in the porous structures of colonial corals. One Pelee Island sample (GSC loc. C-38963, Station 32, Table 5a) was submitted for carbon analysis, and the following results were obtained (L.R. Snowdon, pers. comm., Aug. 1973): total carbon = 9.604 per cent of total weight (includes mineral and organic carbon), organic carbon = 0.207 per cent of total (average of three tests). The sample gave characteristic "petroliferous" odour on breakage and, during acidizing treatment, produced a thin layer of black scum, again with the same characteristic odour, on top of the acid solution.

A complete section of the Dundee Formation is not exposed in southwestern Ontario. The thickest known outcrop is that of the quarry at St. Marys where about 15 m of strata are exposed (Winder et al., 1975). According to Sanford (1968), the formation has a maximum thickness of approximately 120 m in the Saginaw Bay area of Michigan but thins to less than 20 m in certain parts of southwestern Ontario. It again thickens southwestward, reaching a maximum of about 40 m beneath central Lake Erie.

The Dundee Formation overlies the Detroit River Group with a sharp disconformity. As described earlier, the contact with the Amherstburg Formation is well exposed in the Port Dover area and the contact with the Lucas Formation may be seen at St. Marys and along the Maitland River near Goderich. In quarries near Amherstburg traces of sand are present at the base of the Dundee. This sand may be of aeolian origin and its presence suggests subaerial accumulation and subsequent submergence and reworking (Summerson and Swann, 1970). Diffendal (1972) suggested that the base of the formation may be transgressive. The upper boundary of the Dundee Formation is not exposed in

TABLE 4a

Distribution of conodonts in the Lucas Formation, Detroit River Group

LEGEND

Simple .... s
Intermediate i
Advanced .... a

FORMATION	MEMBER	STATION NUMBER	GSC LOC. NO.	*Polygnathus costatus patulus* ⟶	*Polygnathus cooperi cooperi* (Pa)	*Polygnathus linguiformis linguiformis* (Pa)	*Polygnathus* sp. (Pa)	*Icriodus latericrescens robustus* (I;s)	*Icriodus latericrescens robustus* (I;i)	*Icriodus latericrescens robustus* (I;a)	*Icriodus* aff. *I. l. retrodepressus* (I)	*Icriodus* aff. *I. l. retrodepressus* (S_2)	*Icriodus* aff. *I. l. retrodepressus* (M_2)	*Icriodus* sp. (I)	unassigned Sc	unassigned S_2	unassigned M_2	*Belodella* spp.	*Coelocerodontus* spp.	INTERVAL ABOVE BASE OF SECTION; OR *ABOVE BASE OF FM., OR **BELOW TOP OF FM. (m)	WEIGHT (kg)
LUCAS FORMATION		18	C-38923												1					**0.0 - 0.15	3.0
		17	73868				1							1						**0.0 - 0.08	1.7
	Anderdon Member	40	C-38989		BARREN															1.16 - 1.34	4.0
			C-38990		BARREN															2.04 - 2.35	4.2
			C-38991													1				3.93 - 4.11	4.1
			C-38992		BARREN															4.66 - 4.97	4.0
			C-38993		BARREN															5.73 - 6.04	4.0
			C-38994		BARREN															6.64 - 6.95	4.0
			C-38995		BARREN															7.80 - 8.11	4.0
		29	73709		BARREN															*0.0 - 1.09	1.6
			73708		BARREN															1.09 - 1.67	
			73707		BARREN															1.67 - 2.16	
			73706		BARREN															2.16 - 3.26	
			73705		BARREN															3.26 - 4.32	
			73704		BARREN															4.32 - 5.12	
			73703		BARREN															5.12 - 6.34	
			73702								1									6.34 - 9.38	1.8
			73701			1														9.38 - 11.06	1.7
		14	C-38886		BARREN															0.82 - 0.98	6.1
			C-38887		BARREN															1.95 - 2.26	5.8
			C-38888		BARREN															3.11 - 3.26	5.9
			C-38889		BARREN															4.18 - 4.39	5.9
			C-38890		BARREN															5.61 - 5.91	6.5
			C-38891		BARREN															6.31 - 6.40	6.4
			C-38892		BARREN															7.74 - 7.96	13.0
			C-38893																1	8.96 - 9.27	6.7
			C-38894		BARREN															10.79 - 11.09	6.0
			C-38895		BARREN															12.56 - 12.74	6.1
			C-38896		BARREN															14.66 - 14.81	6.7
			C-38897		BARREN															16.40 - 16.58	6.7
			C-38898		BARREN															17.53 - 17.65	6.6
			C-38899		BARREN															19.20 - 19.51	7.1

NOTE: *Icriodus latericrescens robustus*: fragmentary specimens that cannot be assigned to the three morphotypes are not listed.

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the study area but subsurface records indicate an abrupt lithological change from micritic limestone to shales of the Marcellus[1] or Bell Formations.

Fossils, Age, and Correlation

The Dundee Formation and Delaware Limestone of Ohio are probably, at least in part, laterally equivalent. Other lateral relationships are more obscure, however. Sanford (1968) suggested that the Dundee Formation grades eastward into the Moorehouse and Seneca Members of the Onondaga Formation, whereas Oliver (1976a) correlated the Dundee with the Seneca and lower Marcellus Shale of the Hamilton Group. However, the Tioga Bentonite, which separates the Moorehouse and Seneca Members, and is an excellent marker horizon in the Allegheny Basin, has not been positively identified in the Ontario Devonian sequence.

Sanford (1968, p. 987) reported that, in the north-central Lake Erie region, in southern parts of Norfolk and Oxford Counties, "a consistent bentonite seam occurs from 60 to 100 feet [18.3 to 30.5 m] above the base of the Moorehouse in subsurface." He equated this with the Tioga Bentonite and, according to the correlations expressed in his paper, it lay within the Dundee Formation. Winder and Sanford (1972) reiterated that the Tioga Bentonite occurred 9 to 12 m above the base of the Dundee Formation at several localities in Ontario. Baltrusaitis (1974) questioned these assignments and correlated the Kawkawlin Bentonite (within the Lucas Formation in the Michigan Basin) with the Dundee bentonite bed in Ontario. If Sanford's (op. cit.) contention is correct, then the Dundee of southern Ontario correlates, at least in part, with the Seneca and Moorehouse Members of the Onondaga Limestone of New York. The Seneca Member, in turn, is a facies equivalent of the lower part of the Marcellus Formation (Union Springs Shale and Cherry Valley Limestone Members) of the Hamilton Group (Rickard, 1975, p. 6, Pl. 3; Oliver, 1976a, Fig. 3). These correlations are supported by conodont evidence, as reported below.

Conkin and Conkin (1977) considered the Kawkawlin Bentonite in the subsurface of the Michigan Basin to be correlative of the bentonite beds in the Grand Tower Limestone of the Illinois Basin, the Jeffersonville Limestone and Detroit River Formation of Indiana, and the Columbus Limestone of Ohio. According to these authors (op. cit.; 1975, Text-fig. 10), the bentonite beds are situated in the upper part of the Lower **Paraspirifer acuminatus** Subzone which, in turn, occurs in Stauffer's (1909) Zone G in the Columbus Limestone in central Ohio. The Tioga Bentonite Bed, on the other hand, occurs either between Stauffer's Zone H and the Delaware Limestone in Ohio (Oliver, 1976a, Fig. 3), or possibly in the lowermost part of the Delaware Limestone (Conkin and Conkin, 1975, Text-fig. 2).

As stated earlier, one of the earliest faunal studies of the Dundee Formation at its type area was by Bassett (1935). Later, Fagerstrom (1971, p. 9) noted that of the 28 species (in 19 genera) of brachiopods from the type area listed by Bassett (op. cit.), only one species and nine genera are also present in the **Prosserella** Zone of the Detroit River Group.

Some Dundee megafossils, including **Brevispirifer lucasensis** (Stauffer), **Atrypa elegans** Grabau, and **A. costata** Bassett, from Alpena and Presque Isle Counties in northeastern Michigan, were listed and illustrated by Ehlers and Kesling (1970, p. 25, Pl. 7).

The formation in Ontario is characterized by an abundant and highly diverse brachiopod fauna (listed by Best, 1953, p. 188-190, 216-220). Minor megafaunal constituents are molluscs (including a large coiled cephalopod, **Gigantoceras elegans** (Meek)), bryozoans, and

[1]The Marcellus Formation was defined in New York by Hall (1839). Although known from subsurface records in the Port Stanley-Port Burwell area bordering Lake Erie (Sanford, 1969), the unit does not crop out in Ontario and for this reason is not described in detail in this report.

TABLE 4b

Distribution of conodonts in the Lucas Formation, Detroit River Group

LEGEND

Simple .... s
Intermediate i
Advanced ....a

FORMATION	MEMBER	STATION NO.	GSC LOC. NO.	*Polygnathus costatus patulus* →	*Polygnathus cooperi cooperi* (Pa)	*Polygnathus linguiformis linguiformis* (Pa)	*Icriodus latericrescens robustus* (I:s)	*Icriodus latericrescens robustus* (I:i)	*Icriodus latericrescens robustus* (I:a)	*Icriodus* aff. *I. retrodepressus* (I)	*Icriodus* aff. *I. retrodepressus* (S_2)	*Icriodus* aff. *I. retrodepressus* (M_2)	unassigned Sc	unassigned S_2	unassigned M_2	*Belodella* spp.	*Coelocerodontus* spp.	INTERVAL ABOVE BASE OF SECTION (m)	WEIGHT (kg)
LUCAS FORMATION	Anderdon Member	13	C-38860	BARREN														0.43 - 0.98	6.6
			C-38861	BARREN														1.40 - 1.65	7.0
			C-38862	BARREN														2.26 - 2.56	6.6
			C-38863	BARREN														3.29 - 3.60	5.6
			C-38864	BARREN														5.06 - 5.36	7.0
			C-38865	BARREN														6.64 - 6.95	5.7
			C-38866	BARREN														6.95 - 7.44	5.5
			C-38867	BARREN														8.44 - 9.05	6.6
			C-38868	BARREN														10.18 - 10.33	6.2
			C-38869	BARREN														11.19 - 11.49	6.9
			C-38870	BARREN														12.80 - 12.95	6.8
			C-38871	BARREN														14.14 - 14.30	6.7
			C-38872	BARREN														15.70 - 15.91	6.9
			C-38873	BARREN														17.62 - 17.92	6.7
			C-38874	BARREN														19.81 - 20.12	6.8
			C-38875	BARREN														20.85 - 21.15	6.1
			C-38876	BARREN														22.34 - 22.65	6.5
			C-38877	BARREN														23.99 - 24.29	6.6
			C-38878	BARREN														26.24 - 26.37	7.0
	Sandy facies, Anderdon Member		C-38879				4	1		16								26.37 - 26.82	4.0
			C-38880	6			8	14	8	78				53	38			26.82 - 27.31	5.9
			C-38881							93	2	3				1		27.86 - 28.01	4.0
			C-38882							2		1						28.71 - 28.86	4.4
			C-38883					2		6								29.35 - 29.50	4.0
			C-38884							3								30.17 - 30.33	4.0
			C-38885							2								31.21 - 31.36	4.0

NOTE: *Icriodus latericrescens robustus*: fragmentary specimens that cannot be assigned to the three morphotypes are not listed.

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trilobites. The microscopic, orange algal cyst, **Tasmanites,** first appears in the Dundee. One-celled algae, **Leiosphaeridia** spp., are also present in the formation (B. Taylor, pers. comm., 1977).

The megafauna of the Dundee Formation on Pelee Island is more diverse than elsewhere in southwestern Ontario, and includes solitary and colonial rugose corals, tabulate corals, and a variety of brachiopods, bryozoans, molluscs, and trilobites.

The Rogers City Limestone of northern Michigan is considered herein to be a part correlative of the Dundee Formation. The Rogers City contains a diverse fauna, some of which were listed and illustrated by Ehlers and Kesling (1970, p. 22-23, Pls. 9, 10). At the Calcite Quarry at Rogers City, the type section of Rogers City Limestone, the lower-most **Emanuella** Zone contains **Carinatrypa dysmorphostrata** (Crickmay) (Ehlers and Kesling, op. cit.). At Powell Creek in western District of Mackenzie, the **dysmorphostrota** Zone in the upper part of the Hume Formation, is associated with **Parapolygnathus angusticostatus** (Wittekindt), **Polygnathus curtigladius** Uyeno, and at locality 3 (GSC loc. C-2522) in an isolated outcrop on Carnwath River, in a similar interval within the Hume as at Powell Creek, these occur together with **Polygnathus intermedius** (Bultynck) (Uyeno, 1979, Fig. 2, p. 252, 253). The conodont evidence suggests a late Couvinian age (Co2c to Co2d) (Bultynck, 1970, Pl. 38), and a late Eifelian age (**kockelianus** Zone) (Weddige, 1977, Table 2); see also Klapper in Klapper and Ziegler (1979, Fig. 4) and Klapper and Johnson (1980).

Chitinozoans from the Columbus Limestone at Marion, Ohio, were described and discussed by Wright (1976). He noted the common occurrence of some species with the Dundee Formation at St. Marys, Ontario. No correlation of the Columbus was proposed in the study.

The Dundee Formation yielded the most diverse conodont fauna of any units in the Devonian of southwestern Ontario (Table 1; see also Tables 5 and 8). With the exclusion of the Pelee Island collections, the fauna includes, among other species, **Polygnathus costatus costatus** Klapper, **Parapolygnathus angusticostatus, Icriodus angustus** Stewart and Sweet, and **I.** sp. C. There appear to be two faunas represented here: the **Polygnathus costatus costatus-P.** aff. **P. trigonicus** fauna of Klapper (1971) (equivalent in part to the **costatus costatus** Zone; see Weddige, 1977, Table 3, and Klapper in Klapper and Ziegler, 1979, Fig. 4), and the overlying **Polygnathus pseudofoliatus-P.** aff. **P. eiflius** fauna of Klapper (equivalent in part to the **australis** and **kockelianus** Zones of Philip and Jackson (1973); see Klapper, 1977a, p. 45, 47, Weddige, 1977, Table 3, and Klapper in Klapper and Ziegler, 1979, Fig. 4). This is especially so when one considers the fact that at both St. Marys and Amherstburg (Stations 17 and 29; Orr, 1971, p. 104), **P. costatus costatus** occurs in the lower half of the sections. The former fauna or zone occurs in the uppermost foot (0.3 m) of the Moorehouse Member and the Seneca Member of the Onondaga Limestone, whereas the latter is present in the **Werneroceras** Bed and the Cherry Valley Member of the Marcellus Formation, all in New York (Klapper, 1971, p. 60).

In Michigan, **Polygnathus costatus costatus** is present in the lower part of the Rogers City Limestone, at its type locality (the quarry of United States Steel Corporation, at Rogers City; Bultynck, 1976, locality 1; see Ehlers and Kesling, 1970, p. 18, 26), in the interval of 2.8 to 3.1 m above the base of that unit (Bultynck, 1976, Table 1). **Polygnathus angustipennatus** Bischoff and Ziegler ranges from 3.1 to 3.8 m above the base of the formation at this locality, and its occurrence may represent the base of the **P. pseudofoliatus-P.** aff. **P. eiflius** faunal unit. In view of the facts that i) there is an overlap of these taxa at the level of 3.1 m, and ii) in the Eifelian Hills, **P. costatus costatus** ranges up to the lower part of the **australis** Zone, with the first occurrence of **P. angustipennatus** immediately above the upper range of the former (Weddige, 1977, Tables 2, 5), it seems reasonable to assign the lower Rogers City to the lower part of the **australis** Zone. The fauna, consisting primarily of species of **Icriodus,** which occurs at the top of the Rogers City, and the basal part of the Bell Shale of the Traverse Group, was considered to be of Couvinian age (Bultynck, 1976, p. 124). The underlying Dundee Formation in the Rogers City quarry carries **Icriodus angustus** which, in Ontario, occurs below and above the intervals with **Polygnathus costatus costatus** (Table 5a).

The basal part of the Elm Point Formation of southwestern Manitoba, and the upper part of the Hume Formation at Powell Creek, carry the **Parapolygnathus angusticostatus-Polygnathus curtigladius** fauna of Uyeno (1979, p. 236, 238), which is equivalent, certainly in part if

TABLE 5a

Distribution of conodonts in the Dundee Formation

LEGEND

Simple .... s
Intermediate i
Advanced .... a

FORMATION	STATION NO.	GSC LOC. NO.	*Polygnathus costatus costatus* (Pa)	*Polygnathus costatus costatus* (Pb)	*Polygnathus costatus costatus* (M)	*Polygnathus costatus costatus* (Sc)	*Polygnathus* cf. *P. costatus* (Pa)	*Polygnathus* cf. *P. costatus* (Pb)	*Polygnathus* cf. *P. costatus* (M)	*Polygnathus* cf. *P. costatus* (Sb)	*Polygnathus intermedius* (Pa)	*Polygnathus linguiformis linguiformis* (Pa)	*Polygnathus linguiformis linguiformis* (Pb)	*Polygnathus linguiformis linguiformis* (M)	*Polygnathus linguiformis linguiformis* (Sc)	*Polygnathus linguiformis linguiformis* (Sb)	*Polygnathus linguiformis linguiformis* (Sa)	*Polygnathus* aff. *P. trigonicus* (Pa)	*Polygnathus* sp. (Pa)	*Parapolygnathus angusticostatus* (Pa)	*Parapolygnathus angusticostatus* (Pb)	*Parapolygnathus angusticostatus* (M)	*Parapolygnathus angusticostatus* (Sc)	*Parapolygnathus angusticostatus* (Sb)	*Parapolygnathus angusticostatus* (Sa)	*Icriodus angustus* (I)	*Icriodus* sp. C. (I)	*Icriodus* sp. C. (S_2)	*Icriodus* sp. C. (M_2)	*Icriodus* cf. *I.* sp. A. (I)	*Icriodus* cf. *I.* sp. A. (S_2)	*Icriodus* cf. *I.* sp. A. (M_2)	*Icriodus* aff. *I. retrodepressus* (I)	*Icriodus latericrescens robustus* (I:s)	*Icriodus latericrescens robustus* (I:i)	*Icriodus latericrescens robustus* (I:a)	*Belodella* spp.	*Coelocerodontus* spp.	*Coelocerodontus* (with lateral denticles)	cf. *Coelocerodontus* spp.	*Panderodus* spp.	unassigned Pb	unassigned M	unassigned Sb	unassigned S_2	unassigned M_2	NOTE: *Icriodus latericrescens robustus* fragmentary specimens that cannot be assigned to the three morphotypes are not listed.	INTERVAL ABOVE BASE OF FM. OR *ABOVE BASE OF SECTION (m)	WEIGHT (kg)
DUNDEE	17	C-38912									21		3	1	1										2										4										0.15 - 0.30	2.0
		C-38913									25	2	1		1	1												2							2										0.55 - 0.88	2.0
		73670	1								13				1										14																				2.13 - 3.66	2.8
		C-38914									32	5	10	2	4	2									23	2	2																			2.26 - 2.41	2.0
		C-38915									32	2	9	2	3										20										1										3.11 - 3.29	2.0
		C-38916									28	5	6	3	3	6									60	1	2							1	5			1							4.15 - 4.48	2.0
		C-38917									121	11	22	5	5	5									86	9	3								10										5.36 - 5.52	2.0
		C-38918									144	5	23	1	1	6									80	40	3																			6.55 - 6.71	2.0
		C-38919									1	2		1		1			51	4	7	1		2		175	42	39								3	18	12	17	2							7.71 - 8.05	6.1
		C-38920									13	1				3			4	11		6	2	3	5	111											11	3	6	2		17		17	23		8.75 - 9.05	6.1
		C-38921									151	15	13	5	4	4									70	2	5								3										9.39 - 9.54	2.0
		C-38922																							27	4	2								1		2								10.94 - 11.13	2.0
	32	C-38962					1																			9								2										1			*0.0 - 0.37	4.0
		C-38963	13	1	5	1	4																			10							13	4		6	3		1	1				29	17		0.94 - 1.25	4.0
		C-38964					6	1																		24							1	3						1				16	2		1.55 - 1.71	4.0
		C-38965					7				2															22							3	16	2		6					3	1	4	1		2.23 - 2.53	4.0
		C-38966					13		1	1																12								14	2	5	2							5	2		2.93 - 3.29	4.0
		C-38967					10			1																17							4	4	1	2	2								1		3.60 - 3.90	4.0
		C-38968																								22							1	7		3	5				1		1	9	18		4.36 - 4.66	4.0
		C-38969									1															53							8	20	1	3	12		3					19	16		5.15 - 5.46	4.0
		C-38970																								28							1	18	2	3	5					1		32	61		5.46 - 5.97	4.0
		C-38971																								9							4	3	3		1							4	2		5.97 - 6.25	4.0
	33	C-38972					12		1									2							1	18						2	3	7			2							4	1		*0.21 - 0.37	4.0
		C-38973	3				2											2								4							2	4		1	4						1	1	3		1.10 - 1.25	4.0
		C-38974																3											20	1	2		3	6	1		1										2.10 - 2.32	4.0
		C-38975																											29				7	17	8	11	13							77	123		2.53 - 2.62	4.0
		C-38976																	1										18				1	11	2		5		3					1	1		3.32 - 3.44	4.0
		C-38977									1?							1?											8					12			2										3.84 - 3.93	4.0
		C-76601																											5					2			1							1			4.24 - 4.30	4.0

GSC

not entirely, to the **Polygnathus pseudofoliatus–P.** aff. **P. eiflius** fauna (Uyeno, 1979, and in Norris et al., in press). In turn, both faunal units are probably equivalent to the **australis** and **kockelianus** Zones (see comments above). A very similar correlation of the New York and Powell Creek faunas with the European zonation was reached independently by Klapper (in Klapper and Ziegler, 1979, Fig. 4).

In terms of the Couvinian sequence, the age of the Dundee conodonts ranges from Co2bIII to Co2d (Bultynck, 1970, Pl. 38). In the Eifelian Hills, the range of the fauna is from the middle part of the Lauch Formation to the upper part of the Junkerberg Formation, from the **costatus costatus** Zone to **kockelianus** Zone (Weddige, 1977, Table 5).

The Dundee fauna on Pelee Island (Stations 32 and 33) contains, among other species, **Polygnathus costatus costatus, P. intermedius** (Bultynck), **P.** aff. **P. trigonicus** Bischoff and Ziegler, **Icriodus angustus,** and **I.** sp. C. This represents the **P. costatus costatus–P** aff. **P. trigonicus** fauna of the **costatus costatus** Zone, the occurrences of which, in other areas, have been cited above. Based on conodont correlation, the Dundee Formation on Pelee Island may perhaps be equivalent to the lower half of that unit on the mainland.

The conodont fauna of Pelee Island, which belongs to the **costatus costatus** Zone, is distinctly younger than that in the sandy facies of the Lucas Formation at Beachville (Station 13). The latter fauna is assignable to the undivided **patulus** Zone, as noted earlier. Moreover, in terms of the New York sequence, there is a slight possibility of a hiatus between these two faunas. As noted earlier, the **patulus** Zone is undivided and, as such, may not represent the uppermost part of the zone. The intervening **Polygnathus robusticostatus** fauna of Klapper (1971, p. 60), which has been reported from the upper part of the Moorehouse Member of the Onondaga Limestone, is absent in Ontario. This fauna, however, is developed within the **costatus costatus** Zone in New York (Fig. 5), and its absence in Ontario may well be owing to ecologic factors.

The bone beds of the Columbus Limestone of central Ohio carries **Icriodus latericrescens robustus, I. angustus,** and **Polygnathus linguiformis linguiformis,** with the latter two extending into the bone beds of the overlying Delaware Limestone (Stewart and Sweet, 1956, Table 1). Ramsey (1969) reported **Polygnathus webbi** Stauffer, **I. l. robustus,** and simple cone elements from that part of the Columbus Limestone above the Bellepoint Member, also in central Ohio. **P. webbi** is probably referable to **P. costatus costatus** on the basis of BVS's collections from the uppermost part of the Columbus Limestone and lowermost part of the Delaware Limestone at the Marble Cliff quarry at San Margherita, Ohio (see Table 9 and appendix for precise locality). Other species present in these collections are **Polygnathus** cf. **P. costatus, P. l. linguiformis, I. l. robustus** and **Icriodus** sp. C. The Delaware Limestone was reported by Ramsey (ibid.) to carry **I. angustus** and **P. linguiformis.**

The conodont fauna from the uppermost part of the Columbus Limestone and the lowermost part of the Delaware Limestone in central Ohio is similar to that of the Dundee Formation on Pelee Island, and to the lower half of the Dundee on mainland. The remainder of the overlying Delaware Limestone, with **Icriodus angustus,** may suggest correlation with the upper half of the Dundee Formation in southwestern Ontario.

The above correlation differs slightly from that suggested by Oliver (1976a, Fig. 3), wherein Stauffer's (1909) Zone H (the uppermost part of the Columbus Limestone) equates with the "Columbus limestone" (=sandy facies of the

TABLE 5b

Distribution of conodonts in the Dundee Formation

LEGEND: *Simple* .... s; *Intermediate* ... i; *Advanced* ...... a

CONODONTS

NOTE: *Icriodus latericrescens robustus*: fragmentary specimens that cannot be assigned to the three morphotypes are not listed.

STATION NO.	GSC LOC. NO.	*Polygnathus* cf. *P. costatus* (Pa)	*Polygnathus linguiformis linguiformis* (Pa)	*Polygnathus linguiformis linguiformis* (Pb)	*Polygnathus linguiformis linguiformis* (M)	*Polygnathus linguiformis linguiformis* (Sc)	*Polygnathus linguiformis linguiformis* (Sb)	*Polygnathus linguiformis linguiformis* (Sa)	*Icriodus latericrescens robustus* (I:s)	*Icriodus latericrescens robustus* (I:i)	*Icriodus latericrescens robustus* (I:a)	*Icriodus latericrescens robustus* (S_2)	*Icriodus latericrescens robustus* (M_2)	*Icriodus* cf. *I.* sp. A. (I)	*Icriodus* cf. *I.* sp. A. (S_2)	*Icriodus* aff. *I. retrodepressus* (I)	*Icriodus* aff. *I. retrodepressus* (S_2)	*Icriodus* aff. *I. retrodepressus* (M_2)	*Belodella* spp.	*Coelocerodontus* spp.	*Coelocerodontus* (with lateral denticles)	*Panderodus* spp.	unassigned S_2	unassigned M_2	cf. *Coelocerodontus* spp.	INTERVAL ABOVE BASE OF FM. OR *ABOVE BASE OF SECTION (m)	WEIGHT (kg)
29	73700	1	5				1		3	3				17		5				2			4	3		0.0 - 0.61	1.6
	73699		11				1				1			4		6										0.61 - 2.44	1.6
18	C-38925		9		4	1	3									8	1	5	4	8		1				0.15 - 0.46	4.0
	C-38926		3		1														13	1		3				1.16 - 1.31	4.0
	C-38927		31	2	9	1	1	3						9		7			2	2			1			2.47 - 2.65	4.0
	C-38928		26	8	14	1	1	4						6		2			1	3		4		1	2	4.33 - 4.48	4.0
	C-38929		18	3	8	6	5	3						10	2					3						5.36 - 5.67	4.0
	C-38930		92	11	11	1	9	3						9		6			1	1		3	1	1	7	7.59 - 7.89	4.0
	C-38931		143	7	34	6	6	5						30		4				4	2		4		4	8.81 - 9.11	4.0
8	C-38844								7	5	1	10	1	2					4	14	11	3			10	*0.52 - 0.67	4.0
	C-38845								1	2	1	2							22	27	9	2			2	1.37 - 1.46	4.0
	C-38846									1										1						2.44 - 2.65	4.0
	C-38847		BARREN																							3.93 - 4.11	4.0
	C-38848		BARREN																							4.94 - 5.03	4.0
38	C-38984		BARREN																							*0.21 - 0.30	2.0
	C-38985									4	1									1						0.82 - 1.07	2.0
	C-38986									1	1									3						1.86 - 1.98	2.0
	C-38987																			2		1				2.68 - 2.83	2.0
	C-38988																			6						3.66 - 3.72	2.0

GSC

Anderdon Member, Lucas Formation) at Beachville, Ontario. This correlation further lends credence to Sanford's (1968, p. 987) contention that the Tioga Bentonite Bed occurs within the Dundee Formation (or its equivalent) in the subsurface of southwestern Ontario. In Ohio, the Tioga lies between the Columbus and Delaware Limestones (Oliver, 1976a, Fig. 3).

As noted earlier, the Bellepoint Member of the Columbus Limestone (Stauffer's Zones A to C) is correlated with the Bois Blanc and Schoharie Formations of New York, and therefore, by extension, with the Bois Blanc of Ontario. The intervening succession of the Detroit River Group may be represented in central Ohio by that part of the Columbus Limestone lying between the Bellepoint Member and the uppermost part. A similar correlation was offered previously by Oliver (1976a, Fig. 3).

The **Pelekysgnathus pedderi-Polygnathus parawebbi** faunal unit of Uyeno (1979, p. 236), present in the middle part of the Hume Formation at Powell Creek, western District of Mackenzie, and the **P. pedderi** faunal unit of Chatterton (1979), have been suggested as equivalents of the **australis** Zone by Klapper (in Klapper and Ziegler, 1979, Fig. 4) and by Klapper and Johnson (1980). This tentative correlation was achieved principally on the first occurrences of **P. parawebbi** in Nevada and in the western District of Mackenzie.

The **Parapolygnathus angusticostatus-Polygnathus curtigladius** faunal unit of Uyeno (1979, p. 236, 238) in the upper part of the Hume Formation at Powell Creek was suggested to correlate with part of the **kockelianus** Zone in Nevada (Klapper in Klapper and Ziegler, 1979, Fig. 4; Klapper and Johnson, 1980).

Hamilton Group

Definition and Distribution

The name Hamilton was introduced in New York by Vanuxem (1840) who used it as a formational term. Usage of the name as a formation or group term has varied over the years but, at present, it is accepted procedure to refer to the Hamilton Group (Sanford, 1968; Rickard, 1975; Winder and Sanford, 1972). This revised usage facilitates ease of comparison with the well known Traverse Group of Michigan. Lithostratigraphic units within the Hamilton Group are mappable over many kilometres (Telford, 1976) and can be designated quite properly as formations.

In southwestern Ontario the Hamilton Group comprises the following formations (in ascending order): Bell, Rockport Quarry, Arkona, Hungry Hollow, Widder, and Ipperwash. They form the bedrock of an irregular area extending across the southwestern Ontario peninsula from Port Glasgow on Lake Erie to Ipperwash Beach on Lake Huron. They also underlie several small areas near Petrolia, Tilbury, and Windsor. Outcrops of the group are rare and occur only along the valley of the Ausable River near Arkona and in the vicinity of Thedford and Ipperwash Beach. Only the Ipperwash, Widder, and Hungry Hollow Formations, and upper part of the Arkona Formation are exposed.

The erosional edge of the Hamilton Group forms an escarpment with up to 40 m of relief which extends partly across the southwestern Ontario peninsula (Karrow, 1973). It is mostly buried by glacial drift but forms a distinct feature of bedrock topography (see Cooper, 1976). Some surface expression of the escarpment is evident in the Thedford area. This structure is probably the result of differential erosion of the limestone and shale units within the group.

Lithology, Contacts, and Thickness

Maximum thickness of the Hamilton Group in southwestern Ontario is about 93 m (Winder and Sanford, 1972).

i) Bell Formation. The Bell Formation does not outcrop in southwestern Ontario but its distribution and lithology are well known from oil and gas well drilling records. It disconformably overlies either the Dundee or Marcellus Formation (see Fig. 4) and consists of soft, blue and grey, calcareous shale. Thin limestone lenses often occur in the lower part of the unit.

Near its type section in Alpena County, northeastern Michigan, the formation is very fossiliferous and is up to 20 m in thickness (Ehlers and Kesling, 1970). It thins southeastward to only about 10 m in the northern part of Kent County in Ontario (Sanford, 1968).

ii) Rockport Quarry Formation. No outcrops of the Rockport Quarry Formation occur in southwestern Ontario, and the unit is known only from drilling records. It consists of grey and brown, very fine grained limestone with occasional thin shale layers. In their outcrop area in northeastern Michigan the limestones and shales are highly fossiliferous. At the type locality in Alpena County, Michigan, the formation has a thickness of 13 m (Ehlers and Kesling, 1970). Elsewhere in the northern part of the Michigan Basin the formation averages about 20 m in thickness but in southwestern Ontario, near the southeastern limit of the unit, it is only about 6 m thick (Sanford, 1968).

iii) Arkona Formation. The uppermost part of the Arkona Formation is exposed in the banks of the Ausable River east of Arkona and in a clay pit at Thedford. It consists of blue-grey, plastic, clay shale with occasional thin and laterally discontinuous limestone lenses. The unit is poorly fossiliferous with only local concentrations of spiriferid brachiopods (**Mucrospirifer arkonensis** (Shimer and Grabau)) and tentaculitids. Only about 4.5 m thickness of the shales are exposed in the Thedford clay pit but a maximum thickness of 37 m is known in southwestern Ontario (Sanford, 1968). Where limestones of the Rockport Quarry Formation pinch out beneath central Lake Erie, the Bell and Arkona shales cannot be distinguished in subsurface samples. For convenience, the entire shale sequence is then termed Arkona Formation (Winder and Sanford, 1972, Fig. 2).

iv) Hungry Hollow Formation. The thin Hungry Hollow Formation is completely exposed on the banks of the Ausable River and several of its tributaries in the Arkona area, and in the Thedford clay pit. The term was introduced by Cooper and Warthin (1941, p. 260) to include the Encrinal limestone (of Shimer and Grabau, 1902) and coral bed at the base of the Widder shale. The type locality was designated as the banks of the Ausable River in Hungry Hollow, 4.0 km east of Arkona (Station 25), where the formation is 1.8 km thick. An attempt was made by Mitchell (1967, p. 177) to redefine the term by including within the formation the underlying 15 to 17.5 cm of shale and limestone beds of the Arkona Formation. A generalized sequence of the formation, following Mitchell's scheme, is as follows in descending order:

G: 70-75 cm	grey shale with abundant solitary rugose corals
F: 15 cm	grey shale with abundant brachiopod and crinoid debris
E: 30-38 cm	single bed of brown, coarse grained, crinoidal bioclastic limestone
D: 2.5 cm	grey shale
C: 15-20 cm	single bed of brown, coarse grained, crinoidal bioclastic limestone
B: 7.5 cm	black shale with abundant, flattened **Leiorhynchus** along bedding planes
A: 7.5-10 cm	dark brown, argillaceous limestone with crinoidal bioclastic debris and abundant sulphides
147-168 cm	total thickness

Units C, D and E constitute the Encrinal limestone, and G the coral bed mentioned above. In the original definition, the base of unit C marked the base of the formation. There are arguments for and against such revision. It allows for easier mapping by utilizing the occurrence of the lowest limestone bed as the base of the formation. On the other hand, the original definition is well ingrained in the literature and the Encrinal limestone is a persistent and readily identifiable unit. In sampling for the present conodont study (Stations 25 and 26; see Appendix) this tradition was carried on, and the term Hungry Hollow Formation is used in the original sense.

Irrespective of whether Cooper and Warthin's (1941) or Mitchell's (1967) definition is used, the lower boundary with the Arkona Formation is very sharp and may be disconformable. The upper boundary with the Widder Formation is somewhat gradational although the abundance of corals decreases rapidly upwards. The Hungry Hollow Formation is extremely thin compared with other Devonian units in southwestern Ontario. However, it is persistent and maintains a uniform thickness over a large area, and can be easily identified in neutron activation and gamma ray logs utilized in many of the oil and gas wells drilled in this area (Beards, 1967; Telford, 1976).

v) Widder Formation. The name Widder Formation was introduced by Stauffer (1915, p. 10). His original definition has undergone extensive revision and the term now refers to the shale-limestone sequence lying between the coral-rich upper shale unit of the Hungry Hollow Formation and limestone of the Ipperwash Formation (e.g., Winder and Sanford, 1972, p. 69). The formation contains a variety of lithologies with soft, grey, calcareous shale interbedded with blue grey, fine grained, argillaceous limestone, coarse grained, crinoidal bioclastic limestone, and several beds of nodular limestone. Shale constitutes over 50 per cent of the unit. All lithologies are fossiliferous, containing a profusion of brachiopods (e.g., **Mucrospirifer thedfordensis** (Shimer and Grabau)), bivalves, cephalopods, and trilobites (**Greenops, Phacops**). Also present are one-celled algae, **Leiosphaeridia** spp., colonial algae, and algal cysts (B. Taylor, pers. comm., 1977).

A reference section for the formation, suggested by Stauffer (1915, p. 10) in a railway cutting on the northeastern outskirts of Thedford, is now overgrown and covered with vegetation. However, excellent exposures of at least the lower two-thirds of the formation occur along the Ausable River and its tributaries near Arkona and in several isolated outcrops along Highway 7, southeast of Thedford. One section on a tributary of the Ausable River northeast of Arkona, at a locality known as "No. 4 Hill" (Stauffer, 1915, p. 10; Station 26 herein) was designated as a "lectotype" section of the Widder Formation by Wright and Wright (1961, p. 294-295). The more significant fossil taxa were listed by the latter authors (op. cit.).

The maximum exposed thickness of the formation in the Arkona-Thedford area is about 13 m. Subsurface records indicate thicknesses of up to 14 m.

As noted previously, the lower boundary with the Hungry Hollow Formation is gradational over a short distance. The upper boundary is nowhere exposed but subsurface records suggest that it is quite sharp (Beards, 1967).

vi) Ipperwash Formation. The Ipperwash Formation was defined by Stauffer (1915, p. 11). It is very poorly exposed in southwestern Ontario and the type section at Stony Point (at the northern end of Ipperwash Beach on Lake Huron; Station 28 herein) contains less than 1 m thickness of strata. These consist of medium to coarse grained, grey brown, bioclastic limestone and represent only the lowermost part of the formation. Some beds are coquinoid with a rich brachiopod fauna and crinoids, bryozoans, corals, and bivalves are also present. Chert nodules are a minor constituent. A remarkable feature of the type section is the occurrence of extremely large burrows(?) on the lower surface of the uppermost bed. These are up to 15 cm in diameter, several metres in length, and are very uniform in size and shape.

TABLE 6

Distribution of conodonts in the Hamilton Group

FORMATION	STATION NO.	GSC LOC. NO.	*Polygnathus* sp. (Pa)	*Polygnathus linguiformis linguiformis* (Pa)	*Polygnathus linguiformis linguiformis* (Pb)	*Polygnathus linguiformis linguiformis* (M)	*Polygnathus linguiformis linguiformis* (Sb)	*Polygnathus linguiformis linguiformis* (Sa)	*Polygnathus timorensis* (Pa)	*Polygnathus timorensis* (Pb)	*Polygnathus timorensis* (M)	*Polygnathus timorensis* (Sc)	*Polygnathus timorensis* (Sb)	*Polygnathus timorensis* (Sa)	*Polygnathus varcus* Group (Pa)	*Polygnathus varcus* Group (Pb)	*Icriodus brevis* (I)	*Icriodus difficilis* (I)	*Icriodus difficilis* (M_2)	*Icriodus obliquimarginatus* (I)	*Icriodus* aff. *I. retrodepressus* (I)	*Icriodus latericrescens latericrescens* (I)	*Icriodus latericrescens latericrescens* (S_2)	*Icriodus latericrescens latericrescens* (M_2)	*Oulodus* sp. (Pa)	*Oulodus* sp. (Pb)	*Oulodus* sp. (Sb)	*Oulodus* sp. (Sc)	*Belodella* spp.	*Coelocerodontus* spp.	cf. *Coelocerodontus* spp.	*Panderodus* spp.	unassigned M	unassigned Sc	unassigned Sa	unassigned S_2	unassigned M_2	INTERVAL ABOVE BASE OF FM.; OR *ABOVE BASE OF SECTION; OR **BELOW TOP OF FM. (m)	WEIGHT (kg)
ARKONA	25	C-38942	1	44											104			52			26	8											1			3	3	**0.21 - 0.30	4.0
HUNGRY HOLLOW *Encrinal Limestone		*C-38943		169											41			91			29	38							1	2	3	1				6	13	0.0 - 0.34	4.0
		C-38944		6											2							1	7	19					7	11					1			1.01 - 1.31	4.0
WIDDER		C-38945		49	2										51	3						1											2	1	1			0.0 - 0.43	4.0
		C-38946		9	1										4																							0.43 - 0.73	4.0
	26	C-38947		119	5	5	3	3	120	11	14	5	5	3			5	51							2	2	5	3								2	4	11.52 - 11.92	4.0
		73695		6																2																		10.79 - 11.28	
		C-38948		51		4			21	5	5	3		1												2		1										9.30 - 9.45	4.0
		C-38949		236	4	4			19	8	20		1	5				8	4							2	1			3								1.22 - 1.28	4.0
IPPERWASH	28	C-38950		51	1	1		3	60	1	2		2				19	94				7			1		1	4								11	3	*0.0 - 0.76	4.0

GSC

Other outcrops of the Ipperwash Formation have been reported at the southern end of Ipperwash Beach near Kettle Point (Stauffer, 1915, p. 180, 182). These, now obscured by the high lake level, represent the upper part of the formation. According to Stauffer (ibid.) and Wright and Wright (1963, p. 119-125), the lower and upper parts have different megafaunal contents, the upper being characterized by **Spinocyrtia ravenswoodensis** Ehlers and Wright, and the lower, by **S. carinata** Ehlers and Wright.

Because of the poor exposures an accurate thickness of the Ipperwash Formation cannot be determined. Subsurface records also show variation (2 to 13 m) which may have been due to irregular erosion of the limestones during the hiatus that apparently took place before deposition of the Kettle Point Formation.

Fossils, Age, and Correlation. The rich Hamilton faunas have been the subject of many studies in the past. Extensive lists, especially from around the Thedford-Arkona area, have been made by, among others, Shimer and Grabau (1902), Williams (in Parks, 1913), Stauffer (1915, p. 229-237), and Stumm and Wright (1958). Similar listings and illustrations of fossils from the Traverse Group of Michigan, a correlative of the Hamilton, were given by Ehlers and Kesling (1970). The chitinozoans and acritarchs of the Hamilton Group, as recovered from cores in three wells in southwestern Ontario, were studied by Legault (1973). Lack of similar information from Middle Devonian rocks elsewhere in the Michigan Basin precluded dating and correlation of the group based on these microfossils.

On the basis of common occurrences of **Leiorhynchus kelloggi** Hall, Driscoll et al. (1965) correlated the top of the Arkona Shale in the Thedford-Arkona area (Station 26), with the top of the Silica Shale at Sylvania, Ohio, and the Plum Brook Shale at Sandusky, Ohio. They found closer morphologic similarity in specimens of **L. kelloggi** from the east side of the Findlay Arch (i.e., from Thedford-Arkona and Sandusky) than with those from the west side (Sylvania).

The Hamilton Group of southwestern Ontario correlates with the lower and middle parts of the Hamilton of New York State. Parts of the Marcellus Shale of New York are equivalent to the Dundee Formation in Ontario, and parts of the Moscow Formation have no correlatives in Ontario. Cooper and Warthin (1941, 1942), Cooper et al. (1942, Chart no. 4), and Cooper and Phelan (1966, Fig. 2) have correlated the Hungry Hollow Formation with the Centerfield Limestone of the Ludlowville Formation, Hamilton Group, in New York; the upper part of the Alpena and Four Mile Dam Formations, Traverse Group, in Michigan; the Logansport Limestone of northern Indiana (a unit which subsequently has been placed in the Traverse Formation by Orr, 1969); Beechwood Member, North Vernon Limestone of southern Indiana and northern Kentucky (see also Orr and Pollock, 1968), and the Lingle Formation of southern Illinois (see also Orr, 1964).

The rather uniform conodont fauna of the Hamilton Group is discussed here as a single entity (see Table 6). The new forms added to, and which occur throughout, this stratigraphic interval include the **Polygnathus varcus** Group of Klapper et al. (1970), **Icriodus difficilis** Ziegler and Klapper, and **I. latericrescens latericrescens** Branson and Mehl. **Polygnathus linguiformis linguiformis** and **Icriodus** aff. **I. retrodepressus** Bultynck continue up from underlying units. The Arkona Formation carries **Polygnathus** sp., the Widder Formation, **Icriodus obliquimarginatus** Bischoff and Ziegler, and both the Widder and Ipperwash Formations have **Polygnathus timorensis** Klapper, Philip, and Jackson, and **Icriodus brevis** Stauffer.

The **varcus** Zone, originally introduced by Bischoff and Ziegler (1957), was redefined and subdivided into three units, the Lower, Middle, and Upper **varcus** Subzones, by Ziegler et al. (1976). Of these units, the conodont fauna from the outcropping part of the Hamilton Group (upper part of the Arkona to Ipperwash Formations) can be assigned entirely to the Lower **varcus** Subzone. The first occurrence of **Polygnathus timorensis** marks the base of the subzone (Ziegler et al., 1976, p. 113), and this species is present in the Widder and Ipperwash Formations, and may be present in the Arkona and Hungry Hollow Formations as well (see Table 6; on this table the lower occurrences are probably included in the **Polygnathus varcus** Group).

The Lower **varcus** Subzone is represented in the Ludlowville Formation (Centerfield Limestone and Tichenor Limestone Members) in New York, in the Beechwood Limestone in Indiana, and in the lower part of the **discoides** Kalk in Germany (Klapper et al., 1970, p. 655; Ziegler et al., 1976, p. 113). In Manitoba this subzone occurs in the Winnipegosis Formation (Norris et al., in press), and in western District of Mackenzie, it is represented in the upper part of the Hare Indian Formation (Uyeno, 1979).

Kettle Point Formation

Definition and Distribution

The name Kettle Point Formation was proposed by Caley (1943, p. 59) and later redefined by Sanford and Brady (1955, p. 7) to include "only those beds that occur between the top of the Hamilton Formation and the base of the Port Lambton beds". MacDonald (1960) provided a further detailed description of the unit. The Kettle Point Formation of southwestern Ontario is part of the widespread Upper Devonian black shale of eastern North America that is known by a variety of names, e.g., Antrim, Chattanooga, New Albany, and Ohio Shales (Oliver et al., 1968) and, in the Hudson Bay Lowlands, the Long Rapids Formation (Sanford and Norris, 1975).

The unit underlies a large portion of southwestern Ontario extending from Lake Erie to southern Lake Huron and to the St. Clair River in the west. This region lies within the downwarped area of the Chatham Sag. Outcrops of the unit are very rare because of a thick cover of Quaternary glacial and glaciolacustrine deposits and low relief of the area. The only extensive exposure is at the type locality at Kettle Point on Lake Huron and most data on the unit have come from drilling records.

Lithology, Contacts, and Thickness

The formation consists of black, highly fissile, bituminous shale with minor interbeds of grey-green silty shale. The latter interbeds gradually increase in number southeastward beneath Lake Erie (Sanford, 1968). At the type locality at Kettle Point (Station 27 herein) the shales contain a large number of subspherical and elliptical limestone concretions with diameters up to 1.2 m that are locally referred to as "kettles". They have a massive core and an outer halo of radiating calcite crystals. Elliptical pyrite nodules up to 7 cm in diameter are also common in the shale (Winder et al., 1975).

A major inadequacy of the type section is that it exposes only about 3.6 m of the black shales. Beneath southern Lake Huron the formation is approximately 75 m thick. It thins to less than 30 m in southwestern Ontario where units within the Chatham Sag have been bevelled by erosion, but thickens rapidly beneath Lake Erie to a maximum of nearly 300 m.

The Kettle Point Formation overlies the Ipperwash Formation of the Hamilton Group with sharp disconformity. The boundary is marked by a persistent 20 to 25 mm bed of dark grey or black chert. This is a basal lag bed, referred to as the "conodont hash" by Winder (1968, p. 716, Pl. 1, fig. 2), and is probably similar in origin to the phosphatic quartzose sandstone found at the very base of the Exshaw Formation (black shale), immediately above the Palliser Formation (limestone) in the Alberta Rocky Mountains (see Macqueen and Sandberg, 1970, p. 37-38). Other disconformities could be present within the Kettle Point Formation, as has been postulated for other correlative black shale units (Oliver et al., 1968, p. 1026), but Winder's study (1966) does not indicate this (see below). The upper boundary of the formation with the Port Lambton Group is not exposed in southwestern Ontario. Subsurface data suggest that there is an abrupt lithological change (Beards, 1967) but whether the boundary is disconformable has not been determined.

Fossils, Age, and Correlation

The Kettle Point fauna is small in terms of diversity as well as in number, except for **Tasmanites**, an orange or amber coloured cyst of a marine planktonic alga (Wall, 1962), which is abundant on many bedding planes. It is also present in the concretions (B. Taylor, pers. comm., 1977). Pyritized radiolarians and sponge spicules were reported by Winder (1966, p. 715) and Winder and Sanford (1972, p. 39). Rare megafossils include plant remains, the inarticulate brachiopod, **Lingula**, and fish remains. Small, unidentified brachiopods and crinoid fragments have been observed in drill cuttings (MacDonald, 1960).

Parts of a concretion ("kettle") from the type section of the Kettle Point Formation has yielded **Palmatodella quadrantinodosa quadrantinodosa** (Branson and Mehl) and **P. glabra glabra** (Ulrich and Bassler) (see Table 7). Both species are restricted to the basal Famennian, regardless of whether the Lower or the Middle **triangularis** Zone of Ziegler (1962) is considered as the base of the stage (Bouckaert and Ziegler, 1965; Bouckaert et al., 1972; Ziegler in Ziegler, ed., 1977, p. 291-292, 371-372).

Conodonts imbedded in the indurated black shale of the Kettle Point Formation at the 12-foot (3.66 m) thick type section were identified and illustrated by Winder (1962). Subsequently, a well (Stanwell-Imperial Sombra 2-6), penetrating almost the entire section of the Kettle Point Formation, was drilled at a location about 3.2 km east of Port Lambton (see Fig. 1). Some of the critical species of conodonts from this well were identified and illustrated by Klapper (in Winder, 1966). The type section of the formation was shown to correlate with the interval of 49 to 77 ft (14.94 to 23.47 m) above the base of this stratigraphic unit in the Sombra 2-6 well. In terms of the conodont zonation established by Ziegler (1958, 1962, 1971), the range of the Kettle Point conodonts extends from the Middle **asymmetricus** Zone to possibly the **costatus** Zone (Winder, 1966, Text-fig. 3), thus demonstrating that almost the entire Upper Devonian (ranging in age from early Frasnian to late Famennian) may be represented by the formation in the subsurface.

The Kettle Point is probably correlative with the greater part of the Upper Devonian sequence (Genesee to Conewango Groups) in New York. The reader is referred to Rickard (1975) for a summary of conodont zonation of the New York succession.

The lower part ("dolomite bed" and "bivalve bed") of the Squaw Bay Formation at its type locality in Michigan, carries conodonts assignable to the **dengleri** Zone (undivided; of Klapper and Johnson, 1980), whereas the fauna from the upper part ("pelmatozoan bed" and "cephalopod bed") belongs to the Lower **asymmetricus** Zone (as emended by Ziegler, 1971; Müller and Clark, 1967; Klapper et al., 1971, Fig. 3; Bultynck, 1976, Table 4). These datings suggest that the Squaw Bay at its type locality is slightly older than the

TABLE 7

Distribution of conodonts in the Bertie, Oriskany, and Kettle Point Formation

FORMATION	STATION NUMBER	GSC LOC. NO.	*Ozarkodina remscheidensis remscheidensis* (Pa)	*Ozarkodina remscheidensis remscheidensis* (Pb)	*Ozarkodina remscheidensis remscheidensis* (Sc)	*Ozarkodina* ? sp. (Pa)	*Ozarkodina* ? sp. (M)	*Palmatodella quadrantinodosa quadrantinodosa* (Pa)	*Palmatodella glabra glabra* (Pa)	*Icriodus* sp. (I)	*Icriodus* sp. (S_{2a}?)	unassigned Sa	unassigned M	INTERVAL BELOW TOP OF FORMATION (m)	WEIGHT (kg)
BERTIE	16	C-38901	5	2	1									0.0 - 2.4	5.1
KETTLE POINT	27	C-38951						3	3			1	1	concretion	4.0
ORISKANY	42	C-80199				3	1			6	2			general collection	9.7

GSC

Kettle Point Formation in the Sombra 2-6 well. According to Sanford (1968, p. 991) and Winder and Sanford (1972, p. 39), the Squaw Bay extends locally into Ontario, but is only recorded in the subsurface. In these parts of the Michigan Basin, the Squaw Bay intertongues with the basal Kettle Point, which suggests that the two units are coeval, at least in part (Sanford, 1968, p. 993).

As stated earlier in this paper, the placements of the intra-Devonian boundaries are currently under discussion by the Subcommission on Devonian Stratigraphy. In Canada the traditional and most useful level for the Middle-Upper Devonian boundary is the base of the Upper **dengleri** Subzone or the base of the **Pandorinellina insita** fauna. The second choice is the base of the Lower **asymmetricus** Zone, which coincides approximately with the base of the Assise de Frasnes (F2) in Belgium (Mouravieff and Bouckaert, 1973, Text-fig. 1; Bultynck, 1975; House and Ziegler, 1977, p. 90, Fig. 4). Should either of these alternatives be chosen, the Middle-Upper Devonian boundary will fall within or at the base of the Squaw Bay Formation in Michigan.

Port Lambton Group

Definition and Distribution

Stauffer (1915, p. 13) introduced the name Port Lambton beds although Caley (1946) included the unit within his broadly defined Kettle Point Formation which encompassed all Paleozoic strata above the Hamilton Group. Sanford and Brady (1955) showed the Port Lambton beds as distinct from the Kettle Point Formation and, subsequently, the unit was elevated to group status (e.g., Winder and Sanford, 1972). The group includes, in ascending order, the Bedford, Berea, and Sunbury Formations. There are no outcrops of these formations in southwestern Ontario and, in the subsurface, they are restricted to a small area in Lambton County, bordering the St. Clair River south of Sarnia.

Lithology, Contacts, and Thickness

i) The Bedford Formation consists of soft, grey shale which may be silty or sandy near its upper boundary with the Berea Formation. The contact is apparently gradational, although Beards (1967) noted that it is easily identified in drilling records. In the Saginaw Bay region of eastern Michigan, the Bedford Formation reaches a maximum thickness of about 60 m, and thins to less than 30 m in Lambton County, Ontario.

ii) The Berea Formation consists mainly of grey, fine to medium grained sandstone which is often dolomitic and interbedded with grey shale and siltstone. It is up to 75 m thick in eastern Michigan. Sanford (1968) noted that, in southwestern Ontario, shoestring sands of the Berea Formation have cut through the Bedford Formation and into the Kettle Point Formation, producing anomalous thicknesses of over 60 m.

iii) The Sunbury Formation consists of up to 20 m of black shales similar to those of the older Kettle Point (Ontario) and Antrim (Michigan) Formations. Where the Sunbury directly overlies the Antrim it is difficult to separate the two units. The contact between the Sunbury and underlying Berea (or Bedford) Formation is sharp and probably disconformable.

Fossils, Age, and Correlation

The age of the Port Lambton Group has been in doubt with some workers assigning it to the Late Devonian and others suggesting that it is Mississippian.

Retispora lepidophyta (Kedo) Playford has been reported from the Kettle Point Formation and the Port Lambton Group of Ontario (McGregor, 1970), and from Bedford Shale, Berea Sandstone, and Sunbury Shale in their type localities in the Appalachian Basin (de Witt, 1970). (For regional occurrence of this spore, the reader is referred to Streel, 1974. Correlations of the **lepidophyta** Zone, and its position relative to faunal zones, were shown by McGregor, 1979, Fig. 10). According to de Witt (op. cit.), the basal Bedford Shale also contains **Bispathodus aculeatus anteposicornis** (Scott), a conodont species which ranges from the **Protognathodus** fauna (of Ziegler, 1969) to the **sandbergi-duplicata** Zone of Sandberg and Klapper (1967, p. B47). The **lepidophyta** assemblage is of Fa2d to early Tn1b age (i.e., late Famennian to early Tournaisian), according to Bouckaert et al. (1969, Text-fig. 2), and Streel (1972, Table 1). In Montana, this spore assemblage has been found associated with the **praesulcata** Zone (Sandberg et al., 1972) which lies close to the Devonian-Carboniferous boundary. The **Protognathodus** fauna, which was regarded as a biofacies of the **praesulcata** Zone by Sandberg and Poole (1977, Fig. 2), similarly lies close to the upper systemic boundary (Alberti et al., 1974). As noted already in introductory remarks, the Devonian-Carboniferous boundary is currently being discussed.

CONODONT STUDY

Previous Investigations

The earliest study of Devonian conodonts of North America was by Hinde (1879), with descriptions of specimens from the black shales of the Kettle Point Formation at its type locality at Kettle Point on Lake Huron (Station 27), at Bear Creek, Lambton County, and from glacial drift deposits of these beds found on the north shore of Lake Huron. The same list of Kettle Point conodonts was given later by Stauffer (1915, p. 227, 228), and by Caley (1945, p. 49). Hinde (ibid., p. 353) also mentioned that conodonts were found "in a thin band of limestone of the Hamilton group at

Arkona, Lambton County, Ontario", probably referring to the Arkona Formation. Hinde's types, stored at the British Museum in London, were re-described and re-illustrated (with extensive retouching) by Branson and Mehl (1933b).

Much later, Stauffer (1938) described and illustrated some Middle Devonian conodonts from the Hamilton Group (Arkona, Hungry Hollow, and Widder Formations) all from the Thedford-Arkona area (including Station 25 herein). In that, as well as in an earlier study (Stauffer, 1915), he miscorrelated the Arkona Formation with the Olentangy Shale of central Ohio, an error that was corrected by Grabau (1917) and Cooper et al. (1942, Chart 4). Stauffer's (1938) paper was a natural extension of an earlier investigation, which resulted in the first comprehensive stratigraphic and faunal study of the Devonian of southwestern Ontario, and published in 1915.

The conodonts imbedded in the black shales of the Kettle Point Formation at Lake Huron were also examined by Winder (1962), and subsequently, that author (1966) examined for conodonts the 79 m thick interval of this formation encountered in the Stanwell-Imperial Sombra 2-6 well, located 3.2 km east of Port Lambton.

The known data on the distribution of various microfossils, including conodonts, in the Devonian of southwestern Ontario, were summarized by Winder (1968). In the shale pebbles of the Marcellus Formation, he noted the presence of **Polygnathus linguiformis** Hinde, a species, with the exception of some of its subspecies, that has a long range in Ontario and elsewhere.

Conodonts from the Dundee Formation at St. Marys (Station 17) were examined by Ferrigno (1968, 1971), who attempted to group them, at the form-taxonomic level, based on their stratigraphic distribution. Attempts were then made to relate these groupings to lithologic changes within the limestone sequence. A similar distribution was encountered in the present investigation (see Table 5a). Ferrigno (1971, p. 378) concluded that the conodonts suggest an Eifelian (Middle Devonian) age for the Dundee Formation.

From the same section at St. Marys, Klapper and Philip (1971) reconstructed the apparatuses of **Parapolygnathus angusticostatus** (Wittekindt) and **Polygnathus linguiformis linguiformis** Hinde, in one of the first of such endeavours dealing with Devonian conodonts.

More recently, the conodont distribution in the Devonian strata of southwestern Ontario in some of the key sections (including Stations 13, 16, 17, 25, 27, and 28 herein) was given by Uyeno in Winder et al. (1975) and Telford et al. (1977). Much of the information in the former report was the preliminary result of the present investigation.

The conodont successions of the Devonian in adjoining areas of the United States have been studied by a number of authors. Those of the Appalachian Basin have been summarized by Oliver et al. (1968, 1969), whereas accounts on that part of the basin in New York State have been given by, among others, Barnett (1972), Hass (1959), Huddle (1969, 1974), Kirchgasser (1975), Klapper (1971), Klapper and Ziegler (1967), Klapper et al. (1971), Orr and Klapper (1968), Ziegler et al. (1976), Klapper (in Klapper and Ziegler, 1979), and Klapper and Johnson (1980). Devonian conodonts of Ohio have been studied by Stewart and Sweet (1956), Ramsey (1969), and Ziegler et al. (1976, p. 117), and those of the Michigan Basin by Orr (1971), Droste and Orr (1974), and Bultynck (1976).

TABLE 8

Distribution of conodonts in the United Steel Co. DDH No. 1

LEGEND: *Simple* ..... s; *Intermediate* ..... i; *Advanced* ..... a

FORMATION	GSC LOC. NO.	DEPTH INTERVAL (m)	*Icriodus latericrescens robustus* (I;s)	*Icriodus latericrescens robustus* (I;i)	*Icriodus latericrescens robustus* (I;a)	*Icriodus latericrescens robustus* (I;fragments)	*Coelocerodontus* spp.	*Panderodus* spp.	*Belodella* spp.	*Icriodus* sp. C (I)	*Icriodus* aff. *I. retrodepressus* (I)	*Parapolygnathus angusticostatus* (Pa)	unassigned S_2	INTERVAL ABOVE BASE OF FORMATION (m)	WEIGHT (kg)
DUNDEE FORMATION	C-53292	62.94 - 64.62									1			32.00 - 33.68	1.7
		64.62 - 66.14										1		30.48 - 32.00	1.8
		66.14 - 67.36		BARREN										29.26 - 30.48	1.3
		67.36 - 68.88								2	1			27.74 - 29.26	1.5
		68.88 - 69.80									1			26.82 - 27.74	1.5
		69.80 - 70.71											1	25.91 - 26.82	2.0
		70.71 - 71.32									1			25.30 - 25.91	1.8
		71.32 - 72.24			1									24.38 - 25.30	2.0
		72.24 - 72.85									1			23.77 - 24.38	1.8
		72.85 - 73.46		BARREN										23.16 - 23.77	1.6
		73.46 - 74.37					1				3			22.25 - 23.16	1.9
		74.37 - 75.29							1		1			21.33 - 22.25	1.9
		76.81 - 77.42					12		1		1	1		19.20 - 19.81	1.6
		78.94 - 79.55					1							17.07 - 17.68	1.5
		81.08 - 81.69								1	1			14.94 - 15.54	1.8
		83.21 - 83.82								1				12.80 - 13.41	2.0
		85.34 - 85.95							10	1				10.67 - 11.28	1.7
		87.48 - 88.09					3		6					8.53 - 9.14	1.1
		89.61 - 90.22			2		1	1	5					6.40 - 7.01	1.1
		91.74 - 92.35		BARREN										4.27 - 4.88	1.5
		93.88 - 94.49		BARREN										2.13 - 2.74	1.5
		96.01 - 96.32		BARREN										0.30 - 0.61	0.8
		96.32 - 96.62		BARREN										0.0 - 0.30	1.1
DETROIT RIVER GROUP AMHERSTBURG FORMATION		96.62 - 96.93		BARREN										24.69 - 25.00	0.6
		96.93 - 97.23		BARREN										24.39 - 24.69	0.7
		98.76 - 99.36		BARREN										22.26 - 22.86	1.4
		100.89 - 101.50		2										20.12 - 20.73	2.5
		103.02 - 103.63	1											17.99 - 18.60	2.0
		105.16 - 105.77		BARREN										15.85 - 16.46	0.5
		107.29 - 107.59	1											14.03 - 14.33	1.6
		109.12 - 109.73		BARREN										11.89 - 12.50	1.9
		111.25 - 111.86		BARREN										9.76 - 10.37	1.1
		113.39 - 114.00				3								7.62 - 8.23	1.6
		114.91 - 115.52			1									6.10 - 6.71	1.7
		115.52 - 116.13		BARREN										5.49 - 6.10	1.6
		116.13 - 116.74	1	3			1							4.88 - 5.49	0.7
		116.74 - 117.04		BARREN										4.58 - 4.88	1.4
		117.04 - 117.65		8										3.97 - 4.58	1.6
		117.65 - 118.26		1										3.36 - 3.97	1.9
		118.26 - 118.87			1									2.75 - 3.36	1.8
		118.87 - 119.48				1								2.14 - 2.75	1.5
		119.48 - 120.40			1									1.22 - 2.14	1.9
		120.40 - 121.01			1									0.61 - 1.22	1.6
		121.01 - 121.62		1	2									0.0 - 0.61	1.6
BOIS BLANC FORMATION		121.62 - 122.22	1	5	2									20.12 - 20.72	1.5
		122.22 - 122.83		8	2									19.51 - 20.12	1.7
Springvale Member		122.83 - 123.44		1										18.90 - 19.51	1.1
		132.89 - 133.50		BARREN										8.84 - 9.45	1.4
		135.03 - 135.64		BARREN										6.70 - 7.31	1.3
		137.16 - 137.77		BARREN										4.57 - 5.18	1.6
		139.29 - 139.90		BARREN										2.44 - 3.05	1.2
		141.43 - 142.04		BARREN										0.30 - 0.91	1.4

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Summary of Conodont Biostratigraphy

Parts of the following brief summary have been previously mentioned under the separate headings of individual formations. Refer to Table 1 and Figure 5.

The sparse and highly fragmented conodont collection from the Oriskany Formation can be dated only questionably as Pragian. The specimens are too poorly preserved to allow any precise identification.

The succeeding Bois Blanc Formation and the Amherstburg Formation, including the Formosa Reef Limestone Member, of the Detroit River Group contained a low diversity conodont fauna dominated by a long-ranging species, **Icriodus latericrescens robustus.** The fauna is assignable to the **robustus** Zone, a probable biofacies equivalent, at least in part, of the **serotinus** Zone and possibly of the **patulus** Zone as well. The **serotinus** Zone has been dated as late Emsian (Weddige, 1977, Table 2; Klapper et al., 1978, Fig. 2).

The upper unit of the Detroit River Group, the Lucas Formation, was found to be highly variable in conodont productivity. The Lucas, in its restricted sense, i.e., the laminated dolostone facies, yielded only three fragmented specimens. The very high purity limestone facies, the Anderdon Member, was similarly impoverished. The sandy facies of the Anderdon Member (the so-called "Columbus limestone" of authors), however, was relatively rich in conodonts. They are assignable to the undivided **patulus** Zone, and represent the same fauna as that reported from the Nedrow Member of the Onondaga Limestone in New York by Klapper (1971).

The diverse conodont fauna of the Dundee Formation is assignable to three conodont zones: the **costatus costatus** Zone in the lower part, and the **australis** and **kockelianus** Zones in the upper. The **costatus costatus** Zone and the underlying **patulus** Zone play a critical role in the current discussion on the placement of the Lower-Middle Devonian boundary (e.g., see Klapper et al., 1978, Fig. 2, p. 106-107). The Dundee correlates with the uppermost part of the Moorehouse Member, the Seneca Member, both of the Onondaga Limestone, and the lower part of the Marcellus Formation (the Cherry Valley Member and the **Werneroceras** bed of the Union Springs Member) of New York (Klapper, 1971). In Michigan, the Dundee correlatives are the Dundee Formation and at least a part of the overlying Rogers City Limestone.

Only the outcropping part of the Hamilton Group was studied, i.e., the interval from the upper part of the Arkona Formation to the Ipperwash Formation. The well-preserved, abundant and relatively diverse conodont fauna is assignable to the Lower **varcus** Subzone, of Givetian age. The same fauna occurs in the Centerfield and Tichenor Limestones of the Ludlowville Formation, Hamilton Group, in New York (Ziegler et al., 1976), and in the outcropping part of the Winnipegosis Formation in Manitoba.

The Squaw Bay Formation was not studied because in Ontario it is a thin unit, only known in the subsurface. In the type area in Michigan, its conodonts are assignable to the undivided **dengleri** Zone and Lower **asymmetricus** Zone (a.o., Bultynck, 1976, Table 4).

The conodonts of the Kettle Point Formation range from the Middle **asymmetricus** Zone to possibly the **costatus** Zone (Winder, 1962; Klapper in Winder, 1966). Almost the entire Upper Devonian (early Frasnian to Famennian age) is represented by the formation in the subsurface.

The overlying Port Lambton Group which, in Ontario, is known only in the subsurface, was not included in the study.

Paleoecological Interpretation

In recent years, the environmental conditions in which conodont-bearing animals lived has come under intensive study. A symposium volume on conodont paleoecology has been published (C.R. Barnes, editor, 1976), but its conclusions are far from clear or consistent (see Klapper and Barrick, 1978). The following discussion is presented with the hope that it will add information to this intriguing subject. Two points should be noted: i) the authors' names of different taxa are given only in their first mention, and ii) the nominate subspecies **Polygnathus linguiformis linguiformis** Hinde is identical with the gamma morphotype of Bultynck (1970) and is used in this sense (see under Systematic Paleontology).

The Devonian strata of southwestern Ontario were deposited on a shallow platform, in warm equatorial to low latitudinal waters, and at times even under arid and subaerial conditions (see Ziegler et al., 1979, Fig. 5; Klapper and Johnson, 1980, Fig. 5), with possible deepening in Late Devonian times. This resulted in an initial conodont population of rather provincial aspect, especially in the Bois Blanc and Amherstburg times, with abundance of specimens of **Icriodus latericrescens robustus** Orr.

In terms of biostratigraphy, the conodont faunas of the Bois Blanc and Amherstburg Formations are similar. With regards to paleoecological interpretation, however, there appear to be some slight differences. In the Bois Blanc fauna specimens of **Icriodus latericrescens robustus** are relatively more abundant than in the Amherstburg fauna. Simple cone elements, such as **Belodella** spp., represent Biofacies I, according to Druce (1973), whereas **Icriodus latericrescens** subspp. occur in Biofacies II or III. In a picture combining a model of simple vertical stratification (Seddon and Sweet, 1971) with relative abundancy within these layers, the upper (shallow) interval was termed Biofacies I, the intermediate layer, Biofacies II, and the lower (deep) interval, Biofacies III. If Druce's suggestions were followed, then, one might conclude that the Bois Blanc fauna existed in a slightly deeper water environment than that of the Amherstburg. Evidence presented below, shows that the paleoecology of **I. latericrescens** subspp. was more complex than this.

The conodont fauna in the Formosa Reef Limestone of the Amherstburg Formation is typically that found near biohermal buildups, in shallow water environments. It consists predominantly of very thin-layered forms of coelocerodontids and simple icriodontids (**Icriodus hankae,** n. sp.), and some complex icriodontids (**Icriodus latericrescens robustus**).

The exceptionally pure limestone of the Anderdon Member of the Lucas Formation was found to be essentially barren of conodonts. An obvious conclusion is that the Anderdon was deposited in an environment that was totally inhospitable to the conodont animal, perhaps in extremely shallow waters, as suggested by the lithology. Yet the Anderdon carries a moderately diverse megafauna, notably of rugose tabulate corals.

The sandy facies of the Anderdon Member, Lucas Formation ("Columbus limestone" of Ehlers and Stumm, 1951) at Station 13 herein, yielded a relatively rich conodont fauna, suggesting a return to a more "normal", open marine platform environment, of at least intertidal, or more probably subtidal, depth (Biofacies II of Druce, 1973). This facies is developed only locally, with a highly diachronous relationship with the enveloping Anderdon beds (Winder and Sanford, 1972, p. 67).

The Dundee-time was a continuation of the open marine platform environment. It was also a time of the greatest conodont proliferation (in terms of diversity) during the Devonian of southwestern Ontario. A possible exception to this might be the Kettle Point fauna, which is still incompletely known.

Icriodus latericrescens robustus is sparsely represented in the Dundee Formation, and was replaced, to a certain degree, by "simple" icriodontids (**Icriodus angustus** Stewart and Sweet, **I.** cf. **I.** sp. A, and **I.** sp. B). This change suggests a shift from Biofacies II to III, to more basically II, in the scheme of Druce (1973).

Icriodus latericrescens robustus and **Polygnathus linguiformis linguiformis** Hinde are mutually exclusive in the Dundee Formation, with the exception of two samples from Station 29 at Amherstburg (see Tables 5a, b), and the lowermost 0.3 m at St. Marys (Station 17 herein; Ferrigno, 1968, p. 62-63). One notes that Station 29 is situated on the Findlay Arch, whereas Station 17 is on the Algonquin Arch (Figs. 1 and 2), both localities which were probably under the influence of both the Michigan and Allegheny Basins. Those sections with **I. l. robustus** only include Stations 32 and 33 on Pelee Island, and 8 and 38 in Haldimand County, all located within the Allegheny Basin. Station 18, near Goderich and in the Michigan Basin, on the other hand, has only **P. l. linguiformis.**

Extending into New York, and going ever farther into the Allegheny Basin, the Dundee-equivalent strata of Seneca and Moorehouse Members of the Onondaga Limestone (with **Polygnathus costatus costatus-P.** aff. **P. trigonicus** fauna of Klapper, 1971, p. 60) similarly and almost exclusively carry **I. latericrescens robustus,** with the exception of a single specimen of **P. linguiformis linguiformis** in the basal part of the Seneca Member (Klapper, 1971, Tables 1, 3 and 4).

An exact reversal of the Seneca-Moorehouse Members occurs in the **Werneroceras** bed and the Cherry Valley Member of the Marcellus Formation in New York. These beds carry the **Polygnathus pseudofoliatus-P.** aff. **P. eiflius** fauna of Klapper (1971, p. 60), and so are here considered to be correlative, at least in part, with the upper part of the Dundee Formation of Ontario (Fig. 5). **P. linguiformis linguiformis** occurs in great profusion in this interval, almost to the total exclusion of **I. latericrescens**; a single specimen of undetermined subspecies, was found in the Cherry Valley Member (Klapper, 1971, Table 5; Ziegler et al., 1976, p. 115).

The bone beds of the Columbus Limestone of central Ohio have yielded both **I. latericrescens robustus** and **P. linguiformis linguiformis,** whereas in the bone beds of the overlying Delaware Limestone the former subspecies was found to be missing (Stewart and Sweet, 1956). Ramsey (1969), on the other hand, reported **P. l. linguiformis** from the Delaware Limestone only, a result which is in accordance with BVS's collections from the basal part of the unit in central Ohio (Marble Cliff quarry at San Margherita; Table 9).

Moving west and northward into the Michigan Basin and completing the circle, **P. linguiformis linguiformis** is present to the exclusion of **I. latericrescens robustus** in the Detroit River Formation of northeastern Indiana (Orr, 1971; Droste and Orr, 1974, Fig. 2), and in the Dundee Formation and Rogers City Limestone of northern Michigan (Bultynck, 1976, Table 1).

In the Moose River Basin of Ontario and Quebec, which lies north of the Algonquin Arch, the correlative of Dundee Formation is the Murray Island Formation. It is interesting to note that the latter carries **P. linguiformis linguiformis,** but not **I. latericrescens robustus** (Uyeno in Sanford and Norris, 1975, Table 16).

It is difficult to draw any firm conclusion from the above account on the distribution of **I. latericrescens robustus** and **P. linguiformis linguiformis.** With exception of the Texas and Great Basin occurrences (Merrill, 1966; Ziegler et al., 1976, p. 115; Klapper, 1977a, p. 45), **robustus** is restricted to eastern North America, whereas **linguiformis linguiformis** is known for its ubiquity (regional distribution of these conodonts has been summarized by Klapper in Ziegler, ed., 1975, p. 133-134, 466-470). Their virtually mutual exclusion suggests that perhaps they competed for similar ecological niches during Dundee-time, and/or that **robustus** preferred the normal salinity (?) waters of the Allegheny Basin to the slightly more saline (?) environment of the Michigan Basin. The latter possibility is suggested by the

TABLE 9

Distribution of conodonts in the Columbus and Delaware Limestones, central Ohio

FORMATION	GSC LOC. NO.	*Polygnathus costatus costatus* (Pa)	*Polygnathus* cf. *P. costatus* (Pa)	*Polygnathus linguiformis linguiformis* (Pa)	*Polygnathus linguiformis linguiformis* (Sb)	*Polygnathus linguiformis linguiformis* (Sa)	*Icriodus* sp. C (I)	*Icriodus latericrescens robustus* (I)	*Coelocerodontus* spp.	cf. *Coelocerodontus* spp.	unassigned S_{2a}	INTERVAL ABOVE BASE OF FM. OR * BELOW TOP OF FM. (m)	WEIGHT (kg)
Columbus Ls.	C-74389	4	6				10	4	1	1	1	*1.5	2.2
Delaware Ls.	C-74388	1		25	1	1	1	8		1	1	1.5	2.3

GSC

fact that in the Michigan Basin at the close of the Amherstburg time, restrictive conditions set in with the resulting deposition of evaporites of the Lucas Formation. Although these conditions were largely removed prior to deposition of the Dundee Formation, a slightly saline condition still prevailed (Sanford, 1968, p. 983; pers. comm., March 1979).

An ecological change appears to be one of the more obvious factors to account for the faunal difference in the transition from the Seneca-Moorehouse Members to the lower Marcellus Formation in New York (i.e., from **robustus** to **linguiformis linguiformis**). The Cherry Valley Limestone represents more offshore, deeper water deposits, according to Boucot (1975, p. 336). Such a shift in the conodont population is in accordance with the finding of Weddige and Ziegler (1976). The preference of **I. latericrescens latericrescens,** the probable successor to **robustus** (Klapper and Ziegler, 1967, p. 73), to the relatively shallow water environment was suggested by Ziegler et al. (1976, p. 115).

Although the above discussion has centred around the fauna of the Dundee Formation of Ontario and its correlatives in neighbouring areas, similar cases on the distribution of **linguiformis linguiformis** and **robustus** may be presented, at least within southern Ontario and New York, for the underlying beds as well (Lucas Formation, Detroit River Group, and Nedrow Member, Onondaga Limestone). However, this case of mutual exclusion no longer holds for younger beds than the Dundee and its correlatives, and which carry the nominate subspecies. The Hamilton Group of Ontario, the Tully Limestone of New York (Ziegler et al., 1976, Tables 1-4), and the Traverse Group of Michigan (Orr, 1971) all have **P. linguiformis linguiformis** together with **I. latericrescens latericrescens.** Perhaps the environmental conditions were more suitable for the simultaneous existence of the two subspecies, or the latter subspecies was more eurytopic than its predecessor, **robustus** (as evidenced by its widespread distribution; see Klapper in Ziegler, 1975, p. 128-129), and was able to successfully compete with **P. linguiformis linguiformis.** There seems to be no simple answer in attempting to unravel what is obviously the result of a complex and multiple set of interplaying factors.

The open marine platform environment persisted throughout deposition of the Hamilton Group. The Kettle Point time probably represented relative deepening, although plant remains in it suggest proximity to land (see Winder, 1966, p. 1288-1290 for environmental interpretation). The fauna in the Late Devonian shales is characterized by the genus **Palmatodella,** probably belonging to the palmatolepid-polygnathid biofacies of Sandberg (1976, p. 181-182) and to Biofacies III of Druce (1973, p. 215).

Organic Diagenesis (Conodont Colour Alteration)

Epstein et al. (1977) and Harris et al. (1978) arranged the conodonts of different colours in an order of increasing darkness, grouped them according to similarity in darkness, and then assigned each set a value of colour alteration index (CAI). They demonstrated that the colour changes are directly related to the depth and duration of burial, and geothermal gradient, and that the different colours of conodonts, therefore, can be used as a tool to assess organic diagenesis or thermal maturity of the host rock. The conodont CAI values were correlated with vitrinite reflectance and fixed carbon ranges. Using the Appalachian Basin as their test model, they found that a CAI value of 1.5 coincides with that level of organic metamorphism above which there is no known commercial oil and condensate production. However, the upper thermal limits, inferred from conodont CAI values, for oil production for different stratigraphic intervals are not the same everywhere (Epstein et al., 1977, p. 24).

The relationship between the CAI and the degree of organic diagenesis may be related, aside from being dependent on temperature, to variations in the host rock and the history of burial. For these reasons, Epstein et al. (1977, p. 15) limited their study to one rock type, namely limestone, in order to eliminate the unknown effect of host rock texture and composition on the colour alteration of conodonts.

Although only limestone was digested for conodonts for this study (with the single exception of a sandstone sample from the Oriskany Formation), there were wide variations in lithologies. They included: cherty, microsucrosic dolostone and dolomitic limestone (e.g., Bois Blanc Formation), coarse-grained coral bioclastic limestone (e.g., Amherstburg Formation), micritic limestone matrix within reefal or biohermal buildup (Formosa Reef Limestone), sandy limestone (part of the Anderdon Member, Lucas Formation), thick-bedded, highly fossiliferous, micritic limestone (e.g., Dundee Formation), and limestone concretions (Kettle Point Formation).

The degree to which certain contents, such as clay or carbon, may have influenced the coloration of conodonts is open to speculation, but probably was minimal. This is suggested by the fact that the CAI values of these Ontario Devonian conodonts are within fairly narrow limits, ranging from 1 (Formosa Reef Limestone, and Widder and Ipperwash Formations of the Hamilton Group), 1.5 (Kettle Point concretions), and 1.5 to 2 (Oriskany, Bois Blanc, Amherstburg, Lucas (including Anderdon Member), and Dundee Formations, and Arkona and Hungry Hollow Formations of the Hamilton Group). Conodonts from the Amherstburg Formation at Station 36 may possibly have a CAI value of 2, which would make them the darkest, and therefore presumably the most highly metamorphosed, conodonts in the study. On interpreting these CAI values in terms of the results of Epstein et al. (1977, Fig. 5), the Devonian rocks of southwestern Ontario were apparently subjected to temperatures ranging from mostly 50 to 90°, to as high as 60 to 140°C.

A study is currently being conducted on the organic diagenesis (with the use of conodont CAI) of Paleozoic rocks in southern Ontario (Barker et al., 1979). In it, attempts are being made to collate organic diagenesis with the results of organic geochemistry and carbon isotopes. In a preliminary study, based on two deep wells in southwestern Ellesmere Island, Canadian Arctic Archipelago, Mayr et al. (1978, p. 397) found that there was no obvious direct relationship between the CAI and organic source rock potential, the latter representing the yield of liquid hydrocarbons as a percentage of the total organic carbon.

Systematic Paleontology

The type and figured specimens are deposited in the collections of the Geological Survey of Canada.

CONODONTA

Family Polygnathidae Bassler, 1925

Type genus. **Polygnathus** Hinde, 1879.

Genus **Ozarkodina** Branson and Mehl, 1933a

Type species. **Ozarkodina confluens** (Branson and Mehl, 1933a) [=**Ozarkodina typica** Branson and Mehl, 1933a].

Ozarkodina remscheidensis remscheidensis (Ziegler)

Plate 1, figures 1-3

Spathognathodus remscheidensis Ziegler, 1960, p. 194-196, Pl. 13, figs. 1, 2, 4, 5, 7, 8, 10, 14 (Pa); Link and Druce, 1972, p. 92-93, Pl. 10, figs. 1-7, text-fig. 60 (Pa); Savage, 1973, p. 329, figs. 19-29, 33-42, text-figs. 28A, B (Pa).

Hindeodella steinhornensis remscheidensis (Ziegler), Jeppsson, 1974, p. 35.

Ozarkodina remscheidensis remscheidensis (Ziegler), Klapper in Ziegler, ed., 1973, p. 241-242, **Ozarkodina** Pl. 2, fig. 4 (Pa) (includes synonymy); Klapper and Murphy, 1975, p. 41-43, Pl. 7, figs. 22, 25-30 (Pa) (includes additional synonymy); Mehrtens and Barnett, 1977, p. 497, Pl. 1, figs. 7, 10 (Pa); Chatterton and Perry, 1977, p. 789-791, Pl. 3, figs. 28-35, Pl. 4, figs. 24, 26, 31, 33-36 (multielement); Klapper and Johnson, 1980, Tables 1, 2; Uyeno, in press, p. 41-42, Pl. 3, figs. 1-12, 21-23, 29-38 (multielement).

Ozarkodina remscheidensis (Ziegler), Savage, 1976, p. 1182, Pl. 1, figs. 1-15 (multielement).

Remarks. At Požárech Quarry in Bohemia, Czechoslovakia, the lowest level at which **Ozarkodina remscheidensis remscheidensis** is the more dominant of the two subspecies [the other being **O. remscheidensis eosteinhornensis** (Walliser)], is at 5.4 m above the base of the Lochkov Limestone (Mehrtens and Barnett, 1977). In New York State, on the other hand, these authors (see also Barnett, 1971, 1972) found that only the nominate subspecies, to the exclusion of **O. remscheidensis eosteinhornensis**, is present in strata of late Pridolian-early Lochkovian age.

Based primarily on the prominence of the cusp and the denticles at the anterior end of the blade, Chatterton and Perry (1977, p. 790-791) subdivided **Ozarkodina remscheidensis remscheidensis** into three morphotypes, alpha, beta and gamma. These morphotypes were believed to have stratigraphic significance as well. Of the three, the Bertie specimens are closest to the alpha morphotype, which also includes the holotype specimen of the subspecies.

Occurrences. **O. remscheidensis remscheidensis** was recovered only from the uppermost 0.24 m of strata of the Bertie Formation at an abandoned quarry at Innerkip (Station 16). Telford et al. (1977, p. 4, Tables 1, 2) reported **Ozarkodina** sp. (possibly **O. remscheidensis**, including Pa, Pb, M, Sb and Sc elements), from the Bois Blanc Formation at their localities 1 and 2 (1=quarry of G.C. Campbell Co. Ltd., not studied herein; 2=quarry of Ridgemount Quarries Ltd., Station 4 herein). The curious aspect of these occurrences is that at both localities the intervals carrying **Ozarkodina** sp. are not in immediate contact with the unconformably underlying Bertie Formation. Rather, these intervals occur at 1.6 to 1.9 m and 0.5 to 0.7 m above the top of the Bertie Formation, at Localities 1 and 2, respectively (Telford et al., 1977, p. 11; Tarrant, pers. comm., Jan. 1978). At both localities, there are intervening clastic units between the limestone beds of the Bois Blanc Formation, which yielded **Ozarkodina** sp., and the dolostone beds of the Bertie Formation.

Figured specimens. GSC 56162 to 56164, Station 16.

Genus **Palmatodella** Bassler, 1925

Type species. **Palmatodella delicatula** Bassler, 1925.

Remarks. The apparatus of **Palmatodella** was modified by Philip and McDonald (1975, p. 101, 103-104), so that the Pb element is ozarkodinan or palmatodellan and the M, lippertiform. The Sa element was considered to be highly variable, ranging from diplododellan through scutulan to tripodellan. Following their practice, the genus **Palmatodella** is used herein to include those apparatuses with a palmatolepan Pa element.

Pa elements of two species of **Palmatodella** were recovered from a part of a concretion from the Kettle Point Formation at its type section: **P. quadrantinodosa quadrantinodosa** (Branson and Mehl) and **P. glabra glabra** (Ulrich and Bassler). Of these, only the former is dealt with herein; the latter is too minute for adequate illustration.

Palmatodella quadrantinodosa quadrantinodosa

(Branson and Mehl)

Plate 5, figure 17

Palmatolepis quadrantinodosa Branson and Mehl, 1934, p. 235-236, Pl. 18, figs. 3, 17, 20 (Pa).

Palmatolepis quadrantinodosa quadrantinodosa Branson and Mehl, Winder, 1966, Pl. 156, fig. 7 (Pa); Ziegler in Ziegler, ed., 1977, p. 371-372, **Palmatolepis** Pl. 8, figs. 10-16 (Pa) (includes synonymy).

Remarks. Three specimens of the Pa element of **Palmatodella quadrantinodosa quadrantinodosa** were obtained. Conodonts from the shale beds of the Kettle Point Formation at its type section were first described by Winder (1962). Some representative species of this fauna were illustrated by sketches, and **P. quadrantinodosa quadrantinodosa** may be represented by the Text-fig. 1:2 of that reference. In a more complete subsurface section of the Kettle Point Formation in the Stanwell-Imperial Sombra 2-6 well (located 3.2 km west of Port Lambton, Ontario), Winder (1966, Pl. 1, fig. 7, Table 1) reported this subspecies in the interval of 22.56 to 25.60 m above the base of the formation.

Range. According to Ziegler (1971, Chart 6; in Ziegler, ed., 1977, p. 372), **P. quadrantinodosa quadrantinodosa** ranges from the uppermost part of the **rhomboidea** Zone through the Lower **marginifera** Zone, both of Ziegler (1962).

Genus **Pandorinellina** Müller and Müller, 1957

Pandorina Stauffer, 1940, p. 428.

Pandorinellina Müller and Müller, 1957, p. 1082-1083.

Type species. **Pandorina insita** Stauffer, 1940.

Pandorinellina? sp. B.

Plate 1, figure 4

Remarks. A single Pb element that may possibly belong to a **Pandorinellina** apparatus, was recovered from the Bois Blanc Formation at Station 7. It is a small and fragmentary specimen and, consequently, detailed comparison with previously described Pb elements of **Pandorinellina** is difficult to make. The general morphology, especially the recurved cusp, is vaguely similar to the Pb element of **Pandorinellina** n. sp. A of Uyeno and Mason (1975, Pl. 1, fig. 8).

Figured specimen. GSC 56165, Station 7.

Genus **Polygnathus** Hinde, 1879

Type species. **Polygnathus dubius** Hinde, 1879.

Polygnathus costatus Klapper

Remarks. Four, and possibly five, subspecies of **Polygnathus costatus** have been recognized thus far: the nominate subspecies, **P. costatus oblongus** Weddige, **P. costatus partitus** Klapper, Ziegler and Mashkova, and **P. costatus patulus** Klapper. The possible fifth subspecies is **P. costatus** n. subsp. A of Chatterton (1979, p. 192). Of these, **P. costatus costatus** and **P. costatus patulus** were initially based on material collected in the New York State (Klapper, 1971, p. 62-63) with the former being present in southwestern Ontario strata as well. A transitional form between **P. costatus patulus** and **P. cooperi cooperi** was also recovered in the present study. A form provisionally referred to **P. costatus** is illustrated on Plate 1, figures 5-9 (see under **P. costatus costatus** for details).

Polygnathus costatus costatus Klapper

Plate 1, figures 11-17, 24, 25

Polygnathus costatus costatus Klapper, 1971, p. 63, Pl. 1, figs. 30-36, Pl. 2, figs. 1-7 (Pa); van den Boogaard, 1972, p. 6, Pl. 1, figs. e-h; Klapper in Ziegler, ed., 1973, p. 347-348, **Polygnathus** Pl. 1, fig. 3 (Pa) (includes synonymy); Klapper in Perry et al., 1974, p. 1087, Pl. 7, figs. 1-7, 10 (Pa); Bultynck, 1976, fig. 2, Table 1; Weddige and Ziegler, 1977, fig. 1, p. 75; Klapper, 1977a, fig. 2, p. 45; Klapper, 1977b, Table 1; Weddige, 1977, p. 309, Pl. 4, figs. 75, 76, text-fig. 4(6) (Pa); Klapper et al., 1978, Pl. 2, figs. 10-12 (Pa); Chatterton, 1979, p. 192, Pl. 8, figs. 2, 4, 3? (Pa); Klapper and Johnson, 1980, Tables 7, 8.

(?) **Polygnathus costatus costatus** Klapper, Savage, 1977, p. 1350, 1352, Pl. 3, figs. 13-16 (transitional to **Polygnathus parawebbi** Chatterton) (Pa).

(non) **Polygnathus costatus costatus** Klapper, Uyeno in Uyeno and Mayr, 1979, p. 238, Pl. 38.1, figs. 13-15, 20, 27-33 (=**P. c. partitus** Klapper, Ziegler and Mashkova) (Pa).

Remarks. Klapper (in Perry et al., 1974, Pl. 7, fig. 10) illustrated a Pb element of **Polygnathus costatus costatus**, from the Ogilvie Formation of Yukon Territory. Although there are similarities, detailed comparison of the Ontario specimen with that from the Yukon is difficult to make as the former is fragmentary. The Ontario collection also yielded the accompanying M and Sc elements.

Present in the Dundee Formation (Tables 5a, b) are Pa elements (illustrated on Pl. 1, figs. 5-9) that are close to those identified as **P. costatus costatus** from adjacent beds, but differ mainly in exhibiting deeper adcarinal grooves on a slimmer platform. These specimens differ from **Polygnathus parawebbi** Chatterton in lacking a prominent flange-like development on the outer margin of the platform, and a platform which has a sharp inward bend in its posterior third (Chatterton, 1974, p. 1473; Klapper in Ziegler, ed., 1977, p. 477). Similarly narrow platforms, however, occur on those Pa elements of **P. costatus costatus** from the Ogilvie Formation of northern Yukon, illustrated by Klapper (in Perry et al., 1974, Pl. 7, figs. 1, 3, 4), and from the Landry Formation of western District of Mackenzie, illustrated by Chatterton (1979, Pl. 8, figs. 2, 4).

The illustrated specimen from the Wadleigh Limestone of southeastern Alaska (Savage, 1977) appears to be a transitional form to **Polygnathus parawebbi** Chatterton.

Occurrences. Dundee Formation (Table 5a). Orr (1971, p. 104) also reported **Polygnathus costatus costatus** from the Dundee Formation at Amherstburg, Ontario (Station 29 herein). In adjoining areas of northern Michigan, it has been reported from the lower Rogers City Limestone (Bultynck, 1976, fig. 2, Table 1), in northern Indiana from the Detroit River Formation (Orr, 1971, p. 55), and in BVS's collections from the uppermost part of the Columbus Limestone and the lowermost Delaware Limestone of central Ohio (Table 9). Elsewhere the species occurs in the Ogilvie Formation of northern Yukon Territory (Klapper in Perry et al., 1974, p. 1087), and in the lower thrust plate sequences in central Nevada (Klapper, 1977a). In the Eifelian Hills of Germany, the species spans from the upper Lauch to lower Ahrdorf Beds (=Formations of Struve, 1976) (Weddige, 1977, Table 5). In the type Couvinian of the Ardennes, it spans from Co2bIII to Co2cIII (Bultynck, 1970, Pl. 38). Klapper (1977b, Table 1) and Klapper et al. (1978, Fig. 1) noted its occurrence in the basal Chotec̆ Limestone in the Barrandian of Czechoslovakia. The reader is referred to Klapper (in Ziegler, ed., 1973, p. 347-348) and Klapper and Johnson (1980, Tables 7, 8) for other occurrences.

Figured specimens. GSC 56172 to 56176, Station 32; 56177, Station 33, and 56178, Station 17.

Polygnathus costatus patulus Klapper → **P. cooperi cooperi** Klapper

Plate 1, figures 10, 18-23, 32-34

Polygnathus costatus patulus Klapper → **P. linguiformis cooperi** Klapper, Klapper, 1971, p. 65, Pl. 1, figs. 10-16, Pl. 2, figs. 16, 17 (Pa).

Remarks. The Ontario Pa specimens of this transitional form are close to those from New York (Nedrow and the middle part of the Moorehouse Member of the Onondaga Limestone, reported by Klapper, 1971). The transverse ridges at the posterior end of the platform are only incipiently developed. Six specimens were recovered from the sandy facies of the Lucas Formation, Detroit River Group (see Table 4b).

Except for two samples, the New York occurrences of the transitional form are below the lower range of **P. costatus costatus** Klapper. The two exceptions are in the upper part of the Nedrow Member (Loc. 6, sample no. 8), and the middle part of the Moorehouse Member (with the **Polygnathus robusticostatus** fauna; Loc. 10, sample no. 26). The intervals with this form, therefore, largely represent the **patulus** Zone (undivided, but perhaps the upper part of the zone; see Klapper in Klapper and Ziegler, 1979, p. 207, Fig. 4), with the highest occurrences within the lower parts of the **costatus costatus** Zone. In Ontario, this form occurs entirely within the **patulus** Zone, again undivided, and below the first occurrence of **P. costatus costatus.**

Figured specimens. GSC 56169 to 56171, 56188, all from Station 13.

Polygnathus intermedius (Bultynck)

Plate 1, figures 29-31

Spathognathodus intermedius Bultynck, 1970, p. 133-134, Pl. 18, figs. 2-6 (Pa).

Polygnathus intermedius (Bultynck), Klapper, 1971, p. 65-66, Pl. 3, fig. 26 (Pa); Klapper in Ziegler, ed., 1973, p. 369-370, **Polygnathus** Pl. 1, fig. 4 (Pa) (includes synonymy); Spassov and Filipovič, 1975, p. 113, Pl. 1, figs. 7, 8 (Pa); Klapper, 1977a, fig. 6; Uyeno, 1979, p. 244, Pl. 1, figs. 11-13 (Pa); Chatterton, 1979, p. 193, Pl. 3, figs. 11-14 (Pa); Klapper and Johnson, 1980, Tables 7-9; Uyeno in Norris et al., in press, Pl. 31, figs. 23-25 (Pa).

Tortodus intermedius (Bultynck), Weddige, 1977, p. 327, Pl. 3, fig. 56 (Pa).

Remarks. The illustrated Ontario specimens of the Pa element of **Polygnathus intermedius** is somewhat unusual in exhibiting a rather large platform on the outer side and, in this respect, morphologically approaches **Parapolygnathus angusticostatus** (Wittekindt). Two other specimens, not illustrated owing to their fragmentary nature, have smaller, incipiently developed, platforms that are more characteristic of the species. The species is tentatively retained in **Polygnathus** until its apparatus becomes known.

Occurrences. Dundee Formation (Table 5a). In Manitoba, **Polygnathus intermedius** occurs in the Elm Point Formation (Uyeno in Norris et al., in press); and in western District of Mackenzie, in the Hume Formation associated with the brachiopod **Carinatrypa dysmorphostrota** Zone (Uyeno, 1979, p. 238), and in the transitional beds between the Hume and Hare Indian Formations (Chatterton, 1979, Table 4).

In the type Couvinian of the Ardennes, Bultynck (1970, Pl. 38) recorded the range of **P. intermedius** as Co2cIV/R-V. Weddige (1977, Table 5) observed it in the upper part of the Freilingen to the basal part of the Cürten Beds. In central Nevada, the species is restricted to the **kockelianus** Zone (Klapper, 1977b, fig. 6). See Klapper (in Ziegler, ed., 1973, p. 369-370) and Klapper and Johnson (1980, Tables 7, 8) for regional distribution.

Figured specimen. GSC 56187, Station 32.

Polygnathus linguiformis linguiformis Hinde

Plate 2, figures 20-31

Polygnathus linguiformis Hinde, 1879, p. 367, Pl. 17, fig. 15 (Pa); Winder, 1968, fig. 9 (Pa).

Polygnathus linguiformis linguiformis Hinde gamma forma, Bultynck, 1970, p. 126-127, Pl. 11, figs. 1-6, Pl. 12, figs. 1-6 (Pa); Ziegler and Klapper in Ziegler et al., 1976, p. 122-123, Pl. 4, figs. 9, 13 (Pa); Garcia-Lopez, 1976, Pl. 1, fig. 2 (Pa); Klapper in Ziegler, ed., 1977, p. 463-464, **Polygnathus** Pl. 10, figs. 2a, b, **Polygnathus** Pl. 11, figs. 1-7 (multielement) (includes synonymy); Weddige, 1977, p. 315-316, Pl. 5, figs. 80-82, text-fig. 4(24) (Pa); Johnson and Klapper, 1978, Pl. 1, fig. 12 (Pa); Urbanek, 1978, Pl. 3, fig. 7 (Pa); Orchard, 1978, p. 948, Pl. 110, figs. 18, 22, 24, 27, 31, Pl. 114, figs. 24, 27, 31, 33, 35 (Pa); Orchard, 1979, Pl. 1, fig. 21 (Pa); Klapper and Johnson, 1980, Tables 7-13; Uyeno in Norris et al., in press, Pl. 31, figs. 30, 31, 39-41, Pl. 32, figs. 1-6, 27, 28, Pl. 34, figs. 9-16, 23-25, Pl. 38, figs. 14, 15 (multielement).

(?) **Polygnathus linguiformis linguiformis** Hinde, Savage, 1977, p. 1352, Pl. 3, figs. 1-8 (Pa) (transitional to **P. linguiformis bultyncki** Weddige); Pl. 3, figs. 9-12 (Pa) (transitional to **P. serotinus** Telford).

(non) **Polygnathus linguiformis linguiformis** Hinde, Uyeno, 1978, p. 17, Pl. 4, figs. 50-52 (unassigned morphotype); Miller, 1978, p. 331, Pl. 2, figs. 18, 19 (Pa) (?**P. laticostatus** Klapper and Johnson).

Remarks. Seven morphotypes of **Polygnathus linguiformis linguiformis** have been proposed by Bultynck (1970) and Ziegler and Klapper (in Ziegler et al., 1976). Of these, the alpha, beta and zeta morphotypes have been assigned or reassigned to separate subspecies and formally named (Weddige, 1977, p. 316; Requadt and Weddige, 1978, p. 212). The gamma morphotype was recognized as the nominate subspecies (Ziegler et al., 1976, p. 122; Weddige, 1977, p. 315-316; Orchard, 1978, p. 948), and reference to this subspecies herein is used in this sense. Some of the morphotypes and/or subspecies appear to have restricted ranges and are, therefore, biostratigraphically useful. Only the nominate subspecies has been recovered from the Devonian strata of southwestern Ontario.

The material on which Klapper and Philip (1971, fig. 2, p. 449) based their reconstruction of **Polygnathus linguiformis linguiformis** originated from the Dundee Formation at St. Marys, Ontario (Station 17 herein).

Occurrences. Anderdon Member, Lucas Formation, Detroit River Group (Table 4a), Dundee Formation (Tables 5a, b), and the Hamilton Group (Table 6). See Klapper (in Ziegler, ed., 1977, p. 466-470) for regional distribution of this ubiquitous form.

Figured specimens. GSC 56203 to 56212, Station 18.

Polygnathus aff. **P. trigonicus** Bischoff and Ziegler

Plate 2, figures 1-6

Polygnathus aff. **P. trigonicus** Bischoff and Ziegler, Klapper, 1971, p. 66, Pl. 3, figs. 1-6 (Pa); Klapper in Perry et al., 1974, p. 1091, Pl. 8, fig. 14 (Pa); Klapper and Johnson, 1980, Tables 7, 8.

Remarks. The Dundee specimens of the Pa element of **Polygnathus** aff. **P. trigonicus** are close to those from the uppermost foot (0.3 m) of the Moorehouse Member and the Seneca Member of the Onondaga Limestone in New York (Klapper, 1971, p. 60, 66, Tables 3, 4). Of the illustrated specimens, that figured on Plate 2, figures 1 and 2, is the closest to the Onondaga specimens in terms of platform outline, whereas those on Plate 2, figures 3-6 have an outline approaching **P. linguiformis linguiformis** Hinde delta morphotype of Ziegler et al. (1976, p. 123, Pl. 4, figs. 4-8).

Elsewhere, **P.** aff. **P. trigonicus** has been reported from the Ogilvie Formation of northern Yukon (Klapper in Perry et al., 1974, p. 1091). In southwestern Ontario, it has been recovered from the Dundee Formation (Table 5a).

Figured specimens. GSC 56189 to 56191, Station 33.

Polygnathus timorensis Klapper, Philip, and Jackson

Plate 2, figures 7-19

Polygnathus timorensis Klapper, Philip, and Jackson, 1970, p. 655-656, Pl. 1, figs. 1-3, 7-10 (Pa); Klapper in Ziegler, ed., 1973, p. 385-386, **Polygnathus** Pl. 2, fig. 3 (Pa) (includes synonymy); Klapper and Ziegler in Ziegler et al., 1976, p. 125, Pl. 2, figs. 27-32, Pl. 3, fig. 10 (Pa) (includes further synonymy); Requadt and Weddige, 1978, p. 210-211, text-figs. 11c-f (Pa); Klapper and Johnson, 1980, Tables 10, 11, ?12.

Remarks. The apparatus of **Polygnathus timorensis** is almost identical to that of **P. ansatus** Ziegler and Klapper. (The latter apparatus was reconstructed on material from Member B of the Dawson Bay Formation of Manitoba; Uyeno in Norris et al., in press, Pl. 36, figs. 1-12.) The Pb element of **P. timorensis** and **P. ansatus** approaches **"Spathognathodus" planus** Bischoff and Ziegler; the latter form-species constitutes the Pb element of **P. xylus xylus** Stauffer (based on reconstruction on material from an unnamed unit, western District of Mackenzie; Uyeno, 1978, p. 17-18, Pl. 4, fig. 4). A similar conclusion was reached independently by Orchard (1978, p. 916). The Sa element of **P. timorensis** and **P. ansatus** is diplododellan, whereas it may be hibbardellan in **P. xylus xylus.**

Occurrences. Well preserved elements of **Polygnathus timorensis** occur in the Widder and Ipperwash Formations of the Hamilton Group. The underlying Arkona and Hungry Hollow Formations have yielded numerous fragmentary specimens of a Pa element consisting of detached platforms and free blades that cannot be identified precisely and are referred to the **Polygnathus varcus** Group **sensu** Klapper et al. (1970). The general morphology of the platforms, however, suggests that some of these specimens at least are assignable to **P. timorensis.**

Polygnathus timorensis was reported previously from the lower part of the Widder Formation at Rock Glen Park in Arkona (Stauffer, 1938, loc. 168; see Klapper et al., 1970, p. 656, and Klapper in Ziegler, ed., 1973, p. 386). It has been reported also from the Centerfield Limestone and the Tichenor Limestone Members of the Ludlowville Formation, Hamilton Group, in New York (Klapper et al., 1970, p. 655), and from the lower plate sequences in central Nevada (Klapper, 1977a, fig. 6).

Figured specimens. GSC 56192, Station 28, and 56193 to 56202, Station 26.

Polygnathus sp.

Plate 3, figures 28-30

Remarks. The single specimen originating in the Arkona Formation of the Hamilton Group at Hungry Hollow (Station 25) is tentatively considered as a Pa element of a **Polygnathus** sp. It is illustrated herein as it is rather unique in its form, superficially resembling the Pa element of **Polygnathus beckmanni** Bischoff and Ziegler. It differs substantially, however, as the latter has an upper platform surface that is characterized by strong, rather long nodes or irregular diagonal ribs, as opposed to weak and randomly distributed nodes. Both the holotype specimen, originating in the Flinzkalke ("Siderite Limestones"), at a quarry at Koppen, west of Rhenegge, Rhenish Schiefergebirge (Bischoff and Ziegler, 1957, p. 30, 86, explanation to Pl. 15, fig. 25), and that from the Tully Limestone of New York (Ziegler et al., 1976, Pl. 4, fig. 23) display a sharp inward turn of the extreme posterior end of the platform, a feature that is also lacking in the Ontario individual.

Figured specimen. GSC 56226, Station 25.

Family Cryptotaxidae Klapper and Philip, 1972

Type genus. **Cryptotaxis** Klapper and Philip, 1971.

Genus **Parapolygnathus** Klapper and Philip, 1971

Type species. **Polygnathus angusticostatus** Wittekindt, 1966.

Parapolygnathus angusticostatus (Wittekindt)

Plate 1, figures 26-28, 35-41

Polygnathus angusticostatus Wittekindt, 1966, p. 631, Pl. 1, figs. 15-18 (Pa); Klapper, 1971, p. 65, Pl. 3, figs. 21-25 (Pa) (includes synonymy); Savage, 1977c, p. 1348, Pl. 3, figs. 25-28 (Pa); Weddige, 1977, p. 306-307, Pl. 6, figs. 102-104, text-figs. 4(1, 2) (Pa); Klapper and Johnson, 1980, Tables 7-9.

Parapolygnathus angusticostatus (Wittekindt), Klapper and Philip, 1971, p. 445, 449, fig. 13 (multielement); Uyeno, 1979, p. 238, Pl. 2, figs. 1-3 (Pa); Uyeno in Norris et al., in press, Pl. 31, figs. 11-13, 17-19 (Pa).

Polygnathus angustipennatus Bischoff and Ziegler, Uyeno in Norris and Uyeno, 1972, p. 219, Pl. 3, fig. 2 (Pa).

Polygnathus n. sp. A, Schriel and Stoppel, 1965, p. 88, Pl. 3, fig. 5 (Pa); Uyeno in Norris and Uyeno, 1972, p. 219, Pl. 3, fig. 3 (Pa).

Remarks. The apparatus of **Parapolygnathus angusticostatus** was described and illustrated by Klapper and Philip (1971, p. 445, fig. 13). The material used in their reconstruction originated from the Dundee Formation at St. Marys, Ontario (Station 17 herein). The specimens identified as **Polygnathus**

robusticostatus Bischoff and Ziegler by Ferrigno (1968, 1971), also from the Dundee Formation at St. Marys, are referable to **Parapolygnathus angusticostatus.** This was inferred previously by Klapper and Philip (1972, p. 97-98).

Occurrences. Dundee Formation (Tables 5a and 7); see also Klapper and Philip, 1971, p. 449, and Uyeno in Winder et al., 1975, p. 135, 153. Elsewhere, **Parapolygnathus angusticostatus** occurs in the lower part of the Moorehouse Member of the Onondaga Limestone, and the **Werneroceras** bed and the Cherry Valley Member of the Marcellus Formation, Hamilton Group, in New York (Klapper, 1971, p. 60); in the upper part of the Hume Formation at Powell Creek, western District of Mackenzie (Uyeno, 1979, Fig. 2). In the type Couvinian strata of Belgium, Bultynck (1970, Pl. 38) recorded its range as Co2cIII to Co2d, and in the Eifelian Hills of Germany, it spans from mid-Ahrdorf to upper Junkerberg Beds (Weddige, 1977, Table 5). See Klapper and Johnson (1980, Tables 7-9) for regional distribution.

Figured specimens. GSC 56179 to 56186, Station 17.

Family Icriodontidae Müller and Müller, 1957

Type genus. **Icriodus** Branson and Mehl, 1938.

Remarks. Bultynck (1977) reassigned some species that were previously referred to **Icriodus** to two new genera, **Caudicriodus** and **Praelatericriodus**, and to newly reintroduced **Latericriodus**, previously proposed by Müller (1962). The character of the posterior lateral process ("principal process" of Bultynck, 1977) of the I element played a key role in these reassignments. One of these species, **Icriodus latericrescens** Branson and Mehl, that was reassigned to **Latericriodus**, is retained herein in **Icriodus.** The prime reason for this procedure is the presence in the Ontario material of two species of **Icriodus, I. angustus** Stewart and Sweet, and **I. hankae**, n. sp., that appear to be morphologically transitional between the two genera.

In the following discussions of the I elements, those morphological terms suggested by Bultynck (1977, text-fig. 1, p. 19) are used, with a slight modification of two terms: first ("premier") and last ("dernier") principal denticles are changed herein to read "anterior" and "posterior" denticles, respectively. The term "spindle" is adopted from Weddige (1977, p. 280, Fig. 2).

Genus **Icriodus** Branson and Mehl, 1938

Type species. **Icriodus expansus** Branson and Mehl, 1938.

Remarks. The **Icriodus** apparatus was initially believed to consist of two elements, I and S_2 (Klapper and Philip, 1971, 1972). Subsequently, Klapper and Ziegler (in Ziegler, 1975, p. 67) suggested that a third element, M_2, may be present. This supposition has been borne out in the present collections from southwestern Ontario (with **Icriodus introlevatus** Bultynck), as well as in collections from central Mackenzie Valley (with **Icriodus brevis** Stauffer; referred to as S_{2c} element) (Uyeno, 1978), and from the Canning Basin, Western Australia (with **Icriodus subterminus** Youngquist) (Nicoll, 1977).

Icriodus angustus Stewart and Sweet

Plate 3, figures 1-4

Icriodus angustus Stewart and Sweet, 1956, p. 267, Pl. 33, figs. 4, 5, 11, 15 (I); Klapper in Ziegler, ed., 1975, p. 75-76, **Icriodus** Pl. 2, figs. 6, 7 (I) (includes synonymy); Bultynck, 1976, fig. 2, Table 1; Klapper and Johnson, 1980, Tables 7, 8, Pl. 3, figs. 3-6 (I).

Occurrences. Dundee Formation (see Table 5a). **Icriodus angustus** has also been found in the Dundee formation at Amherstburg (Orr, 1971, p. 104; Station 29 herein). In neighbouring northern Michigan, Bultynck (1976, fig. 2, Table 1) reported it from the Dundee and lower part of the Rogers City Formations. See Klapper (in Ziegler, ed., 1975, p. 76) and Klapper and Johnson (1980, Tables 7, 8) for occurrences in Ohio, Indiana, Illinois, and Missouri.

Figured specimens. GSC 56213 and 56214, Station 17.

Icriodus hankae Uyeno, n. sp.

Plate 3, figures 5-12

Diagnosis. Representative specimens of the I element of **Icriodus hankae** have a subdued middle row, consisting of small nodes in the posterior part of the spindle, and a series of thin, weak ridges anteriorly; the ridges may be aligned or offset diagonally. The distal crest is higher than the nodes of the lateral rows of the spindle, but not conspicuously so. The anterior and posterior principal denticles are of equal size. The unit is narrowly tapering in upper and lower views. The principal process is a short, thin ridge, and joins the posterior margin of the posterior principal denticle. The process forms a 45-degree angle with an imaginary extension of the middle row.

Remarks. The development of ridges in the middle row is a later ontogenetic phenomenon, as smaller specimens have only subdued nodes in this position (see Pl. 3, fig. 5). In one of the paratype specimens, the entire middle row of the spindle consists of thin ridges (Pl. 3, fig. 10).

The position of attachment of the principal process to the posterior principal denticle of **Icriodus hankae** is a feature in common with **Icriodus huddlei** Klapper and Ziegler. The latter, however, may be readily distinguished by its longer, well-developed principal process; its denticulation of the middle row of the spindle (distinct nodes connected by a longitudinal ridge); its principal process that commonly bears ornamentation on its upper surface; and the lower distal crest which is only slightly higher than the lateral row nodes.

Icriodus angustus has a similar lachrymiform outline of the basal cavity (compare Pl. 3, figs. 4, 9, and 12). A few criteria distinguish it from **I. hankae**, however; the former exhibits a high, prominent distal crest, formed by a fusion of the principal denticles (in the holotype specimen, there appears to be additional denticle(s) involved in the fusion; see Stewart and Sweet, 1956, Pl. 33, fig. 11; specimen reillustrated by Klapper in Ziegler, ed., 1975, **Icriodus** Pl. 2, fig. 7), and the middle row on the spindle consists of nodes, often subdued, and not connected by longitudinal ridges.

Derivation of name: From Hanka, a derivative of Anna.

Holotype. GSC 56217, the specimen illustrated on Plate 3, figures 7-9. Locus typicus and Stratum typicum. Formosa Reef Limestone Member, Amherstburg Formation, Detroit River Group, 2.74 to 3.66 m above the road level, GSC loc. C-38935, Station 19 (Table 3b).

Material. 16 specimens (including paratypes GSC 56215, 56216, and 56218, all from Station 19).

Icriodus brevis Stauffer

Plate 5, figures 10-16, 21, 22

Icriodus brevis Stauffer, 1940, p. 424, Pl. 60, figs. 36, 43, 44, 52 (I); Klapper in Ziegler, ed., 1975, p. 89-90, **Icriodus** Pl. 3, figs. 1-3 (I) (includes synonymy); Ziegler and Klapper in Ziegler et al., 1976, p. 117, Pl. 1, figs. 10-16 (I); Weddige, 1977, p. 285, Pl. 2, fig. 37, text-fig. 3(16) (I); Uyeno, 1978, p. 18, Pl. 4, figs. 28-44 (multielement); Requadt and Weddige, 1978, p. 213, fig. 13g (I); Uyeno, 1979, p. 238, Pl. 1, figs. 10-16 (I); Klapper and Johnson, 1980, Tables 10, 11; Uyeno in Norris et al., in press, Pl. 33, figs. 4-7, 9-12, 16-18, 25-28 (multielement).

Icriodus eslaensis Adrichem Boogaert, Garcia-Lopez, 1976, Pl. 1, fig. 1 (I).

Icriodus eslaensis eslaensis van Adrichem Boogaert, Bultynck, 1975, p. 19.

(non) **Icriodus brevis** Stauffer, Nicoll, 1977, p. 222, 225, fig. 7 (=**I. subterminus** Youngquist).

(non) **Icriodus brevis brevis** Stauffer, Druce, 1976, p. 112, Pl. 32, figs. 1, 2 (=**I. subterminus** Youngquist).

Remarks. The posterior extension of the median row in some specimens shows an additional denticle on the outer side of the extension, consistently attached to the last denticle (Pl. 5, fig. 21). Such specimens are morphologically transitional to **Icriodus latecarinatus** Bultynck which may have a similarly attached denticle, but located near the centre of the extension.

Occurrences. Widder and Ipperwash Formations, Hamilton Group (Table 6). In neighbouring Michigan, **Icriodus brevis** occurs in the Ferron Point, Genshaw, and Gravel Point Formations (Bultynck, 1976, Tables 2, 3). In Manitoba, it occurs in the Winnipegosis and Dawson Bay Formations (Uyeno in Norris and Uyeno, 1972, p. 215; Uyeno in Norris et al., in press). Ziegler et al. (1976, p. 113, Table 13) noted its range from the Lower **varcus** Subzone to at least as high as the **hermanni-cristatus** Zone. See Klapper in Ziegler, ed., 1975, p. 90, and Klapper and Johnson, 1980, Tables 10, 11, for regional occurrences.

Figured specimens. GSC 56265 to 56267, Station 26; 56268 and 56269, Station 28.

Icriodus difficilis Ziegler and Klapper

Plate 5, figures 5-9, 18-20

Icriodus difficilis Ziegler and Klapper, in Ziegler et al., 1976, p. 117-118, Pl. 1, figs. 1-7, 17 (I) (includes synonymy); Weddige, 1977, p. 292, Pl. 2, fig. 36, text-fig. 3(11) (I); Klapper, 1977a, fig. 6; Johnson, 1978, p. 120; Orchard, 1978, p. 928, Pl. 109, figs. 9, 12, 13, 16, 18 (I); Klapper and Johnson, 1980, Tables 9-13.

Occurrences. Hamilton Group (Table 6). Orr (1971, p. 86, Section 6, sample 19, Pl. 3, figs. 14-17) reported **Icriodus difficilis** from the Traverse Group in Michigan. The species ranges throughout the **varcus** Zone and through the Lowermost **asymmetricus** Zone (Ziegler et al., 1976; Klapper, 1977a, Fig. 6).

Figured specimens. GSC 56261 and 56262, Station 26; 56263 and 56264, Station 28.

Icriodus latericrescens latericrescens

Branson and Mehl

Plate 4, figures 27-30

Icriodus latericrescens Branson and Mehl, 1938, p. 164-165, Pl. 26, figs. 30-32, 34, 35 (I).

Icriodus latericrescens latericrescens Branson and Mehl, Klapper in Ziegler, ed., 1975, p. 127-129, **Icriodus** Pl. 2, fig. 5 (I) (includes synonymy); Bultynck, 1976, p. 121, fig. 2; Orchard, 1978, p. 930, Pl. 109, figs. 6, 11 (I); Klapper and Johnson, 1980, Tables 10-12, Pl. 3, fig. 15 (I).

Remarks. Bultynck (1976, p. 121, fig. 2) recognized three morphotypes of **Icriodus latericrescens latericrescens**, based on material from Michigan, but they are yet to be described.

Occurrences. Hamilton Group (see Table 6). Previously Stauffer (1938, p. 416, 430, Pl. 52, figs. 30, 31, 34) had illustrated **I. latericrescens latericrescens** from the Arkona Formation, Hamilton Group, at and near Thedford, Ontario (Stauffer's localities 152 and 153). In neighbouring Michigan, Bultynck (1976, Tables 2-4) reported it from the Ferron Point, Genshaw, Gravel Point, Thunder Bay, and Squaw Bay Formations. See Klapper in Ziegler, ed., 1975, p. 128-129, and Klapper and Johnson, 1980, Tables 10-12, for regional occurrences.

Figured specimens. GSC 56257, Station 28; 56258, Station 25.

Icriodus latericrescens robustus Orr

Plate 4, figures 1-26, 31-38

Icriodus latericrescens Branson and Mehl, Winder, 1968, fig. 10 (I).

Icriodus latericrescens bilatericrescens Ziegler, Winder, 1968, fig. 11 (I).

Icriodus latericrescens robustus Orr, 1971, p. 37-38, Pl. 2, figs. 14, 15 (I); Klapper in Ziegler, ed., 1975, p. 133-134, **Icriodus** Pl. 2, figs. 3, 4 (I) (includes synonymy); Klapper and Johnson, 1980, Tables 6-8, Pl. 3, fig. 16 (I).

Remarks. In this study, **Icriodus latericrescens robustus** is divided into three morphotypes, in the manner originally suggested by Telford et al. (1977, p. 8). The division is based on the development of the principal process, and the morphotypes are designated "simple" for those specimens with no principal process to only weakly developed process; "intermediate" for those with a well-developed principal process; and "advanced" for those with an expanded posterior area containing a large denticulated principal process, with an opposing shorter, non-denticulated, "spur" ("eperon" of Bultynck, 1977). The upper surface of the spur may have a thin ridge. These forms are considered herein to represent different morphotypes rather than stages within the ontogenetic development of **I. latericrescens robustus.** The strongest evidence for this consideration is the overlapping to a large extent in size ranges between these morphotypes.

The S_{2a} element of **I. latericrescens robustus** is an acodinan that may have a median thin ridge on its outer surface (Pl. 4, figs. 7, 16, and 24). The S_{2b} element is a simple cone with a widely flaring basal cavity (Pl. 4, figs. 17, 18). The M_2 element is similarly a simple cone but with a very restricted basal cavity opening (Pl. 4, fig. 23).

Occurrences. There is no apparent stratigraphic restriction of any of the above morphotypes of **I. latericrescens robustus.** The subspecies ranges from the Bois Blanc through Dundee Formations (Tables 1 to 5, 8). The holotype specimen of this subspecies is from the Dundee Formation at Amherstburg (Orr, 1971, p. 38, 104; Station 29 herein). The subspecies has been reported also from the Hudson Platform, in the Stooping River and Kwataboahegan Formations (Uyeno in Sanford and Norris, 1975, Part 1, Tables 6, 11). See Klapper in Ziegler, ed., 1975, p. 133-134, and Klapper and Johnson, 1980, Tables 6-8, for regional distribution.

Figured specimens. GSC 56235 to 56238, Station 10; 56239, 56246, 56254, and 56256, Station 16; 56240, 56242 to 56245, Station 9; 56241, Station 4; 56247, Station 19; 56248 to 56251, Station 1; 56252, Station 13; and 56253 and 56255, Station 33.

Icriodus obliquimarginatus Bischoff and Ziegler

Plate 3, figures 20-22

Icriodus obliquimarginatus Bischoff and Ziegler, 1957, p. 62-63, Pl. 6, fig. 14 (I); Ziegler in Ziegler, ed., 1975, p. 135-137, **Icriodus** Pl. 3, figs. 9, 10, (I) (includes synonymy); Ziegler and Klapper in Ziegler et al., 1976, p. 118, Pl. 1, figs. 8, 9 (I) (includes additional synonymy); Bultynck, 1976, Table 2; Weddige, 1977, p. 294-295, Pl. 2, figs. 33-35, text-figs. 3(13,14) (I); Requadt and Weddige, 1978, p. 213, text-fig. 13h (I); Orchard, 1978, p. 930, Pl. 107, figs. 7, 9, 13, 14, 17, 18, Pl. 109, figs. 1, 8 (I); Klapper and Johnson, 1980, Tables 9, 10.

Remarks. The Ontario specimen of the I element of **Icriodus obliquimarginatus** has a widely flaring basal cavity outline on the outer side. This feature is similar to that illustrated by Ziegler et al. (1976, Pl. 1, fig. 9) from the Ense-Kalk at Blauer Bruch 1.

Occurrences. Widder Formation, Hamilton Group (Table 6). In Michigan, Bultynck (1976, Table 2) recorded **Icriodus obliquimarginatus** from the Ferron Point and lower part of the Genshaw Formations. In the Rhenish Schiefergebirge, the species ranges from high in the Eifelian into the Middle **varcus** Subzone (see Ziegler et al., 1976, p. 114, Table 7, Benner quarry near Bicken). In the Eifelian Hills, it ranges from the uppermost part of the Junkerberg Formation through Cürten Formation and higher (Weddige, 1977, Table 5). See Ziegler in Ziegler, ed., 1975, p. 136-137, and Klapper and Johnson, 1980, Tables 9, 10, for other regional distribution.

Figured specimen. GSC 56225, Station 26.

Icriodus aff. **I. retrodepressus** Bultynck

Plate 3, figures 16-19, 23-27

Icriodus nodosus (Huddle), Orr, 1971, p. 38-39, Pl. 2, figs. 20-23 (I); Schumacher, 1971, p. 93-95, Pl. 9, figs. 1-18 (only) (I).

Icriodus sp. B, Uyeno in Norris et al., in press, Pl. 31, figs. 2-7 (I).

Icriodus sp. aff. **I. retrodepressus** Bultynck, Klapper and Johnson, 1980, Tables 7, 8, Pl. 3, figs. 19-23 (I).

Remarks. The specimens of the I element herein assigned to **Icriodus** aff. **I. retrodepressus** Bultynck have a central posterior area of the spindle that is as high as, or even slightly higher than, the lateral row nodes, and ranges from that to an area that is deeply depressed. Although the latter feature is more characteristic of **I. retrodepressus** sensu stricto, that species may be distinguished by its more uniform longitudinal spacing of the lateral row denticles (Klapper and Johnson, 1980). Specimens with the accentuated depressed area have not been found in the collections from Manitoba, but a similar form ranges there from the Elm Point to the lower part of the Dawson Bay Formations (Uyeno in Norris et al., in press).

Icriodus aff. **I. retrodepressus** differs from **I. norfordi** Chatterton in having only thin ridges connecting lateral row denticles with median ones, and in its posterior half of the basal cavity outline that is only moderately expanded.

Occurrences. Lucas Formation (Anderdon Member and the sandy facies), Dundee Formation, and the Hamilton Group (Arkona and Hungry Hollow Formations) (see Tables 4 to 6, 8). The specimens from the Dundee Formation near Amherstburg, Ontario (Station 29 herein), illustrated by Orr (1971) probably belong to this species.

Figured specimens. GSC 56220, 56221, 56223, and 56224, Station 13; 56222, Station 41.

Icriodus cf. **I.** sp. A

Plate 5, figures 1-4

(cf.) **Icriodus** sp. A, Uyeno in Norris et al., in press, Pl. 31, figs. 8-10, 14-16 (I).

Diagnosis. Representative specimens of the I element of **Icriodus** cf. **I.** sp. A have peg-like denticles of almost circular cross-section. The unit is straight to slightly sigmoidal, with the spindle slightly tapering anteriorly. The lateral row denticles (numbering 5 to 8) alternate with median ones (7 to 9). Generally one or two denticles on median row extend anteriorly of the lateral rows. The posterior extension of the middle row consists of 3 to 5 posteriorly inclined denticles, and is slightly lower than the denticles on the spindle. The posterior half of the basal cavity outline is expanded gradually and symmetrically.

Remarks. **Icriodus** cf. **I.** sp. A is morphologically close to **I.** sp. A that was previously described from the Elm Point Formation of Manitoba by Uyeno (in Norris et al., in press). They differ consistently in size and the number of denticles; the Manitoba specimens carry 4 to 5 lateral row and 5 to 6 median row denticles, with two denticles in the posterior extension of the median row.

Occurrences. Dundee Formation (Tables 5a, b).

Figured specimens. GSC 56259 and 56260, Station 18.

Icriodus sp. C

Plate 3, figures 13-15, 31-42

Remarks. The I element of **Icriodus** sp. C differs from that of **I.** cf. **I.** sp. A in exhibiting a spindle that is more stout, i.e., there is more abrupt tapering anteriorly from the widest part located at midway between the centre and the posterior end, and in having lateral row denticles that are slightly elongated laterally, especially near the posterior part of the spindle. The basal cavity outline is more abruptly expanded with a distinct spur developed in the larger specimens (see Pl. 3, fig. 42). In many of these features **I.** sp. C appear to hold an intermediary morphological position between **I.** cf. **I.** sp. A and **I.** aff. **I. retrodepressus** Bultynck.

The Dundee Formation at St. Marys (Station 17) yielded the accompanying S_{2a}, S_{2b}, and M_2 elements.

Occurrences. Dundee Formation (see Tables 5a, 7 and 8).

Figured specimens. GSC 56219, Station 41; 56227 to 56234, Station 17.

Oulodus sp.

Plate 5, figures 36-39

Remarks. A part of an **Oulodus** apparatus, consisting of Pa, Pb, Sb, and Sa elements, was recovered from the Widder Formation of the Hamilton Group at Station 26 (Table 6). In this partial reconstruction, the model suggested by Sweet and Schönlaub (1975) was followed, and their notational nomenclature, modified by Cooper (1975), is used herein.

The apparatus of **Oulodus** sp., reported from the Dawson Bay Formation of Manitoba (Uyeno in Norris et al., Pl. 35, figs. 1-12, 16, 17), is similar to the Ontario species and may be synonymous.

Occurrences. Widder and Ipperwash Formations, Hamilton Group (Table 6).

Figured specimens. GSC 56283 to 56286, Station 26.

Simple cone elements

Plate 5, figures 23-25

Remarks. Some simple cone elements are illustrated herein, but are identified only to generic level. The cones include **Belodella, Coelocerodontus** (including a form with lateral denticles), and cf. **Coelocerodontus** (cones with shallow basal cavity and no lateral striae). They are mentioned here primarily to complete the record of their occurrence.

Figured specimens. **Belodella** spp.: GSC 56277 to 56279, Station 1.

Coelocerodontus spp.: GSC 56280 to 56282, Station 9.

Coelocerodontus spp. with lateral denticles: GSC 56273, Station 1; 56274, Station 7; 56275, Station 19; and 56276, Station 17.

cf. **Coelocerodontus** spp.: GSC 56271 and 56272, Station 17.

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APPENDIX
LIST OF STATION LOCALITIES

Because many of the sections studied herein have been adequately described, and some even illustrated, in the past (e.g., Goudge, 1938; Stauffer, 1914; Caley, 1941, 1943, 1945; Hewitt, 1960; Hewitt and Vos, 1972; Winder and Sanford, 1972), no attempt has been made to duplicate these efforts. Rather, references to latest available publications are given.

With the exception of Station 29, which was visited in June 1966, all sections were measured and sampled in June and July, 1972.

The stations are listed by counties, from east to west.

WELLAND COUNTY

Station 1: the quarry of Canada Cement Co. Ltd., located 3.5 km west of the western edge of Port Colborne, and 1.2 km south of Highway No. 3, in lot 6, Concession I, Wainfleet Township (NTS 30L/14 W½); west face of the west half of the quarry measured and sampled. See Hewitt, 1960, p. 132-134; Telford and Tarrant, 1975(a).

According to B.V. Sanford (pers. comm., 1972), the lowermost few cm of strata in this quarry belong to the Bois Blanc Formation. These beds were covered with debris in the summer of 1972, so the actual contact was not sighted. The remainder of the quarry is assignable to the basal part of the Amherstburg Formation, Detroit River Group. Total thickness at the west face is 7.35 m.

Station 2: the quarry of R.E. Law Crushed Stone Ltd., located 3.4 km west of the western edge of Port Colborne, on north side of Highway No. 3, in lot 5, Concession II, Humberstone Township (NTS 30L/14 W½); west face measured and sampled. See Hewitt, 1960, p. 134-136; Telford and Tarrant, 1975(a).

Amherstburg Fm., Detroit River Gr.=4.33 to 8.60 m above the top of Bertie Fm.

Bois Blanc Fm.=0 to 4.33 m above the top of Bertie Fm.

Bertie Fm. (not measured)

Station 4: the quarry of Ridgemount Quarries Ltd., located 1.2 km north of Highway No. 3, and 6.4 km west of Fort Erie, in lot 3, Concession VIII, Bertie Township (NTS 30L/14 E½); north and west faces measured and sampled. See Hewitt, 1960, p. 130; Telford and Tarrant, 1975a; Winder and Sanford, 1972, p. 65.

Amherstburg Fm., Detroit River Gr.=4.02 to 9.78 m above the top of Bertie Fm.

Bois Blanc Fm.=0 to 4.02 m above the top of Bertie Fm.

Bertie Fm. (not measured)

HALDIMAND COUNTY

Station 7: abandoned quarry located 5.6 km southwest of Dunnville, on north side of road (NTS 30L/13 E½); northeastern corner measured and sampled. See Telford and Tarrant, 1975b.

Amherstburg Fm., Detroit River Gr.=2.29 to 3.96 m above the quarry floor

Bois Blanc Fm.=0 to 2.29 m above the quarry floor

Station 8: section along Dry Creek, on west side of road, located 1.3 km north of Cheapside (property of K. Schweyer) (NTS 30L/13 W½). See Telford and Tarrant, 1975b.

Dundee Fm.=0 to 5.27 m above the creek level (July 1972)

Station 9: the quarry of Cayuga Materials and Construction Co. Ltd., located on north side of Highway No. 3, and 5.7 km west of Cayuga, in lots 45 and 46, Concession I north, North Cayuga Township (NTS 30L/13 W½); west face measured and sampled. See Hewitt, 1960, p. 138-140; Hewitt and Vos, 1972, p. 58.

Bois Blanc Fm.=3.29 to 5.33 m above the top of Bertie Fm.

Oriskany Fm.=0 to 3.29 m above the top of Bertie Fm.

Bertie Fm. (not measured)

Station 10: the quarry of Haldimand Quarries and Construction Ltd., located on the eastern outskirts of Hagersville, in lots 27 and 28, Concession I, Oneida Township (NTS 40I/16 E½); south face of the old quarry located north of the Michigan Central Railway line was measured and sampled. See Hewitt, 1960, p. 140-142.

Amherstburg Fm., Detroit River Gr.=5.36 to 7.04 m above the top of Bertie Fm.

Bois Blanc Fm.=0 to 5.36 m above the top of Bertie Fm.

Bertie Fm. (not measured)

Station 36: bank exposure on both sides of Sandusk Creek, located 0.4 km south of Sandusk, on east side of road (NTS 40I/16 E½).

Amherstburg Fm., Detroit River Gr.=0 to 5.49 m above the creek level (July 1972)

Station 38: abandoned quarry located 0.8 km east of Selkirk, and 0.3 km north of road (property of H. Hoover) (NTS 30L/13 W½).

Dundee Fm.=0 to 3.72 m above the quarry floor

Station 42: abandoned quarry in lots 48-49, Concession II, Oneida Township, lat. 42°56'N, long. 79°57'W (NTS 30L/13 W½); collected by P.G. Telford. See Winder and Sanford, 1972, p. 66, GSC loc. C-80199; Oriskany Fm., ca. 2 m thick.

NORFOLK COUNTY

Station 41: the United Steel DDH no. 1, located in lot 1, 2075 ft (632.5 m) south of lot line, 650 ft (198.1 m) west of lot line, Concession I, Charlotteville Township, lat. 42°44'20"N, long. 80°17'48"W (NTS 40I/9 W½). GSC loc. C-53292.

The following tops were provided by B.V. Sanford:

Dundee Fm.=62.94 to 96.62 m below top of well

Amherstburg Fm., Detroit River Gr.=96.62 to 121.62 m below top of well

Bois Blanc Fm.=121.62 to 142.34 m below top of well

Springvale Mbr.=122.83 to 132.59 m below top of well

Oriskany Fm.=142.34 to 142.95 m below top of well

Bertie Fm. (not measured)

OXFORD COUNTY

Station 13: the quarry of Steel Co. of Canada (Chemical Lime Works), located 1.6 km northeast of Ingersoll and 4.8 km southwest of Beachville, and on north side of Highway No. 2 (NTS 40P/2 W½); northeast face measured and sampled for carbonate beds, and west face for sandy facies. See Hewitt, 1960, p. 155-158; Hewitt and Vos, 1972, p. 71-73; Winder and Sanford, 1972, p. 67-68; Winder et al., 1975, p. 151-152.

Lucas Fm., Detroit River Gr. (sandy facies)=26.37 to 31.70 m above the quarry floor

Lucas Fm., Detroit River Gr., Anderdon Mbr.=0 to 26.37 m above the quarry floor

Station 14: the quarry of Domtar Chemicals Ltd., located 2.5 km southwest of Beachville, and on north side of Highway No. 2 (NTS 40P/2 W½); southeast face along road leading from quarry floor (at tunnel entrance) to ground level, measured and sampled. See Hewitt, 1960, p. 149-152; Hewitt and Vos, 1972, p. 69.

Lucas Fm., Detroit River Gr., Anderdon Mbr.=0 to 19.51 m above the quarry floor

Station 16: abandoned quarry (now used for recreational purposes) located 0.8 km south of Innerkip (NTS 40P/2 E½); southwest face measured and sampled. See Winder et al., 1975, p. 150-151.

Bois Blanc Fm.=0 to 3.90 m above the top of Bertie Fm.

Bertie Fm.=0 to 0.24 m above the water level (June 1972)

PERTH COUNTY

Station 17: the quarry of St. Mary's Cement Co. Ltd., located at southern outskirts of St. Marys, on east side of the north branch of Thames River, in Concessions XVI and XVII, Blanchard Township (NTS 40P/3 E½); south face of the old quarry measured and sampled. See Hewitt, 1960, p. 161-164, 1964, p. 65-66; Winder and Sanford, 1972, p. 68; Winder et al., 1975, p. 152-153.

Dundee Fm.=0 to 11.43 m above the top of Lucas Fm., Detroit River Gr.

Lucas Mbr., Detroit River Gr. (not measured)

BRUCE COUNTY

Station 19: road cut on highway going through Formosa, 0.3 km south of intersection with Highway No. 9 and 4.0 km north of Formosa (NTS 41A/3 E½); central section and south end of the road cut measured and sampled.

This is the type section of the Formosa Reef Limestone, designated by Fagerstrom (1961b, p. 344, 346).

Detroit River Group, Amherstburg Fm., Formosa Reef Limestone=0 to 6.92 m above the road level.

HURON COUNTY

Station 18: south bank of Maitland River, located 1 km north of intersection with Highway No. 8, and intersection located 2.1 km southeast of centre of Goderich (NTS 40P/12 E½). See Liberty and Bolton, 1971, p. 122.

Dundee Fm.=0 to 10.42 m above the top of Lucas Fm., Detroit River Gr.

Lucas Fm., Detroit River Gr. (not measured, but top 0.15 m sampled)

LAMBTON COUNTY

Station 25: north bank of Ausable River, located 1.2 km north of intersection with road going east from Arkona, and intersection located 3.2 km east of Arkona (NTS 40P/4 W½). See Winder et al., 1975, p. 154-155.

This locality is also known as Hungry Hollow, and is the type section of the Hungry Hollow Formation (Cooper and Warthin, 1941). It was described and illustrated by Shimer and Grabau (1902, p. 157-159), and Stauffer (1915, p. 156-157, Pl. 13) under Marsh's (or Marshall's) Mill. Those intervals collected for conodonts at this station were listed as localities 176 to 181 by Stauffer (1938, p. 417); this reference states "Olentangy shale" for Arkona Formation. The section was studied also by Williams (in Parks et al., 1913, p. 107-111), and Mitchell (1967, p. 175-182).

Hamilton Group:

Widder Fm.=3.44 to 4.79 m above the road level

Hungry Hollow Fm.=1.83 to 3.44 m above the road level

Encrinal limestone=1.83 to 2.17 m above the road level

Arkona Fm.=0 to 1.83 m above the road level

Station 26: banks of a tributary of Ausable River, located 1.6 km east of intersection with Highway No. 7, and intersection located 3.2 km north of Arkona (property of Wm. Fuller) (NTS 40P/4 W½).

This locality was designated as "No. 4 Hill" by Stauffer (1915, p. 10), and as a "lectotype" of the Widder Formation by Wright and Wright (1961, p. 294-295).

Hamilton Group:

Widder Fm.=1.52 to 14.11 m above the top of Arkona Fm.

Hungry Hollow Fm.=0 to 1.52 m above the top of Arkona Fm.

Encrinal limestone=0 to 0.37 m above the top of Arkona Fm.

Arkona Fm. (not measured)

Station 27: beach outcrop on Lake Huron, at Kettle Point on Kettle Point Indian Reserve (NTS 40O/1 E½). See Winder and Sanford, 1972, p. 70; Winder et al., 1975, p. 156-157. Only a part of a concretion was sampled for conodonts. Illustrations of the concretions and the enveloping shale are given in Stauffer (1915, Pls. 16, 17) and Sanford (in Poole et al., 1970, Pl. 6-11, p. 285).

Kettle Point Fm.=0 to 3.66 m above water level (see Winder, 1962, p. 86)

Station 28: beach outcrop on Lake Huron, at Stony Point in Ipperwash Provincial Park (NTS 40P/4 W½). See Winder et al., 1975, p. 155.

Ipperwash Fm., Hamilton Gr.=0 to 0.76 m above the water level (June 1972)

ESSEX COUNTY

Station 29: the quarry of Allied Chemical Canada Ltd. (formerly the quarry of Brunner Mond Canada Ltd.), located on the northern outskirts of Amherstburg, in lots 6-8, Concession I, and lots 2 and 3, Concession II, Anderdon Township (NTS 40J/3 E½). The quarry is now abandoned in part and used as filling site. See Hewitt, 1960, p. 164-167.

Dundee Fm. (not measured, but the lowermost 2.44 m sampled)

Lucas Fm., Detroit River Group, Anderdon Mbr.=0 to 11.06 m above the top of Lucas Fm. (in restricted sense)

Lucas Fm., Detroit River Gr. (not measured)

Station 40: the quarry of Allied Chemical Canada Ltd. (also informally called "McGregor Quarry" by the company staff) located about 10 km northeast of Amherstburg, in lot 10, Concession VI, Anderdon Township (NTS 40J/13 E½); southeast and east faces measured and sampled. See Hewitt and Vos, 1972, p. 65-66.

Lucas Fm., Detroit River Gr., Anderdon Mbr.=0 to 8.84 m above the top of quarry floor

Station 32: quarry located 1 km northeast of Scudder, on south side of road, northeast Pelee Island (NTS 40G/15 E½); north face measured and sampled.

Dundee Fm.=0 to 6.25 m above the quarry floor

Station 33: abandoned quarry located about 1.5 km north of the west wharf at Pelee Island village, southwest Pelee Island (property of the Diamond sisters) (NTS 40G/15 E½); north face measured and sampled.

This is formerly the quarry of William McCormick. The descriptions and illustrations of another part of the quarry are given by Stauffer (1915, p. 209, Pl. 20), and Goudge (1938, p. 218, 220, Pl. 30B).

Dundee Fm.=0 to 4.30 m above the quarry floor

State of Ohio, U.S.A.

Marble Cliff Quarries Company quarry, on face south of the village of San Margherita, Franklin Township, Franklin County; 365 m (1200 ft) south of the Trabue Road/McKinley Avenue intersection. Coordinates on the Ohio Coordinate System (10 000-ft grid), south zone, X=1 836 220, Y=726 000. See Janssens, 1969, p. 1-5 to 1-7.

PLATE 1

All figures x40

Figures 1-3. **Ozarkodina remscheidensis remscheidensis** (Ziegler)

1, 2, GSC 56162 and 56163, lateral view of two Pa elements;
3, GSC 56164, lateral view of Pb element;

all specimens from Bertie Formation, 0.0 to 0.24 m below top of formation, Station 16, GSC loc. C-38901.

Figure 4. **Pandorinellina**? sp. B

GSC 56165, inner lateral view of Pb element, from Bois Blanc Formation, 1.13 to 1.28 m above quarry floor, Station 7, GSC loc. C-38839.

Figures 5-9. **Polygnathus** cf. **P. costatus** Klapper

5, 6, GSC 56166 and 56167, oblique upper view of two Pa elements;
7-9, GSC 56168, upper, inner lateral, and lower views of Pa element;

figs. 5, 7-9 (GSC 56166 and 56168) from Dundee Formation, 2.23 to 2.53 m above quarry floor, Station 32, GSC loc. C-38965; fig. 6 (GSC 56167) from Dundee Formation, 1.10 to 1.25 m above quarry floor, Station 33, GSC loc. C-38973.

Figures 10, 18-23, 32-34. **Polygnathus costatus patulus** Klapper → **P. cooperi cooperi** Klapper

10, GSC 56169, upper view of Pa element;
18-20, GSC 56170, upper, outer lateral, and lower views of Pa element;
21-23, GSC 56171, upper, outer lateral, and lower views of Pa element;
32-34, GSC 56188, upper, inner lateral, and lower views of Pa element;

all specimens from the sandy facies, Anderdon Member, Lucas Formation, Detroit River Group, 26.82 to 27.31 m above quarry floor, Station 13, GSC loc. C-38880.

Figures 11-17, 24, 25. **Polygnathus costatus costatus** Klapper

11-13, GSC 56172, upper, outer lateral, and lower views of Pa element;
14, GSC 56173, inner lateral view of Sc element;
15, GSC 56174, inner lateral view of Pb element;
16, 17, GSC 56175 and 56176, inner lateral view of two M elements;

figs. 11-17 (GSC 56172 to 56176) from Dundee Formation, 0.94 to 1.25 m above quarry floor, Station 32, GSC loc. C-38963.

24, GSC 56177, upper view of Pa element, from Dundee Formation, 1.10 to 1.25 m above quarry floor, Station 33, GSC loc. C-38973.

25, GSC 56178, upper view of Pa element, from Dundee Formation, 2.13 to 3.66 m above base of formation, Station 17, GSC loc. 73670.

Figures 26-28, 35-41. **Parapolygnathus angusticostatus** (Wittekindt)

26-28, GSC 56179, upper, outer lateral, and lower views of Pa element;
35, GSC 56180, upper view of Pa element;
36, GSC 56181, inner lateral view of M element;
37, GSC 56182, inner lateral view of Pb element;
38, GSC 56183, inner lateral view of Sc element;

figs. 26-28, 35-38 (GSC 56179 to 56183) from Dundee Formation, 7.71 to 8.05 m above base of formation, Station 17, GSC loc. C-38919.

39, GSC 56184, inner lateral view of Sb element;
40, GSC 56185, inner lateral view of Sc element;
41, GSC 56186, inner lateral view of Sa element;

figs. 39-41 (GSC 56184 to 56186) from Dundee Formation, 8.75 to 9.05 m above base of formation, Station 17, GSC loc. C-38920.

Figures 29-31. **Polygnathus intermedius** (Bultynck)

GSC 56187, upper, outer lateral, and lower views of Pa element, from Dundee Formation, 5.15 to 5.46 m above quarry floor, Station 32, GSC loc. C-38969.

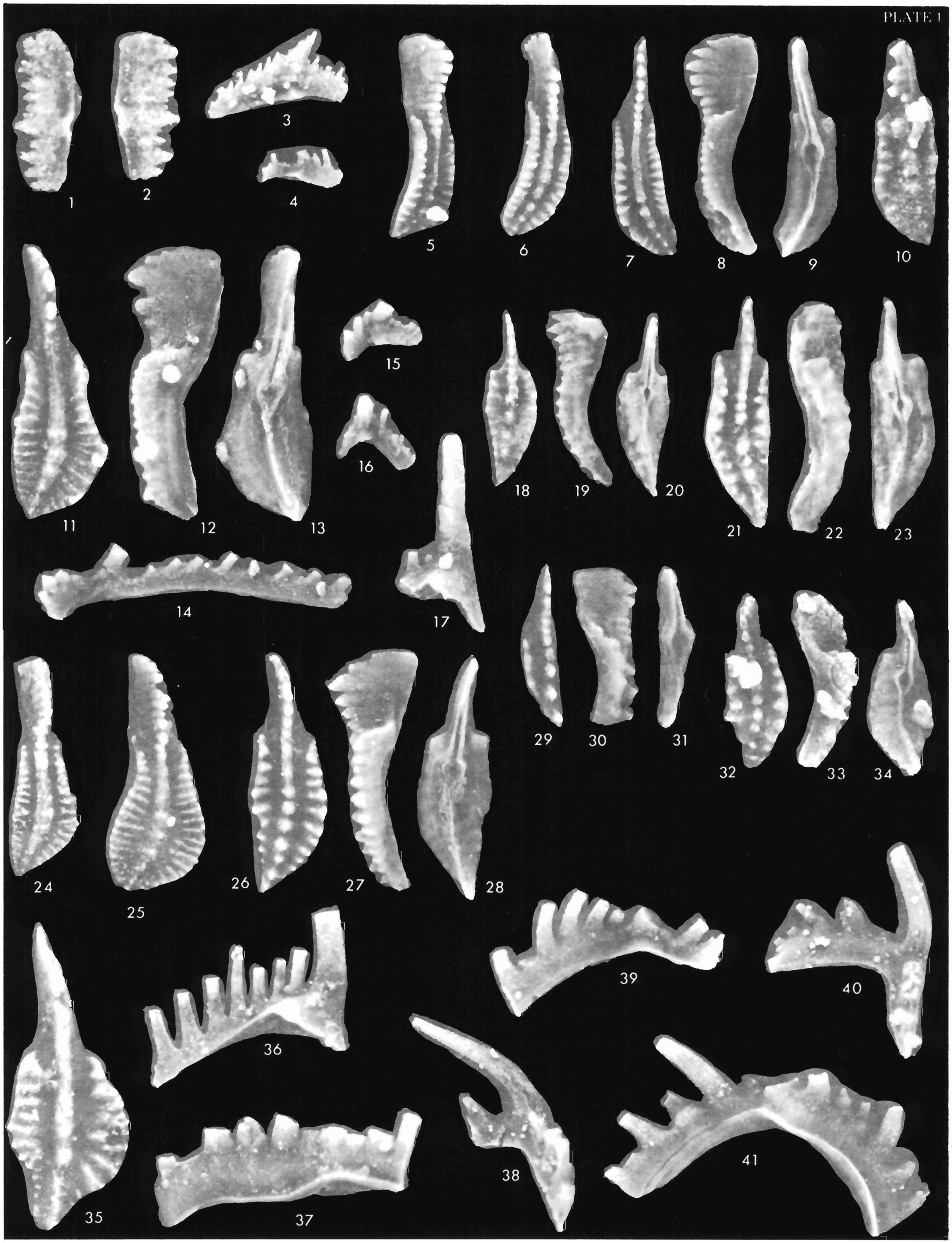
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PLATE 2

All figures x40

Figures 1-6. **Polygnathus** aff. **P. trigonicus** Bischoff and Ziegler

1, 2, GSC 56189, upper and lower views of Pa element;
3-5, GSC 56190, upper, inner lateral, and lower views of Pa element;
6, GSC 56191, upper view of Pa element;

all specimens from Dundee Formation, Station 33, figs. 1, 2, and 6 (GSC 56189 and 56191) from 2.10 to 2.32 m above quarry floor, GSC loc. C-38974, and figs. 3-5 (GSC 56190) from 1.10 to 1.25 m above quarry floor, GSC loc. C-38973.

Figures 7-19. **Polygnathus timorensis** Klapper, Philip, and Jackson

7, 8, GSC 56192 and 56193, inner lateral view of two Pa elements;
9, GSC 56194, inner lateral view of Sc element;
10, 11, GSC 56195 and 56196, posterior and lateral views of two Sa elements;
12, GSC 56197, inner lateral view of M element;
13-15, GSC 56198, upper, outer lateral, and lower views of Pa element (basal plate partly preserved posterior of pit);
16, GSC 56199, upper view of Pa element;
17, GSC 56200, inner lateral view of Sb element;
18, 19, GSC 56201 and 56202, outer lateral and inner lateral views, respectively, of two Pb elements;

fig. 7 (GSC 56192) from Ipperwash Formation, Hamilton Group, Station 28, GSC loc. C-38950; figs. 8-19 (GSC 56193 to 56202) from Widder Formation, Hamilton Group, 11.52 to 11.92 m above base of formation, Station 26, GSC loc. C-38947.

Figures 20-31. **Polygnathus linguiformis linguiformis** Hinde

20, 23, GSC 56203 and 56204, inner lateral view of two Sc elements;
21, GSC 56205, inner lateral view of Pb element;
22, GSC 56206, inner lateral view of Sb element;
24, GSC 56207, posterior view of Sa element;
25, GSC 56208, inner lateral view of M element;
26-28, GSC 56209, upper, inner lateral, and lower views of Pa element;

figs. 20-28 (GSC 56203 to 56209) from Dundee Formation, 8.81 to 9.11 m above base of formation, Station 18, GSC loc. C-38931.

29-31, GSC 56210, 56211, and 56212, upper, oblique upper, and upper views, respectively, of three Pa elements, from Dundee Formation, 7.59 to 7.89 m above base of formation, Station 18, GSC loc. C-38930.

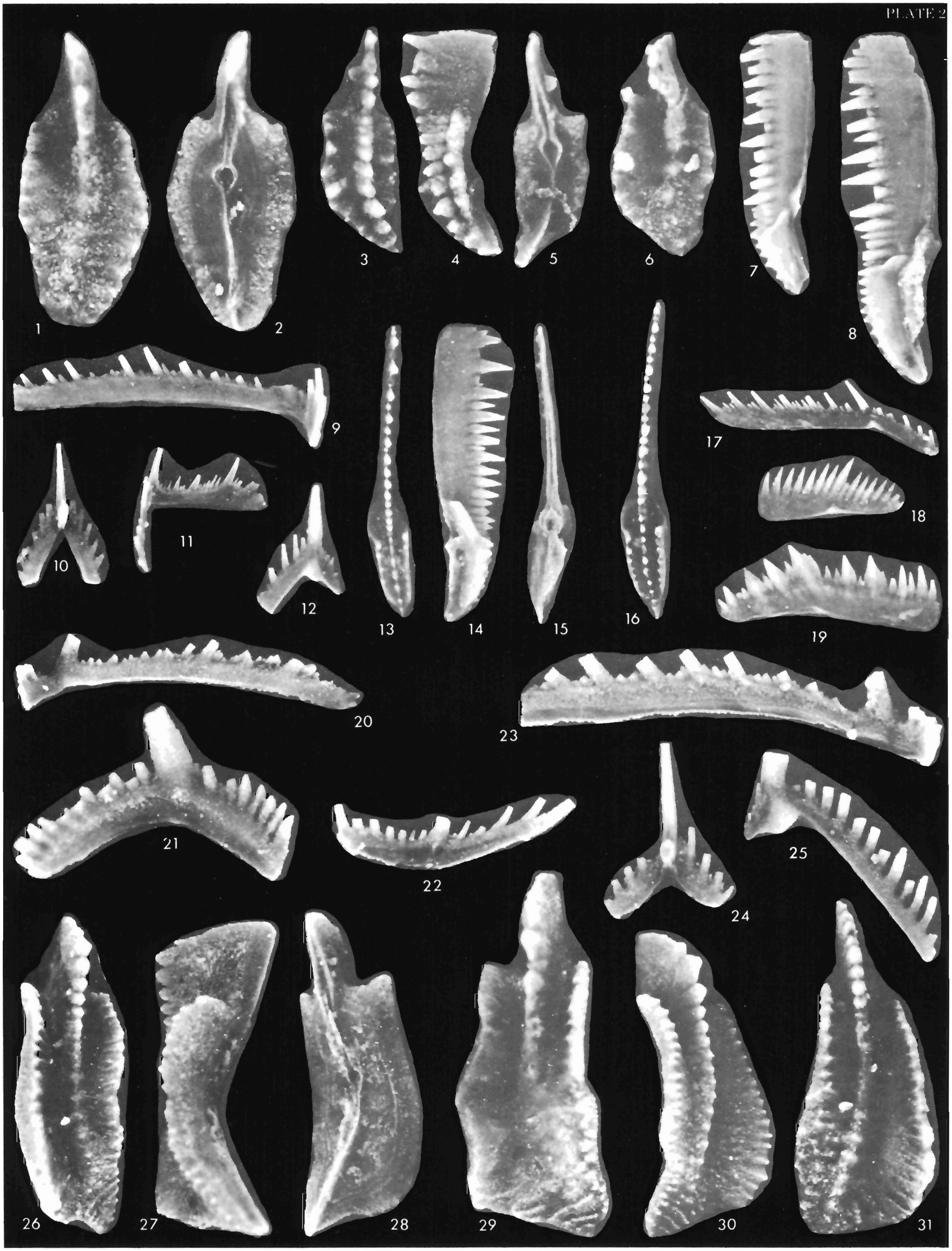
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PLATE 3

All figures x40

Figures 1-4. **Icriodus angustus** Stewart and Sweet

1, GSC 56213, inner lateral view of I element;
2-4, GSC 56214, upper, outer lateral, and lower views of I element;

both specimens from Dundee Formation, 8.75 to 9.05 m above base of formation, Station 17, GSC loc. C-38920.

Figures 5-12. **Icriodus hankae** n. sp.

5, 6, Paratypes, GSC 56215 and 56216, upper view of two I elements;
7-9, Holotype, GSC 56217, upper, inner lateral, and lower views of I element;
10-12, Paratype, GSC 56218, upper, inner lateral, and lower views of I element;

all specimens from Formosa Reef Limestone Member, Amherstburg Formation, Detroit River Group, Station 19, fig. 5 (GSC 56215) from 1.83 to 2.74 m above the road level, GSC loc. C-38934; fig. 6 (GSC 56216) from 3.66 to 4.57 m above the road level, GSC loc. C-38936; and figs. 7-12 (GSC 56217 and 56218) from 2.74 to 3.66 m above the road level, GSC loc. C-38935.

Figures 13-15. **Icriodus** sp. C

GSC 56219, upper, inner lateral, and lower views of I element, from Dundee Formation, 14.94 to 15.54 m above base of formation, Station 41, GSC loc. C-53292/81.08-81.69.

Figures 16-19, 23-27. **Icriodus** aff. **I. retrodepressus** Bultynck

16-18, GSC 56220, upper, inner lateral, and lower views of I element;
19, 23, 24, GSC 56221, 56222, and 56223, upper view of three I elements;
25-27, GSC 56224, upper, inner lateral, and lower views of I element;

figs. 16-19 (GSC 56220 and 56221) from the sandy facies, Anderdon Member, Lucas Formation, Detroit River Group, Station 13, 26.37 to 26.82 m above quarry floor, GSC loc. C-38879; fig. 23 (GSC 56222) from Dundee Formation, 14.94 to 15.54 m above base of formation, Station 41, GSC loc. C-53292/81.08-81.69; figs. 24-27 (GSC 56223 and 56224) from the sandy facies, Anderdon Member, Lucas Formation, Detroit River Group, Station 13, 26.82 to 27.31 m above quarry floor, GSC loc. C-38880.

Figures 20-22. **Icriodus obliquimarginatus** Bischoff and Ziegler

GSC 56225, upper, outer lateral, and lower views of I element, from Widder Formation, Hamilton Group, 10.79 to 11.28 m above base of formation, Station 26, GSC loc. 73695.

Figures 28-30. **Polygnathus** sp.

GSC 56226, upper, outer lateral, and lower views of Pa element, from Arkona Formation, Hamilton Group, 0.21 to 0.30 m below top of formation, Station 25, GSC loc. C-38942.

Figures 31-42. **Icriodus** sp. C

31, GSC 56227, inner lateral view of S_{2a} element;
32, GSC 56228, inner lateral view of S_{2b} element;
33, 34, GSC 56229 and 56230, inner lateral view of two M_2 elements;
35-37, GSC 56231, upper, inner lateral, and lower views of I element;
38, 39, GSC 56232 and 56233, upper view of two I elements;
40-42, GSC 56234, upper, outer lateral, and lower views of I element;

all specimens from Dundee Formation, Station 17, figs. 31-38 (GSC 56227 to 56232) from 6.55 to 6.71 m above base of formation, GSC loc. C-38918; figs. 39-42 (GSC 56233 and 56234) from 2.26 to 2.41 m above base of formation, GSC loc. C-38914.

PLATE 3

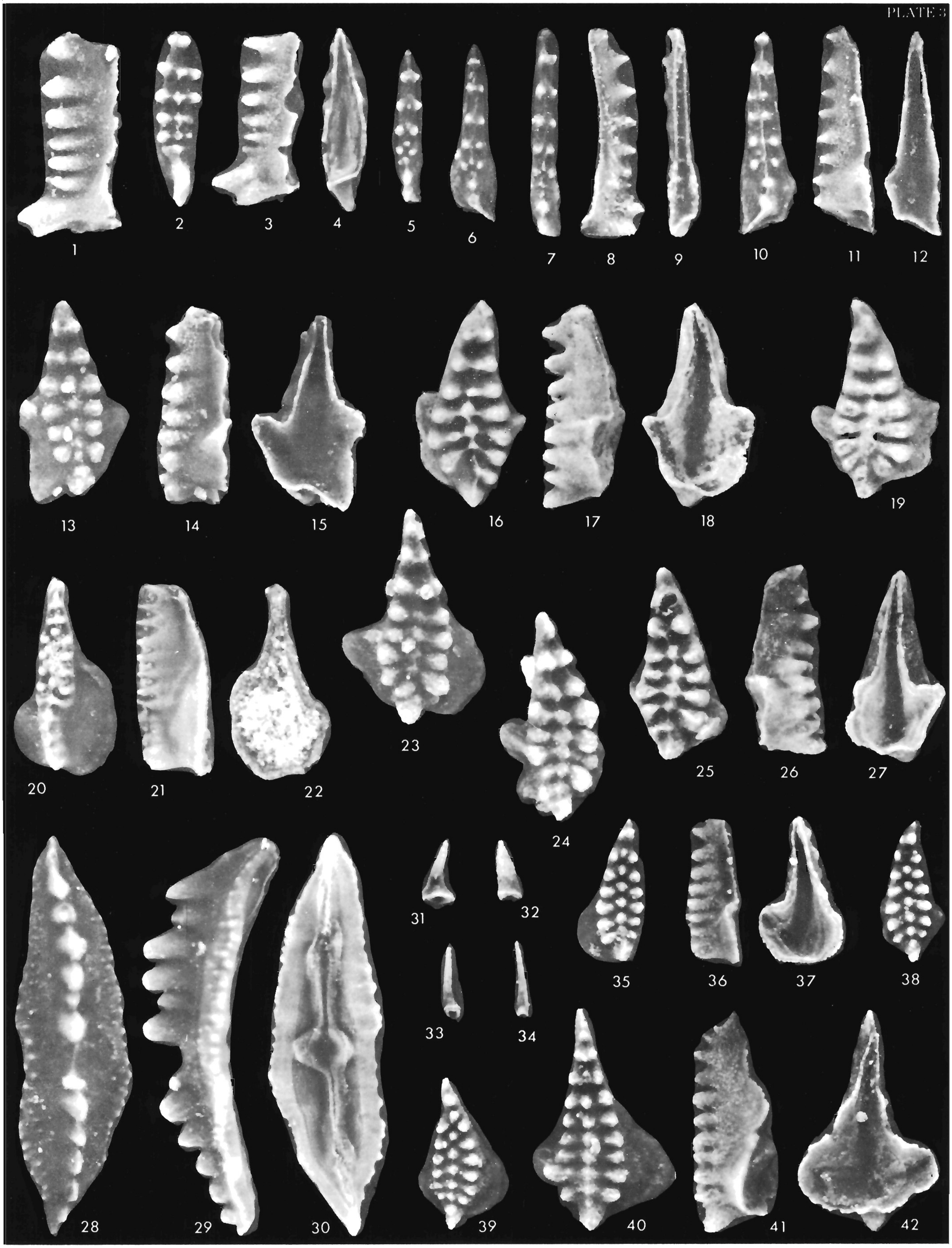

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PLATE 4

All figures x40. All figures are illustrations of I element unless otherwise noted. For **Icriodus latericrescens robustus** Orr, symbols for the I element are s=simple, i=intermediate, and a=advanced; see text for explanation.

Figures 1-26, 31-38. **Icriodus latericrescens robustus** Orr

1-3, GSC 56235, upper, outer lateral, and lower views (s);
4-6, GSC 56236, upper, outer lateral, and lower views (i);
7, GSC 56237, outer lateral view of S_2 element;
8, GSC 56238, upper view (i);

figs. 1-8 (GSC 56235 to 56238) from Bois Blanc Formation, 3.41 to 3.60 m above base of formation, Station 10, GSC loc. C-38856.

9, 10, GSC 56239, upper and lower view (s), from Bois Blanc Formation, 0.0 to 0.30 m above base of formation, Station 16, GSC loc. C-38902;

11, GSC 56240, upper view (i), from Bois Blanc Formation, 5.21 to 5.27 m above base of formation, Station 9, GSC loc. C-38852;

12, 13, GSC 56241, upper and lower views (s), from Bois Blanc Formation, 3.87 to 4.02 m above base of formation, Station 4, GSC loc. C-38829.

14, 15, GSC 56242, upper and lower view (s);
16, GSC 56243, outer lateral view of S_{2a} element;
17, 18, GSC 56244 and 56245, inner lateral views of two S_{2b} elements;

figs. 14-18 (GSC 56242 to 56245) from Bois Blanc Formation, 4.42 to 4.48 m above base of formation, Station 9, GSC loc. C-38851.

19, 20, GSC 56246, upper and lower views (s), from Bois Blanc Formation, 0.61 to 1.04 m above base of formation, Station 16, GSC loc. C-38904;

21, GSC 56247, upper view (i), from Formosa Reef Limestone Member, Amherstburg Formation, Detroit River Group, 1.83 to 2.74 m above the road level, Station 19, GSC loc. C-38934.

22, GSC 56248, upper view (s), from Amherstburg Formation, Detroit River Group, 2.83 to 2.99 m above quarry floor, Station 1, GSC loc. C-38809.

23, GSC 56249, inner lateral view of M_2 element;
24, GSC 56250, inner lateral view of S_{2a} element;
25, 26, GSC 56251, lower and upper views (i);

figs. 23-26 (GSC 56249 to 56251) from Amherstburg Formation, Detroit River Group, 1.92 to 2.10 m above quarry floor, Station 1, GSC loc. C-38808.

31, GSC 56252, upper view (i), from the sandy facies, Anderdon Member, Lucas Formation, Detroit River Group, 26.82 to 27.31 m above quarry floor, Station 13, GSC loc. C-38880;

32, 35, GSC 56253 and 56254, upper view (both i), both specimens from Dundee Formation, 2.53 to 2.62 m above quarry floor, Station 33, GSC loc. C-38975;

33, 34, GSC 56255, upper and lower views (a), from Bois Blanc Formation, 0.0 to 0.30 m above base of formation, Station 16, GSC loc. C-38902;

36-38, GSC 56256, upper, inner lateral, and lower views (a), from Bois Blanc Formation, 0.30 to 0.61 m above base of formation, Station 16, GSC loc. C-38903.

Figures 27-30. **Icriodus latericrescens latericrescens** Branson and Mehl

27-29, GSC 56257, lower, outer lateral, and upper views, from Ipperwash Formation, Hamilton Group, Station 28, GSC loc. C-38950;

30, GSC 56258, upper view, from Encrinal limestone, Hungry Hollow Formation, Hamilton Group, 0.0 to 0.34 m above base of formation, Station 25, GSC loc. C-38943.

PLATE 4

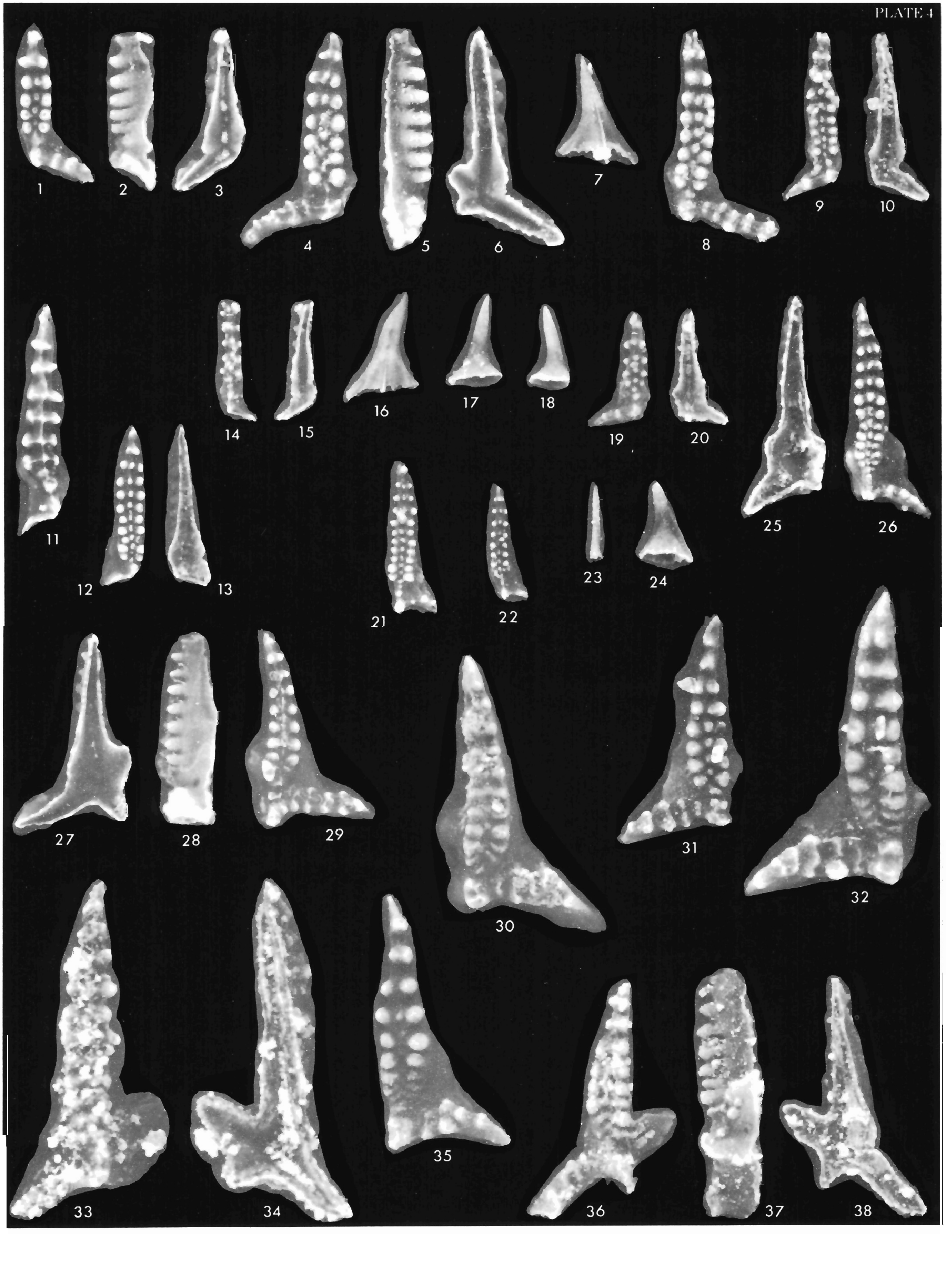

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PLATE 5

All figures x40

Figures 1-4. **Icriodus** cf. **I.** sp. A

1-3, GSC 56259, upper, outer lateral, and lower views of I element;
4, GSC 56260, upper view of I element;

both specimens from Dundee Formation, 8.81 to 9.11 m above base of formation, Station 18, GSC loc. C-38931.

Figures 5-9, 18-20. **Icriodus difficilis** Ziegler and Klapper

5-7, GSC 56261, upper, inner lateral, and lower views of I element;
8, 9, GSC 56262 and 56263, upper view of two I elements;
18-20, GSC 56264, upper, outer lateral, and lower views of I element;

figs. 5-8, GSC 56261 and 56262, from Widder Formation, Hamilton Group, 11.52 to 11.92 m above base of formation, Station 26, GSC loc. C-38947;

figs. 9, 18-20, GSC 56263 and 56264, from Ipperwash Formation, Hamilton Group, Station 28, GSC loc. C-38950.

Figures 10-16, 21, 22. **Icriodus brevis** Stauffer

10-12, GSC 56265, upper, inner lateral, and lower views of I element;
13-15, GSC 56266, upper, inner lateral, and lower views of I element;
16, GSC 56267, upper view of I element;

figs. 10-16 (GSC 56265 to 56267) from Widder Formation, Hamilton Group, 11.52 to 11.92 m above base of formation, Station 26, GSC loc. C-38947.

21, 22, GSC 56268 and 56269, upper view of I elements, Ipperwash Formation, Hamilton Group, Station 28, GSC loc. C-38950.

Figure 17. **Palmatodella quadrantinodosa quadrantinodosa** (Branson and Mehl)

GSC 56270, upper view of Pa element, from a concretion in the Kettle Point Formation, Station 27, GSC loc. C-38951.

Figures 23, 24. cf. **Coelocerodontus** sp.

GSC 56271 and 56272, lateral views, from Dundee Formation, 7.71 to 8.05 m above base of formation, Station 17, GSC loc. C-38919.

Figures 25-29. **Coelocerodontus** sp. (with lateral denticles)

25, 26, GSC 56273, upper and outer lateral views, from Amherstburg Formation, Detroit River Group, 3.84 to 4.02 m above quarry floor, Station 1, GSC loc. C-38810;

27, GSC 56274, outer lateral view, from Amherstburg Formation, Detroit River Group, 1.58 to 1.68 m above base of formation, Station 7, GSC loc. C-38843;

28, GSC 56275, outer lateral view, from Formosa Reef Limestone Member, Amherstburg Formation, Detroit River Group, 0.91 to 1.83 m above the road level, Station 19, GSC loc. C-38941;

29, GSC 56276, outer lateral view, from Dundee Formation, 8.75 to 9.05 m above base of formation, Station 17, GSC loc. C-38920.

Figures 30-32. **Belodella** sp.

GSC 56277, 56278, and 56279, all lateral views, all specimens from Amherstburg Formation, Detroit River Group, 1.92 to 2.10 m above quarry floor, Station 1, GSC loc. C-38808.

Figures 33-35. **Coelocerodontus** sp.

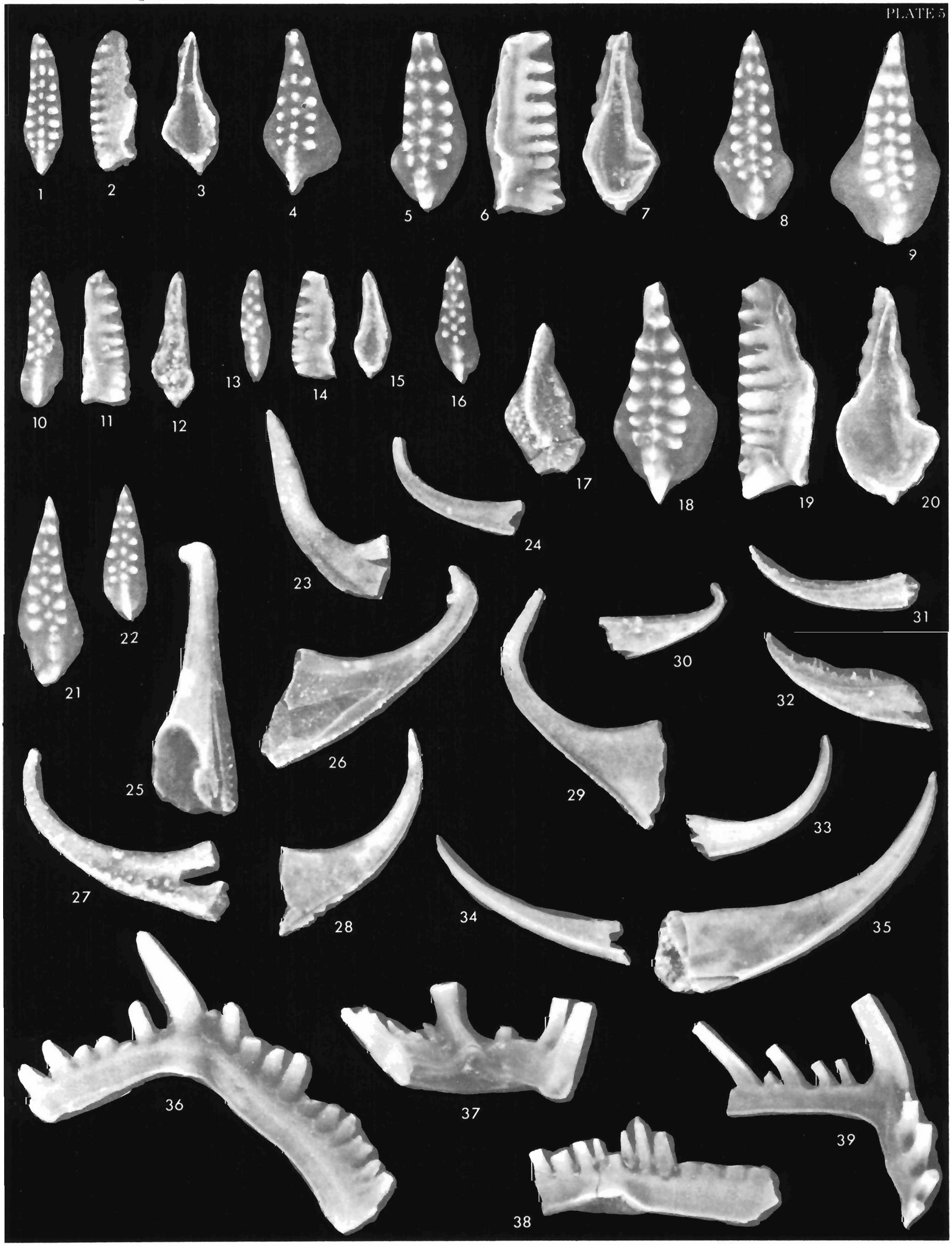
33, 34, GSC 56280 and 56281, lateral view, both specimens from Bois Blanc Formation, 5.21 to 5.27 m above base of formation, Station 9, GSC loc. C-38852;

35, GSC 56282, lateral view, from Bois Blanc Formation, 4.42 to 4.48 m above base of formation, Station 9, GSC loc. C-38851.

Figures 36-39. **Oulodus** sp.

36, GSC 56283, inner lateral view of Pa element;
37, GSC 56284, inner lateral view of Sb element;
38, GSC 56285, outer lateral view of Pb element;
39, GSC 56286, inner lateral view of Sc element;

all specimens from Widder Formation, Hamilton Group, 11.52 to 11.92 m above base of formation, Station 26, GSC loc. C-38947.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