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**DEPARTMENT OF ENERGY,  
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**BULLETIN 232**

**CONODONTS OF THE WATERWAYS FORMATION  
(UPPER DEVONIAN) OF NORTHEASTERN AND CENTRAL  
ALBERTA**

**T. T. Uyeno**

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CONODONTS OF THE WATERWAYS  
FORMATION (UPPER DEVONIAN) OF  
NORTHEASTERN AND CENTRAL ALBERTA

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OF CANADA

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By  
T. T. Uyeno

DEPARTMENT OF  
ENERGY, MINES AND RESOURCES  
CANADA



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## PREFACE

Recent paleontological research has shown the importance of conodonts as key index fossils in the Paleozoic and parts of the Mesozoic. The age of the Waterways Formation, in dispute for many years, has been defined more precisely by the author by means of its conodont assemblages. Such definition is important to our understanding of the boundary between the Middle and Upper Devonian in Alberta. It is now possible to correlate the Waterways Formation with the standard reference sections in Europe and North America and furthermore, the age relationship of the Waterways Formation to the oil-producing Swan Hills Formation of central Alberta has been more clearly established.

Research in systematic paleontology is one of the means by which the Geological Survey of Canada provides data for the calibration of the geological time scale so necessary for the precise dating and correlation of the rocks that make up the geological framework of Canada.

D. J. McLAREN,

*Director, Geological Survey of Canada*

OTTAWA, July 1973



# CONTENTS

	PAGE
INTRODUCTION.....	1
Previous work.....	1
Acknowledgments.....	3
GENERAL STRATIGRAPHY.....	4
The Waterways Formation.....	4
The Swan Hills Formation.....	7
The Beaverhill Lake Group.....	7
The Slave Point Formation.....	7
PREVIOUS PALEONTOLOGICAL INVESTIGATIONS AND CORRELATIONS OF THE WATERWAYS FORMATION AND BEAVERHILL LAKE GROUP.....	9
THE CONODONTS OF THE WATERWAYS FORMATION.....	12
Collecting localities.....	12
Conodont zonation.....	14
Stratigraphically significant conodonts in the Swan Hills Formation and the "basal limestone".....	19
Swan Hills Formation.....	19
"Basal limestone" with <i>Ladogioides</i> .....	20
CORRELATION OF THE WATERWAYS FORMATION ON THE BASIS OF CONODONTS.....	21
SYSTEMATIC PALEONTOLOGY.....	23
<i>Ancyrodella</i> .....	23
<i>Diplododella</i> .....	26
<i>Enantiognathus</i> .....	27
<i>Falcodus</i> .....	27
<i>Hibbardella</i> .....	28
<i>Icriodus</i> .....	29
* <i>Mesotaxis</i> .....	31
<i>Lonchodina</i> .....	31
<i>Nothognathella</i> .....	32
<i>Palmatodella</i> .....	35
* <i>Pandorinellina</i> .....	35
<i>Playfordia</i> .....	36

\*multielement genera

SYSTEMATIC PALEONTOLOGY (con.)	PAGE
<i>Polygnathus</i> .....	36
<i>Spathognathodus</i> .....	42
REFERENCES.....	45
APPENDIX.....	52
Locations and conodont contents of A. W. Norris collection.....	52
Collecting localities of Waterways Formation on Athabasca River.....	52
Collecting localities of Waterways Formation on Clearwater River and its tributaries.....	57
Subsurface sections.....	62
1. Alberta Government Salt Well No. 1.....	62
2. Industrial Minerals Limited Salt Well No. 1.....	63
3. Richfield Oil Corp. Pony Creek No. 2.....	64
4. Union Red Earth 2-22.....	67
5. Calstan Standard Oil of British Columbia House Mountain 2-6.....	68
6. Shell Swan Hills 6-31.....	69
7. Imperial Shell Burntwood 12-6.....	70
8. Imperial Judy Creek 6-7.....	71
9. California Standard Cynthia SW 16-21.....	73
TEXT INDEX TO GENERA AND SPECIES.....	93
Table	
1. Stratigraphic distribution of selected conodont form-species in the Waterways Formation.....	5
2. Upper Middle Devonian through Cretaceous formations in Athabasca-Clearwater Rivers area, northeastern Alberta.....	6
3. Specimens studied from the Waterways and Swan Hills Formations	13
4. (a): Distribution of selected conodont form-species and -genera in the Waterways Formation, outcrops, Athabasca and Clear- water Rivers and tributaries.....	<i>In pocket</i>
(b): Distribution of selected conodont form-species and -genera in the Waterways and Swan Hills Formations, subsurface, northeastern and central Alberta.....	<i>In pocket</i>
5. Locations and conodont contents of samples collected by A. W. Norris in 1956.....	53

## Illustrations

Plates 1 to 8. Illustrations of conodonts.....	75-91
Figure	
1. Index map of the Waterways Formation outcrop areas and local- ities of investigated wells.....	2
2. Outcrops of the Waterways Formation in northeastern Alberta.....	15
3. Columnar sections of the Moberly Member on Athabasca River....	16
4. Cross-section of Waterways and Swan Hills Formations in Wells 1 through 9.....	17

# CONODONTS OF THE WATERWAYS FORMATION (UPPER DEVONIAN) OF NORTHEASTERN AND CENTRAL ALBERTA

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## *Abstract*

Two formal conodont zones and one informal fauna, all of Late Devonian age, are recognized in the Waterways Formation of northeastern and central Alberta. The informal *Spathognathodus insitus* fauna (Klapper *et al.*, 1971) occurs in the Firebag Member and in the lower part of the Calumet Member. The upper part of the Calumet Member and the lowermost part of the Christina Member belong in the Lower *Polygnathus asymmetricus* Zone. The Middle *Polygnathus asymmetricus* Zone extends through most of the Christina Member into the lower part of the Mildred Member. Conodonts of this zone were found previously in the upper part of the Mildred Member (Pollock, 1968). Both zones are regarded as directly correlative with conodont zones defined in the Rhenish Schiefergebirge of Germany (Ziegler, 1958, 1962b, 1971). The age of the underlying Slave Point Formation of northeastern and north-central Alberta is considered to be Middle Devonian (Norris, 1963; McGill, 1966); therefore, the Middle-Upper Devonian boundary is placed at the Slave Point-Waterways contact.

In the reefoid Swan Hills Formation of central Alberta, diagnostic conodonts were recovered only from the upper part of the formation in two wells. They indicate the Lower *P. asymmetricus* Zone for that interval.

Form-taxonomy is utilized in the systematic paleontology, with some form-species grouped into conodont apparatuses (of Klapper and Philip, 1971, 1972) where possible. Ramiform and simple cone form-genera are omitted from this study, although their presence is recorded where recognizable in order to complete the listing of the vicarious skeletal elements of these apparatuses. The conodont collection of 1,915 specimens, referable to 11 genera, 31 species, and 2 subspecies (in form-taxonomy), is described and figured. The collection also includes 2,260 specimens assigned to 11 form-genera and which are identified to form-generic level only.

## *Résumé*

L'auteur reconnaît deux zones définies à conodontes et une faune indéfinie, datant du Dévonien supérieur, dans la formation Waterways du nord-est et du centre de l'Alberta. La faune indéfinie *Spathognathodus insitus* (Klapper *et al.*, 1971) est présente dans le niveau de Calumet. La partie supérieure du niveau de Calumet et la partie la plus basse du niveau de Christina appartiennent à la zone inférieure à *Polygnathus asymmetricus*. La zone moyenne à *Polygnathus asymmetricus* s'étend à travers la plus grande partie du niveau de Christina jusque dans la partie inférieure du niveau de Mildred. On a trouvé précédemment les conodontes de cette zone dans la partie supérieure du niveau de Mildred (Pollock, 1968). On croit

ces deux zones en corrélation directe avec les zones à conodontes définies dans le Rhenish Schiefergebirge d'Allemagne (Ziegler, 1958, 1962b, 1971). On croit que la formation Slave Point du nord-est et du centre-nord de l'Alberta qui forme le substratum daterait du Dévonien moyen (Norris, 1963; McGill, 1966), c'est pourquoi la limite entre le Dévonien moyen et le Dévonien supérieur est fixée au contact Slave Point-Waterways.

Dans la formation récifale de Swan Hills du centre de l'Alberta, on a prélevé dans deux puits des conodontes diagnostiques provenant de la partie supérieure seulement. Ils indiquent la zone inférieure à *P. asymmetricus* pour cet intervalle.

L'auteur a utilisé la taxonomie des formes de la paléontologie systématique avec certaines espèces de formes groupées dans les appareils de conodontes (de Klapper et Philip, 1971, 1972) lorsque c'était possible. Les genres ramifiés et ceux qui ont simplement la forme de cônes sont exclus de cette étude, bien que leur présence, lorsque reconnaissable, soit enregistrée afin de compléter la liste des éléments squelettiques substitutifs de ces appareils. L'auteur décrit et énumère la collection de conodontes de 1,915 spécimens, soit 11 genres, 31 espèces, et 2 sous-espèces (selon la taxonomie de la forme). La collection comprend aussi 2,260 spécimens attribués à 11 genres selon la forme et qui ne sont identifiés qu'au niveau du genre de la forme.

## INTRODUCTION

Since the initiation of the name Waterways Formation by Warren (1933, p. 149), the age of this formation and of its partial subsurface equivalent, the Beaverhill Lake Group, has been subject to considerable debate. In more recent years, for example, Loranger (1965b, p. 824, 833) considered the Waterways Formation to be Middle Devonian (Givetian), whereas McGill (1963, p. 2; 1966, p. 104, 106) has suggested that it is Late Devonian (Frasnian). Pollock (1968, p. 418) dated all but the basal limestone unit of the Beaverhill Lake Group of central Alberta as Frasnian, whereas Mound (1968, p. 455) considered the group to be entirely in the Upper Devonian Upper *Polygnathus asymmetricus* Zone.

The purpose of this paper is to determine whether the age of the Waterways Formation of northeastern (in its type area) and central Alberta can be established more clearly with the aid of conodont identification. It is hoped that this will lead to a clearer definition of the Middle-Upper Devonian boundary in these areas. A summary account of this study has already been presented (Uyeno, 1967).

For this investigation, 259 samples of the Waterways Formation from 35 sections along the Athabasca River and the Clearwater River and its tributaries were studied. Fifty of these samples were collected in 1956 by Dr. A. W. Norris of the Geological Survey of Canada, and the remainder by the author in 1964. In addition, 318 cored samples from nine wells distributed through northeastern and central Alberta were also examined. Localities of the outcrop sections and wells investigated are listed in the appendix, and some outcrop stations are indicated on Figure 1.

Most of the cores studied from central Alberta are from wells in the vicinity of the Judy Creek and Swan Hills field areas. Following Murray (1965, p. 308, 309) and Leavitt and Fischbuch (1968, p. 291) the term Waterways is used instead of Beaverhill Lake for these areas, with the latter used as a group term.

## Previous Work

Insofar as is known, W. D. MacDonald (1955, p. 106) was the first to note conodonts in the Waterways Formation. He recorded these fossils from the Moberly and/or Christina Members in the Alberta Government Salt well No. 1 and/or the Industrial Minerals Limited Salt well No. 1 (see Appendix for details of both wells). Later Carrigy (1959, p. 99, 105, 109) reported conodonts from the Firebag and Christina Members in these same wells. Loranger (1963, Parts 1-3; 1965a) undertook a microfaunal study, including conodonts, of the Waterways Formation and other strata in ten wells, most of which are located at or near the outcrop sites along the Athabasca and Clearwater Rivers. Pollock (1968) and Mound (1968) studied conodonts obtained from cores of the Beaverhill Lake Group from wells in central Alberta.

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## GENERAL STRATIGRAPHY

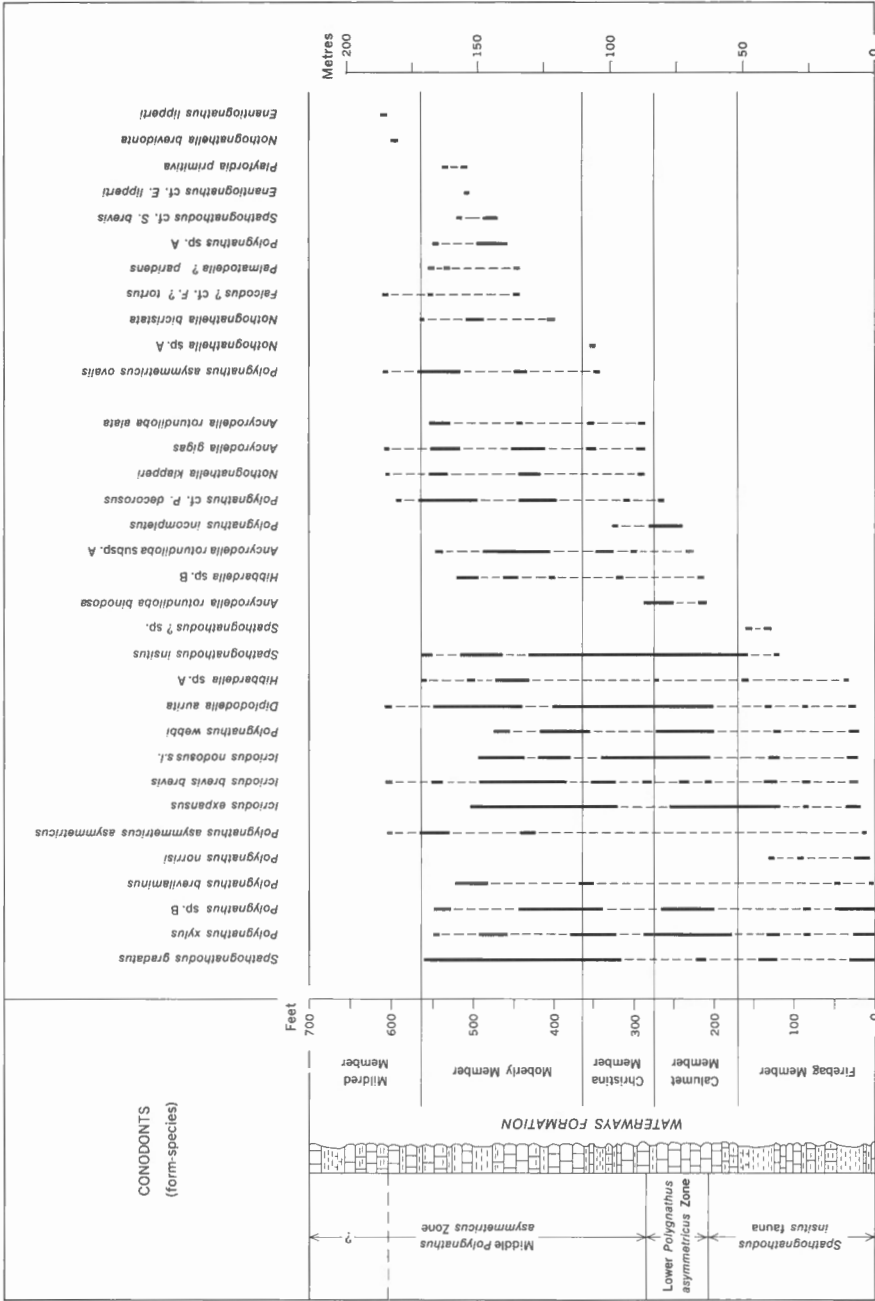
### The Waterways Formation

The stratigraphy and history of geological investigations of the Waterways Formation have been discussed in detail by Norris (1963, p. 25-39). Only a brief résumé of some of the key publications is presented here.

The name Waterways Formation was initially applied by Warren (1933, p. 149) to Devonian rocks overlying an evaporitic sequence in the lower Athabasca River district. Its thickness was given as 405 feet, based on the log of a salt well at McMurray (Alberta Government Salt well No. 1; see Fig. 1 and Appendix for location). The upper boundary was stated as being an erosional surface. Wells subsequently drilled in the area west of McMurray have shown that an additional 300 feet of Devonian strata occurs disconformably below the Lower Cretaceous McMurray Formation (the "Athabasca Tar Sands"). The stratigraphic position of the Waterways Formation in its type area is shown on Table 2.

Belyea (1952, p. 12, 36-44) described the sequence in one of these wells, the Bear Biltmore No. 1 well (7-11-87-17W4th) (see Fig. 1), and referred it to the Beaverhill [Lake] Formation. Crickmay (1957, p. 7-9) noted that the additional 300 feet in this well is both lithologically and paleontologically related to the Waterways Formation. Using the data from both this well and outcrops, he divided the interval into five members which are, in ascending order: Firebag (depth 1,512-1,682.5 feet), Calumet (= Calmut) (1,410-1,512 feet), Christina (1,320-1,410 feet), Moberly (1,120-1,320 feet), and Mildred (980-1,120 feet), and referred the interval to Warren's Waterways Formation. Crickmay (1957) and Norris (1963, p. 26-37) listed the lithologic characters and subsurface thicknesses of each member: Firebag, approximately 170 feet, composed of shale and argillaceous limestone, with *Tecnocyrtina billingsi* (Meek), *Desquamatia* cf. *independensis* (Webster), *Eleutherokomma impennis* Crickmay, etc.; Calumet, about 102 feet, resistant, consists of fine-grained and clastic limestone, argillaceous limestone, and some shale, with *Stropheodonta costata* Stainbrook and *Eleutherokomma* cf. *impennis* Crickmay; Christina, about 90 feet, argillaceous limestone, limestone, shale, and some sandy limestone and sandstone, with small forms of *Eleutherokomma*; Moberly, about 200 feet, composed of dominantly clastic limestone, argillaceous limestone, and some shale, with zones of *Eleutherokomma hamiltoni* Crickmay (upper 80 feet) and *Allanaria allani* (Warren) (lower 120 feet); and Mildred (980-1,120 feet; not exposed), 140 feet, composed of argillaceous limestone and shale, with *Eleutherokomma killeri* Crickmay. The reader is referred to Norris (1963) for complete lists of fossils in these members. The generalized columnar section of the Bear Biltmore No. 1 well is shown on Table 1.

Only part of the formation is exposed in the outcrops, with the lower boundary covered, and the upper boundary an erosional surface. For these reasons, Norris (1963, p. 25) stated that a definitely designated subsurface reference section presenting a complete sequence was desirable, and selected the Bear Biltmore No. 1 well as the logical choice for such a



Note: Generalized columnar section and thickness from the Bear Biltmore No. 1 well (7-11-87-17W4th)

TABLE 1. Stratigraphic distribution of selected conodont form-species in the Waterways Formation.

section of the Waterways Formation. According to Norris (1963, p. 25-26), "In this well the Waterways formation may be defined as the sequence of shale and argillaceous limestone alternating with mainly limestone units lying between the top of the Livock River formation, and the base of the Devonian Cooking Lake formation of the Woodbend group. In this well the Waterways formation is 701.5 feet thick lying between depths of 981 to 1,682.5 feet. The lower contact is drawn at the base of a sequence of greenish grey calcareous shale and argillaceous limestone resting on limestone or dolomitic limestone of the Livock River formation. The upper contact in this area is transitional and is placed at the highest calcareous shale and shaly limestone which is overlain by the Cooking Lake limestone formation of the Woodbend group." Unfortunately, the cores of this well had been utilized almost completely by previous workers and were unavailable to the writer for examination in 1964. A general table of upper Middle Devonian through Cretaceous formations in the outcrop area is shown on Table 2.

Period or epoch	Formation and thickness (feet)	Member and thickness (feet)	Lithology
LOWER CRETACEOUS	McMurray		
Unconformity			
UPPER DEVONIAN	Waterways 1702±	<sup>2</sup> Mildred 1140	Argillaceous limestone and shale
		Moberly 1200±	Clastic limestone, argillaceous limestone, and some shale
		Christina 190±	Argillaceous limestone, limestone, shale, and some sandy limestone and sandstone
		Calumet 1102±	Resistant fine-grained and clastic limestone, argillaceous limestone, and some shale
		Firebag 1170±	Shale and argillaceous limestone
? Unconformity			
MIDDLE DEVONIAN	<sup>2</sup> Livock River 15.5-?13		Limestone, some dolomite in places brecciated and associated with shale

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Thickness in subsurface . . . . . <sup>1</sup> 140  
 Not exposed . . . . . <sup>2</sup> Mildred

Note: (After Norris, 1963, p. 7)

TABLE 2. Upper Middle Devonian through Cretaceous formations in the Athabasca-Clearwater Rivers area, northeastern Alberta.

## The Swan Hills Formation

The oil-producing unit of the Beaverhill Lake Group of central Alberta was named the Swan Hills Member by Fong (1959, p. 97; 1960, p. 199). Murray (1966, p. 4) expressed his belief that this unit should be of formational rank in the Judy Creek field area. In the Swan Hills field area, Leavitt and Fischbuch (1968, p. 290, 291) considered the Swan Hills as a formation, and grouped it together with the Waterways and Fort Vermilion Formations as units within the Beaverhill Lake Group. This practice was continued by Leavitt (1968, p. 306) and by Sheasby (1971, p. 382).

The Swan Hills Formation is composed of organic and bioclastic limestones in the form of massive carbonate reefs. In the type well, the Home Regent "A" Swan Hills 10-10 (10-10-67-10W5th), the formation is 333 feet thick, and occurs in the interval between 8,167 and 8,500 feet (*see* Fig. 1 for location). On the basis of colour and lithology, this interval was divided into the informal lower Dark Brown unit (66 feet thick) and the upper Light Brown unit (267 feet thick) (Fong, 1959, p. 99-101). Leavitt and Fischbuch (1968, p. 294) noted that these informal subdivisions are not everywhere recognizable.

Following Leavitt and Fischbuch (1968, p. 290, 291), the two established names (Waterways and Beaverhill Lake) are retained in the Swan Hills area, with the Waterways and Swan Hills referred to as formations of the Beaverhill Lake Group. This practice has been subsequently followed by others (e.g., Hemphill *et al.*, 1970, p. 56). In the type area of north-eastern Alberta, the name Waterways Formation is used in the sense of Crickmay (1957, p. 7-9) and Norris (1963, p. 25-37).

## The Beaverhill Lake Group

The name Beaverhill Lake Formation was proposed by the geological staff of the Imperial Oil Limited (1950, p. 1832) for the sequence of limestone and shale between the Elk Point and Cooking Lake Formations in the subsurface of central Alberta. The type section was selected in the Anglo-Canadian Beaverhill Lake No. 2 well (11-11-50-17W4th), between the intervals of 4,325 and 5,047 feet, a total thickness of 722 feet (*see* Fig. 1 for location).

The Committee on Slave Point and Beaverhill Lake Formations (1964, p. 60) correlated the upper five members of this formation with the Waterways Formation. It further included within the Beaverhill Lake Formation, in west-central Alberta, the underlying Slave Point and Fort Vermilion Members; and in the east-central and southern part of the province, the "basal limestone."

As noted above, in the Swan Hills area, Leavitt and Fischbuch (1968, p. 290, 291) raised the Beaverhill Lake to a group status, and included in it the Waterways, Swan Hills, and Fort Vermilion Formations.

## The Slave Point Formation

The term Slave Point, as proposed by Cameron (1918, p. 25, 26), included Middle and Upper Devonian rocks in the Great Slave Lake region. Norris (1965, p. 78) excluded the Upper Devonian strata from the Slave Point Formation. Subsequent to Cameron's pro-

posals, the term has been extended to the subsurface, initially by Law (1955a, p. 83; 1955b, p. 1943–1949) and by others since that date (e.g., Belyea and Norris, 1962, p. 13–14).

The formation attains its maximum thickness in the area north of the Peace River arch where it measures from 200 to 400 feet thick (Committee on Slave Point and Beaverhill Lake Formations, 1965, p. 63), or up to 500 feet (Griffin, 1965, p. 14; Hemphill *et al.*, 1970, p. 62). To the south and west of the arch, there is a general thinning of the formation, and in the Bear Biltmore No. 1 well (in the vicinity of McMurray), for example, it is only 5½ feet thick.

The Slave Point Formation, as used by Law (1955a, b) in northwestern Alberta, and by Belyea and Norris (1962, p. 14) in southern District of Mackenzie and adjacent areas, consists of two members: the lower Fort Vermilion, and the upper unnamed. The lower member consists of dolomite, limestone, and anhydrite in northern Alberta. The upper member consists of limestones with intervals of stromatoporoids, commonly containing *Amphipora* (Belyea and Norris, *ibid.*). Fort Vermilion was raised to a formational status by Norris (1963, p. 59). Griffin (1965, p. 35) included only the upper member in his Slave Point Formation, and suggested that it is a facies equivalent of his "Lower Beaverhill Lake" (Firebag and Calumet Members of the Waterways Formation), and the basal part of the Christina Member. The Committee on Slave Point and Beaverhill Lake Formations (1964, p. 60) similarly considered the Slave Point Formation as a partial Beaverhill Lake correlative.

Leavitt and Fischbuch (1968, p. 292, 293) correlated the Slave Point Formation (= Livock River Formation) in the Bear Biltmore No. 1 well with Fong's (1959, p. 99–101) Dark Brown unit plus part of the overlying Light Brown unit of the Swan Hills Formation.

The age of the Slave Point fauna in the Gypsum Cliffs area of northeastern Alberta is clearly Middle Devonian (Norris, 1963, p. 63). In the type area, the formation, in its restricted usage of Norris, was tentatively considered as Middle Devonian (Norris, 1965, p. 78). McGill (1966, p. 104, 106) studied the ostracodes from the Slave Point Formation in the Lesser Slave Lake area, and concluded that they indicate a probable late Givetian age. He further suggested that the Givetian–Frasnian boundary occurs at the Slave Point–Beaverhill Lake contact. In the type Waterways area, the Livock River Formation carries the *Desquamatia independensis* fauna of late Givetian age (Norris and Uyeno, 1972, Fig. 2).

## PREVIOUS PALEONTOLOGICAL INVESTIGATIONS AND CORRELATIONS OF THE WATERWAYS FORMATION AND THE BEAVERHILL LAKE GROUP

A detailed summary of previous age assignments and regional correlations of the Waterways Formation was given by Norris (1963, p. 37-39). Consequently, only a brief résumé of this summary is given here, while those studies published subsequent to Norris' contribution are dealt with in more detail.

Warren (1933, p. 149) considered the Waterways fauna to indicate a Portage age; it was further noted to bear a considerable resemblance to the fauna of the Snyder Creek Shale of Missouri. Subsequently, the Waterways fauna has been compared also with those of the Cedar Valley Limestone of Iowa and the Tully Formation of New York.

Those workers who have considered the Waterways Formation as Middle Devonian and have correlated it with the Cedar Valley Limestone and/or the Tully Formation include Crickmay (1950, p. 220-222) and Taylor (1957, p. 192; 1958, p. 19). McLaren (1954, p. 169) correlated the Waterways with the lower part of the Flume Formation in the Rocky Mountains, and further with the Cedar Valley Limestone; the age of the latter unit, however, was undecided, and considered by him as late Middle or early Late Devonian. Belyea and McLaren (1957, p. 276) noted the anomalous presence of *Pachyphyllum*, a typical Upper Devonian coral genus, in the Waterways' Calumet Member; they were consequently hesitant in a definite correlation of the Waterways Formation with the Cedar Valley Limestone.

Those who considered the Waterways as an Upper Devonian formation, and correlated it with the Snyder Creek Shale include Warren (1933, p. 149), Warren and Stelck (1950, p. 72), McLaren (1962, p. 15), and Norris (1963, p. 39). Three fossil zones were established in the Waterways Formation by Warren and Stelck (1950, p. 70-73), namely, in ascending order: *Lingula* cf. *spatulata*, *Allanaria allani*, and *Eleutherokomma hamiltoni*. Of these, the faunas in the upper two zones were considered to be closely allied to the Snyder Creek Shale. McLaren (1962, p. 13) noted that the lower Waterways Formation contains many new elements bearing little resemblance to the faunas of the beds below. The underlying units carry, in the main, a coral fauna, whereas the Waterways and its equivalents carry a stromatoporoid-tabulate-brachiopod fauna, most of which is new. Further, like the Snyder Creek Shale, the Waterways carries, in addition to these new forms, relict Middle Devonian elements. Norris (1963, p. 39) listed, from among many brachiopod species present in the Snyder Creek and the Waterways Formation, nine species from each of these sequences which were considered to be closely related and probably biostratigraphically significant. Of the nine species from the Snyder Creek, two are present also in the underlying Callaway Limestone and the Cedar Valley Limestone.

Bassett (1952, p. 158) correlated the upper half of the Waterways Formation with the Snyder Creek Shale of Missouri, and the lower half with the Cedar Valley Limestone of Iowa.



The age assignments based on conodonts and macrofaunas of the Snyder Creek Shale and the Cedar Valley Limestone are discussed elsewhere.

In the Swan Hills Formation, Fong (1960, p. 207) recovered some fossils from the lower part of the Light Brown unit, and from the Dark Brown unit of the Home Regent "B" 10-13 well (10-13-67-11W5th), which indicate the uppermost *Lingula spatulata* zone. He noted that these fossils, combined with those from the dense beds overlying the Swan Hills Formation, "...indicate a continuous Waterways equivalence in the cored part from the upper part of the *Lingula spatulata* zone low in the Waterways to the base of the *Eleutherekomma leducensis* zone." The zones are those established by Warren and Stelck (1950). The Swan Hills Formation and the immediately overlying beds, therefore, were correlated with parts of the Waterways Formation.

According to Koch (1962, p. 621), "the fauna of the Swan Hills member belongs in the *Allanaria allani* and *Eleutherekomma* [sic] *hamiltoni* zones of the middle Waterways formation, and there is a suggestion that part of the *Lingula* cf. *spatulata* zone is present in the basal portion."

The Committee on Slave Point and Beaverhill Lake Formations (1964, p. 60) correlated the Light Brown unit with the Waterways Formation (i.e., with the top five members of the Beaverhill Lake "Formation"), and the Dark Brown unit with the Slave Point Formation of northeastern Alberta, and with the "basal limestone" (the lowest member of the Beaverhill Lake "Formation") of east-central and southern Alberta.

Subsequent to Norris' (1963) publication, several papers have appeared on various aspects of the Waterways faunas and their age assignments. Loranger (1963, Parts 1-3; 1965a) undertook a microfaunal study of this formation in ten wells, most of which are located at or near outcrop sites along the Athabasca and Clearwater Rivers. Based on her study of several groups of microfossils, including conodonts, she (1963, Part 1, p. 6) assigned a Givetian age to all of the Waterways Formation, except the uppermost Mildred Member. This was considered as "transitional" between the Givetian and Frasnian beds. In a later paper by Loranger (1965b, p. 824), the Middle-Upper Devonian boundary was still considered as transitional, but placed stratigraphically even higher, ranging from the Cooking Lake-Duvernay boundary up into the Ireton Formation.

McGill (1963, p. 1) dated an ostracode fauna from the Waterways Formation in the Bear Biltmore No. 1 well as latest Middle Devonian and earliest Late Devonian. He later (1966, p. 106) studied ostracodes from the underlying Slave Point Formation in wells located near the Lesser Slave Lake, which he dated as probably late Givetian, and suggested that the Givetian-Frasnian boundary occurs at the Slave Point-Beaverhill Lake contact.

In a series of papers, Stearn (1961a, 1962, 1963) investigated the stromatoporoid faunas of: (1) the Fairholme Group, and Alexo and Palliser Formations of the Rocky Mountains; (2) the Waterways Formation from its outcrop areas in northeastern Alberta; and (3) the Swan Hills Formation in the subsurface of north-central Alberta. He (1961b, p. 155A; 1963, p. 653-654) noted, after comparing the Waterways stromatoporoid fauna with those from its correlative strata, i.e., the Swan Hills Formation, and the Cairn and Flume Formations of the Rocky Mountains, that of 31 species only five occur in more than one area, and only one (*Amphipora ramosa* Phillips) is common to all. The Swan Hills fauna was concluded to be a mixture of late Middle and early Late Devonian elements.

The Swan Hills Formation varies in thickness and, at its maximum development, may indeed occupy the entire time interval represented by the Waterways Formation.

Norris (1965, p. 85) recovered, among other species, *Ladogioides pax* McLaren from the Hay River Formation exposed on the northwest side of Great Slave Lake. On the basis

of this species and associated fossils, he correlated these beds with the Firebag Member of the Waterways Formation of the Clearwater and Athabasca Rivers area, and with the Peace Point Member of the Waterways Formation of the Gypsum Cliffs section of north-eastern Alberta.

Murray (1965, p. 305–306) stated that the term Beaverhill Lake “Formation” should be abandoned in favour of the Waterways in the Judy Creek field area of central Alberta, and gave several valid reasons for its proposal.

Griffin (1965, p. 10, 28) proposed the terms “Lower and Upper Beaverhill Lake” to include the Firebag and Calumet Members, and the Christina, Moberly, and Mildred Members, respectively. He further considered the Slave Point Formation of northeastern British Columbia, and his “Lower Beaverhill Lake” plus the lower part of the Christina Member, to be facies equivalent. Where the Slave Point was sampled for conodonts in the present study, the fauna was meager and undiagnostic (*see* Appendix).

Pollock (1968) and Mound (1968) studied conodonts of the Beaverhill Lake Group obtained from cores in wells located in central Alberta. Both studies extended to other formations, and the Waterways comprised only a small part of the total scope.

Fischbuch (1968), in his stratigraphic study of the Swan Hills reef complexes, examined stromatoporoids, algae, corals, and ostracodes. Within the Swan Hills Formation, he noted the important change in the stromatoporoid faunas at the boundary between his divisions V and VI, and that this boundary also marks the last occurrence of Middle Devonian ostracodes. This, combined with a lithological break at this boundary, led Fischbuch to consider that this hiatus contains the Middle–Upper Devonian boundary.

Leavitt (1968) conducted a facies analysis of the Swan Hills Formation in the Carson Creek North reef complex, located immediately southwest of the Swan Hills reef complex. Besides stromatoporoids, he examined several fossil groups including corals and brachiopods.

Hemphill *et al.* (1970, Fig. 7, p. 63–64) correlated the basal part of the Swan Hills Formation in the Swan Hills field with the Calumet Member of the Waterways Formation. Both the Slave Point Formation and the Firebag Member, Waterways Formation, were considered to wedge out east of the Swan Hills region.

Plicated cyrtiniform brachiopods, common in the lower part of the Waterways Formation of northeastern Alberta, were assigned to a new genus, *Tecnocyrtina* (Johnson and Norris, 1972). Based on the distribution of *T. billingsi* (Meek), they (*ibid.*, p. 566–571) correlated the Waterways Formation with various other localities and stratigraphic units.

## THE CONODONTS OF THE WATERWAYS FORMATION

In this study, form-taxonomy (as opposed to multielement taxonomy, or apparatuses) is utilized. Where possible, these form-species have been referred to the apparatuses that were established by Klapper and Philip (1971, 1972) and by Lindström and Ziegler (1966) and Ziegler (1972).

The general distribution of selected conodont form-species in the Waterways Formation is shown on Table 1. A total of 1,915 specimens are referable to 11 genera, 31 species, and 2 subspecies. In addition, three specimens referable to Lindström and Ziegler's (1966) apparatus are listed, together with 2,147 specimens (ramiform and simple cone elements) that are identified to form-generic level only. Among those samples collected by Dr. A. W. Norris of the Geological Survey of Canada, four yielded specimens that are figured herein. These four samples yielded a total of 188 specimens, referable to 14 selected form-species, and 9 ramiform and simple cone form-genera that are identified to generic level only (*see* Appendix). The number of specimens of each form-species recovered from each member of the Waterways Formation and of the Swan Hills Formation is shown on Table 3. Those specimens from the Norris collection are not included in this table, but are given separately in the appendix.

On Table 1, occurrences in the Swan Hills Formation have been omitted because the exact correlation of this unit to the reference section of the Waterways Formation (of Norris, 1963, p. 25) is not clearly known, although some evidence is present (*see*, e.g., Leavitt and Fischbuch, 1968, p. 295). The evidence provided by conodonts and other fossils is discussed elsewhere in this report.

Well-preserved conodonts were recovered from throughout the formation. The abundance of specimens varies considerably from sample to sample, but generally, of the outcrop samples, the Moberly Member yielded more specimens per unit weight than other members. The highly argillaceous Firebag and Christina Members were the least productive. This may be due to the more rapid deposition of shale in comparison to limestone (*see* Lindström, 1964, p. 68).

The reefoid Swan Hills Formation yielded only a meager conodont collection, and specimens are generally fragmentary. Because all samples were treated similarly, the difference in preservation is very probably of primary sedimentological origin.

### Collecting Localities

#### Outcrops

In preparation of this report, 122 samples from 11 sections along Athabasca River and 87 samples from 24 sections along Clearwater River and its tributaries, of the Waterways Formation, were collected and studied. Some outcrop localities, with the same station numbers of Norris (1963), are marked on Figure 1. A complete list of localities is given

WATERWAYS AND SWAN HILLS FORMATIONS										
CONODONTS (form-species) *Apparatuses of KLAPPER and PHILIP (1971)	Mildred Mbr		Moberly Mbr		Christina Mbr		Calumet Mbr		Firebag Mbr	
	s	o	s	o	s	o	s	o	s	s
<i>Ancyrodella gigas</i>	1		21		3					25
<i>Ancyrodella rotundiloba alata</i>			3		8					11
<i>Ancyrodella rotundiloba binodosa</i>					3	6	1		2	12
<i>Ancyrodella rotundiloba subsp. A</i>		49	6	2	2		1			60
<i>Enantiognathus lipperti</i>	1								1	2
<i>Enantiognathus cf. E. lipperti</i>		1								1
<i>Hibbardella sp. A</i>		8					1		2	11
<i>Hibbardella sp. B</i>		6	1		1	1				9
<i>Icriodus brevis brevis</i>	1	23	16	2	11	8	1	4	9	76
<i>Icriodus expansus</i>		57	12	9	10	65	8	10	13	185
<i>Icriodus nodosus s.l.</i>		43	3		9	12	1	6	9	84
<i>Nothognathella bicristata</i>			4							4
<i>Nothognathella brevidonta</i>	1									1
<i>Nothognathella sp. A</i>					1					1
* <i>Pandorinellina insita</i>										
<i>Spathognathodus insitus</i>		134	2	7	3	590	37	5	8	787
<i>Palmatodella ? paridens</i>			8							8
<i>Playfordia primitiva</i>			2							2
* <i>Mesotaxis asymmetrica</i>										
<i>Diplododella aurita</i>	1	38	9		8	12	1	1	2	75
<i>Falcodus ? cf. F. ? tortus</i>	1		13							14
<i>Nothognathella klapperi</i>	5		23		1					29
<i>Polygnathus asymmetricus asymmetricus</i>	9		16					1(?)		26
<i>Polygnathus asymmetricus ovalis</i>	18	1	40		1					60
<i>Polygnathus brevilaminus</i>		5	1		1			2	2	11
<i>Polygnathus cf. P. decoratus</i>	1	2	34		1		2			40
<i>Polygnathus incompletus</i>					5	22	12		2	41
<i>Polygnathus norrisi</i>								2	3	5
<i>Polygnathus webbi</i>		3	1	1		12	5	4		27
<i>Polygnathus xylus</i>		6	2	3	9	38	6		3	70
<i>Polygnathus sp. A</i>		44	1							45
<i>Polygnathus sp. B</i>			8		2	7	5		12	44
<i>Spathognathodus cf. S. brevis</i>		8								8
<i>Spathognathodus gradatus</i>		78	10	1	7	10	4	19	4	137
<i>Spathognathodus ? sp.</i>								4		4

GSC

Note: \*Apparatuses above with only their partial constituent elements

Subsurface . . . . . s  
Outcrop . . . . . o

TABLE 3. Number of specimens studied from the Waterways and Swan Hills Formations (exclusive of collection by A.W. Norris, 1956; see Appendix).

in the appendix (see Norris, 1963, Figs. 4, 7 for locations). Figure 2 illustrates a representative section of each member of the Waterways Formation exposed at Athabasca River and Clearwater River and one of its tributaries. In addition to this material, 50 samples collected in 1956 by Dr. A. W. Norris were studied. Four of these samples yielded specimens that are figured herein, and only these localities are referred to in the appendix.

Some units of the Moberly Member are encountered repeatedly in outcrops along Athabasca River. For this reason, only those sections which give the most complete composite sequence were studied. Columnar sections and their correlations of these selected sites are shown on Figure 3. Rock units used in the figure are those of Norris (1963), and the reader is referred to that reference for detailed lithologic descriptions.

### Subsurface

Nine wells cored through various stratigraphic intervals of the Waterways and Swan Hills Formations were also studied (see Fig. 1). Of these, one is located within the townsite of McMurray, Alberta, and another in the town of Waterways, 2.7 miles southeast of the former. The other seven wells are distributed throughout the northeastern part and the central plains of Alberta, including the Judy Creek field area. The underlying Slave Point and Elk Point Formations also were examined for conodonts where cores were available. A total of 318 subsurface samples were studied.

Stratigraphic columns of the cored intervals of each well studied, and their possible correlations, are shown on Figure 4. The base of the Swan Hills Formation is drawn as coinciding with the base of the Firebag Member, as has been done by Murray (1965, p. 307–309; 1966, p. 5). The Committee on Slave Point and Beaverhill Lake Formations (1964, p. 60) and Leavitt and Fischbuch (1968, p. 454), however, considered at least the lower Dark Brown unit (of Fong, 1959) of the Swan Hills Formation to be in part correlative with the Slave Point Formation. The alternatives here have little or no bearing on the present study, as diagnostic conodonts were not recovered from either the Slave Point or the lower part of the Swan Hills Formation.

### Conodont Zonation

Ziegler (1962b) established a detailed conodont zonation of the Upper Devonian in Germany, based principally on sections in the Rhenish Schiefergebirge. The position of the Middle–Upper Devonian boundary was further elucidated in his later study (Ziegler, 1966, p. 656–658) by an introduction of a new conodont zone, the *Schmidtognathus hermanni*–*Polygnathus cristatus* Zone. In the Martenberg section (of Ziegler, 1958, p. 9–11), the upper part of this new zone was subsequently found to be associated with a number of diagnostic goniatites, including *Ponticeras pernai* cf. *applanatum* (Wedekind), and was therefore considered to be lower Upper Devonian (Kullmann and Ziegler, 1970, p. 75). The lower part of this zone still was considered to be Middle Devonian although nothing diagnostic was found associated with it.

The reported North American occurrences of the Upper *S. hermanni*–*P. cristatus* Zone have been consistently associated with Middle Devonian megafossils. The reader is referred to Johnson (1970, p. 2081, 2086, 2092–2093) and Klapper *et al.* (1971, p. 297–299) for details.

Klapper *et al.* (1971, p. 300) introduced an informal unit, the *Spathognathodus insitus* fauna, which was defined as “the fauna dominated by the name-giver in strata below the



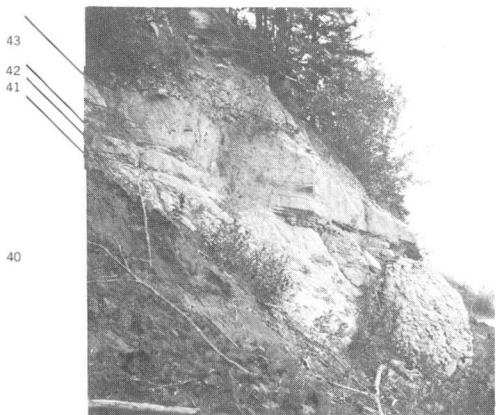
122107

- A. Firebag Member, Station 103, Athabasca River, east bank, 63.7 miles downstream from the Waterway's wharf, on a southern limb of a westward-plunging anticline; Rock Unit 2.



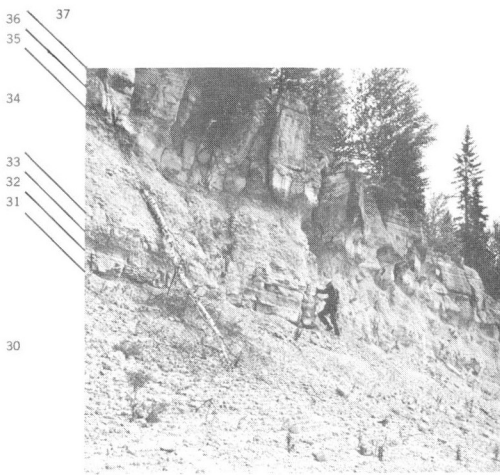
122166

- B. Calumet Member, Station 181, Clearwater River, south bank, 22.4 miles downstream from the confluence of High Hill River; Rock Unit 35.



122170

- C. Christina Member, Station 184, Christina River, west bank, 2.8 miles upstream from the confluence of Clearwater River; Rock Units 40 to 43, and the overlying unnumbered unit. (5-foot rod on the central left side of photo shows scale.)



122127

- D. Moberly Member, Station 70, Athabasca River, east bank, 30.8 miles downstream from the Waterways' wharf, Rock Units 30 to 37.

FIGURE 2. Outcrops of the Waterways Formation in northeastern Alberta.

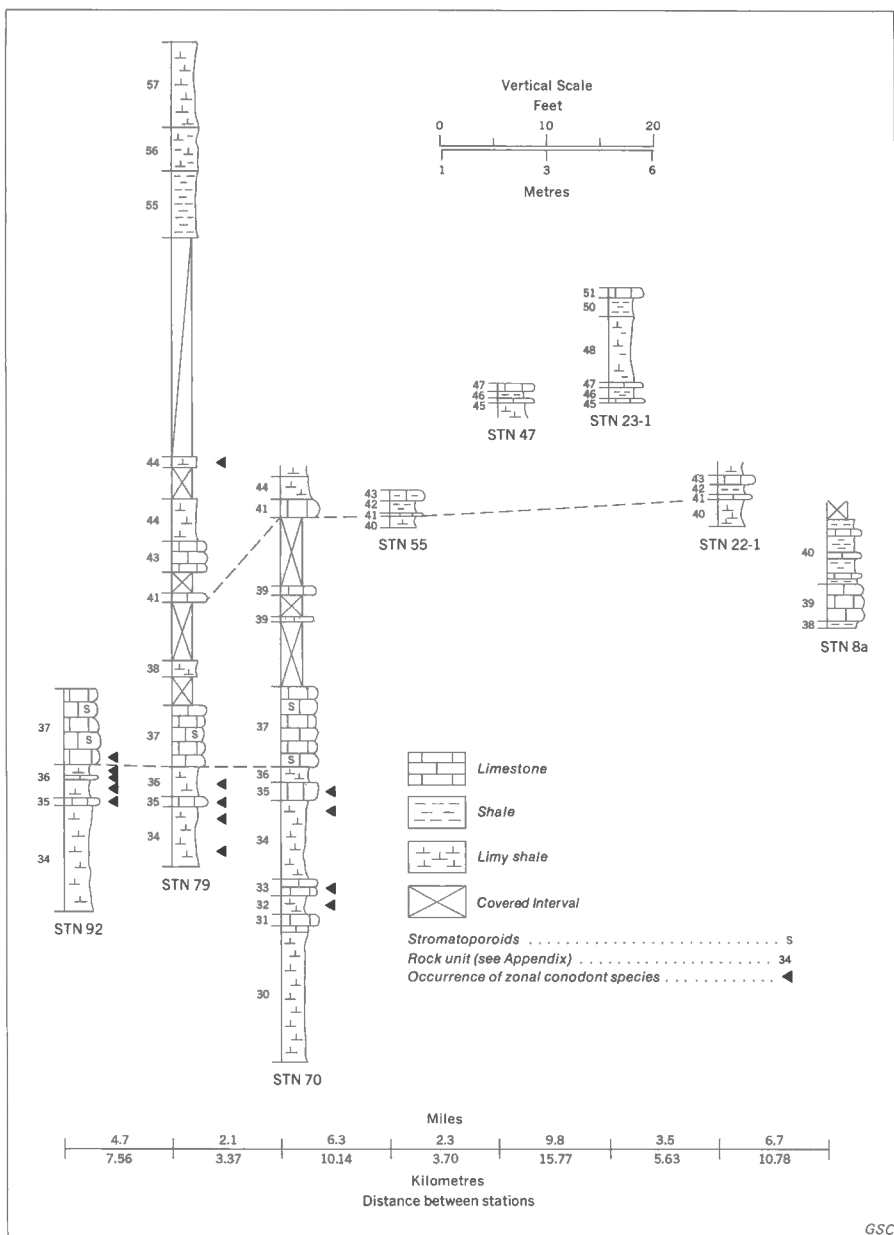


FIGURE 3. Columnar sections of the Moberly Member on Athabasca River.

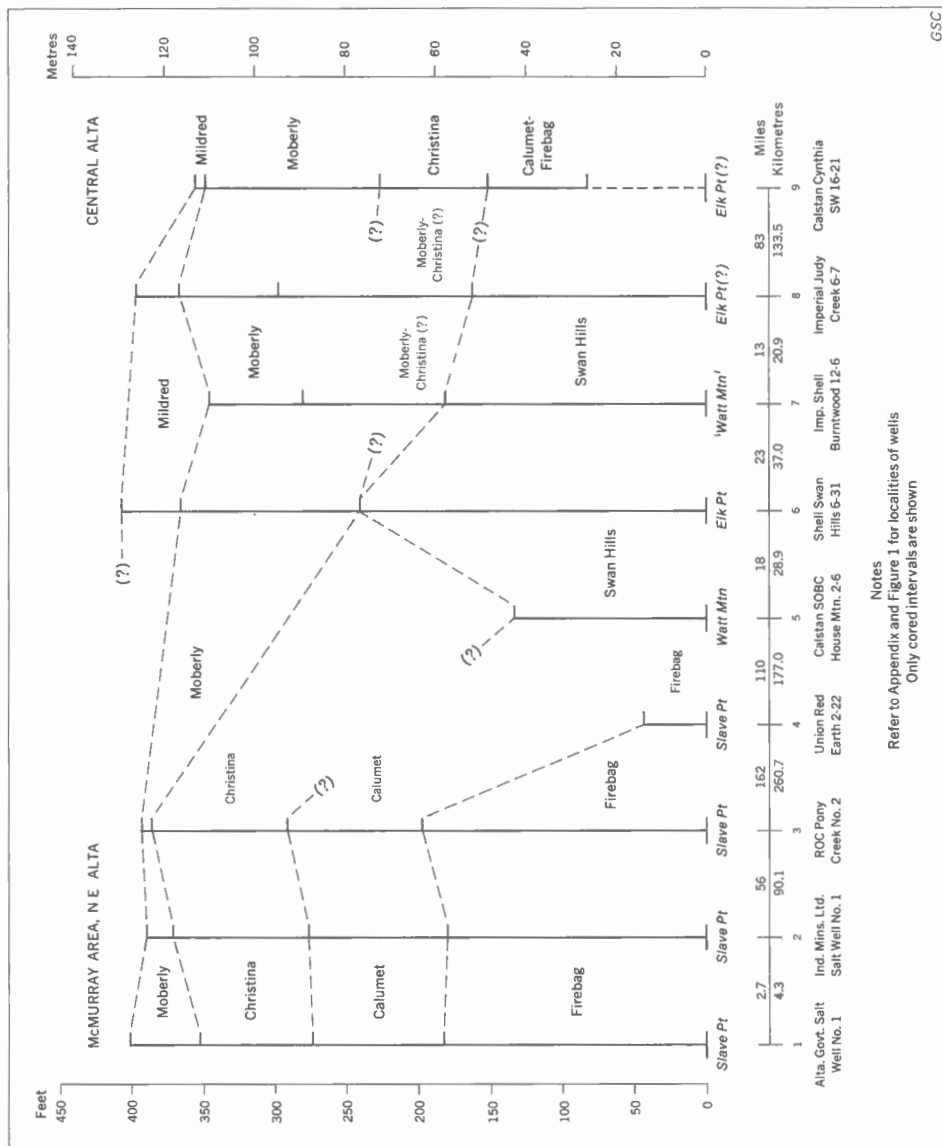


FIGURE 4. Cross-section of Waterways and Swan Hills Formations in wells 1 through 9.



first appearance of *Ancyrodella rotundiloba* (all subspecies).” The interval characterized by this fauna is limited in vertical extent but is widespread in North America, being found in Missouri, Iowa, Illinois, Manitoba, and Alberta. The reader is referred to Klapper *et al.* (1971, Fig. 3, p. 298) for details of correlations of beds containing this fauna. This interval may be subdivided into: (1) the lower beds consisting of the upper parts of the Callaway Formation and Coralville Member, Cedar Valley Limestone of Missouri and Iowa, all of which have not yet been dated conclusively by associated megafaunas; and (2) the upper beds consisting of the Firebag and basal Calumet Members of the Waterways Formation, northeastern Alberta; the Point Wilkins Member, and beds underlying between it and the basal shale, Souris River Formation, central Manitoba; and the State Quarry Limestone in Iowa, all of which contain Late Devonian brachiopods (McLaren, 1962, p. 13–15; Norris and Uyeno, 1972, p. 211–215; Cooper *et al.*, 1942). Consequently, the higher beds containing the *S. insitus* fauna may be dated as Late Devonian, and the lower beds may possibly be Middle Devonian, although they also are probably Late Devonian on the basis of Belgian evidence (see below).

The *S. insitus* fauna may occupy the position of the Lowermost *Polygnathus asymmetricus* Zone, defined as the part below the first occurrence of *Ancyrodella rotundiloba* (Ziegler, 1971, p. 267), but a direct correlation has not been established as *S. insitus* thus far is unreported from Germany. *S. insitus* was reported for the first time in Europe by Coen and Coen-Aubert (1971, p. 17) from the Assise de Fromelennes (F1c) at Ny in the Dinant Basin, Belgium. The F1c interval carries the *Myophoria transrhenana* Zone, and is assigned to the Frasnian (Lecompte, 1970, Table 3). This association further supports the Late Devonian age, at least in part, of the *S. insitus* fauna. Further support is given by a sequence in the Waterways Formation in which there is a probable phylogenetic sequence from the *S. insitus* (Firebag Member) to forms transitional between *S. insitus* and *A. rotundiloba binodosa* (described herein, and by Uyeno, 1967, p. 11, Pl. 2, Figs. 2, 3, as *Spathognathodus*? sp.) (higher in the Firebag), and finally to *A. rotundiloba binodosa* (middle of Calumet and lowest part of Christina Members). This demonstrates the position of the *S. insitus* fauna immediately below the first occurrence of *A. rotundiloba*.

*Polygnathus norrisi* is associated with the *S. insitus* fauna in the Waterways Formation, and in the Souris River Formation (Point Wilkins Member and beds underlying it) (Norris and Uyeno, 1972, p. 215). *P. norrisi* also occurs in the lower 22 feet of the “Allochthonous beds” overlying the Ramparts Formation in western District of Mackenzie, but there it occurs in the Lowermost *P. asymmetricus* Zone, and again in association with Late Devonian brachiopods, including *Tecnocyrtina billingsi* (Meek) (Pedder in Lenz and Pedder, 1972). This supports the suggestion of Klapper *et al.* (1971, p. 300) of the possible equivalency, at least in part, of the *S. insitus* fauna and the Lowermost *P. asymmetricus* Zone.

Schumacher (1971, p. 20–21) studied conodonts of the Middle–Upper Devonian boundary beds (Cedar Valley Formation, Snyder Creek Shale) of Missouri and adjacent states. He noted there the apparent mutual exclusion of *S. insitus* and the Upper *hermanni–cristatus* Zone, and considered the possibility that they, at least in part, are correlative and are facies equivalent.

*Polygnathus asymmetricus*, the name bearer of the lower four Upper Devonian conodont zones, was found in the upper three members of the Waterways Formation, and possibly in the Firebag Member (see Table 1). The combined range of another important index species, *Ancyrodella rotundiloba alata*, *A. rotundiloba binodosa*, and *A. rotundiloba* subsp. *A.* extends from about the middle part of the Calumet through the top of the Moberly Member.

*Ancyrodella gigas* ranges from the basal part of the Christina(?) through Mildred Members. As with earlier practice (Klapper *et al.*, 1971), the first occurrence of *A. gigas* is assumed to be the base of the Middle *P. asymmetricus* Zone (Ziegler, 1962b, p. 19; 1971, Chart 5). The first appearance of the definitive species of the zone, *Palmatolepis punctata* (Hinde), is higher than that of *A. gigas* in North America, although they appear simultaneously for the first time in Germany (Ziegler, 1958, p. 13; 1971, Chart 5). Pollock (1968, p. 428, loc. 3, core depth 4,480 feet), for example, reported *Palmatolepis punctata* from the Mildred Member. It is on this basis that the base of the Middle *P. asymmetricus* Zone is placed near the base of the Christina Member.

*Spathognathodus insitus* ranges from the middle part of the Firebag Member through the Moberly Member. In summary, the Firebag Member and the lower part of the Calumet Member are placed in the *Spathognathodus insitus* fauna, most of the Calumet through basal Christina in the Lower *P. asymmetricus* Zone, and the remainder of the Waterways Formation in the Middle *P. asymmetricus* Zone. Pollock (1968) has demonstrated the Middle *P. asymmetricus* Zone in the Mildred Member, in the interval above the highest point where conodonts were obtained in this study.

## Stratigraphically Significant Conodonts in the Swan Hills Formation and the "Basal Limestone"

### Swan Hills Formation

*Ancyrodella rotundiloba binodosa* occurs in the upper 17 feet of the Swan Hills Formation in the Imperial Shell Burntwood 12-6 well (12-6-64-12W5th) at depths of 9,457 and 9,467 feet (see Appendix). That part of the reefoid unit in this well therefore is suggested to be approximately equivalent to the stratigraphic interval to which this subspecies is restricted in other localities; i.e., from the middle part of the Calumet through the basal Christina Member of the Waterways Formation. There is corroboration to this correlation of the upper part of the Swan Hills Formation in this well. *Polygnathus incompletus* occurs in the upper 17 feet of the unit in this same well, and in approximately the upper 2 feet in the Calstan SOBC House Mountain 2-6 well (2-6-70-10W5th). Its range elsewhere, in the subsurface and the surface, is from the upper part of the Calumet through the middle part of the Christina Member.

*Enantiognathus lipperti* was recovered from about 24 feet below the upper boundary (depth interval 7,471.7-7,473.9 feet) of the Swan Hills Formation in the Calstan SOBC House Mountain 2-6 well (2-6-70-10W5th). About 104 feet below this occurrence (depth interval 7,575.9-7,578.2 feet), a specimen of *Diplododella aurita* was found, suggesting a possible Late Devonian age at least to this depth. The remaining approximately 17 feet of the Swan Hills Formation in this well was barren of conodonts.

It appears, therefore, that, in attempting to correlate the Swan Hills Formation with the non-reefoid Waterways Formation, the conodont evidence is in agreement with the evidence given by others on the basis of macrofaunas and ostracodes (e.g., Stelck *in* Fong, 1960, p. 207; Koch, 1962, p. 621; Braun *in* Fischbuch, 1968, p. 452).

"Basal limestone" with *Ladogioides* (=Firebag Member)

*Polygnathus norrisi* was found only in the Firebag Member in two wells and in the outcrop samples. In a third well, the Union Red Earth 2-22 well (2-22-88-8W5th), it also occurs in the "basal limestone" with *Ladogioides*, in an interval now considered to be Firebag Member (H. R. Belyea, pers. com., 1972). Conodont evidence, therefore, is in agreement with that of the brachiopod genus *Ladogioides* which is restricted to the Firebag Member (Norris, 1963, p. 27, Fig. 8), and which is of early Frasnian age (McLaren, 1962, p. 66). The occurrence of *Polygnathus norrisi* elsewhere has already been noted in this paper.

## CORRELATION OF THE WATERWAYS FORMATION ON THE BASIS OF CONODONTS

In terms of the conodont-ammonoid zonation in the Rhenish Schiefergebirge of Germany (Ziegler, 1962b, p. 16-19; p. 267, Chart 5), the Waterways Formation correlates with the Lowermost(?), Lower, and Middle *P. asymmetricus* Zones. These zones occur in the lowest part of the *Manticoceras* Stufe (*doIa*).

The following correlations of the Waterways Formation with some other localities in North America are drawn heavily from Klapper *et al.* (1971, Fig. 3, p. 298). As noted earlier, the *Spathognathodus insitus* fauna with *Polygnathus norrisi*, and also associated with Late Devonian brachiopods, is present in the Firebag and basal part of the Calumet Members. This interval occurs in the State Quarry Limestone of Iowa, the Coralville Member of the Cedar Valley Limestone of Illinois, the Point Wilkins and lower beds of the Souris River Formation of Manitoba (also associated with *Polygnathus norrisi*; Norris and Uyeno, 1972, p. 215), and the Maywood Formation of southwestern Montana (Klapper, 1968, p. 6-12). In the Dinant Basin in Belgium, this interval is probably represented, at least in part, in the Assise de Fromelennes (Flc) which carries the *Myophoria transrhenana* Zone of Frasnian age (Lecompte, 1970, Table 3). The Lowermost *P. asymmetricus* Zone (without *S. insitus*, but with *P. norrisi*) is represented in the "Allochthonous beds" of the Powell Creek section, western District of Mackenzie (Uyeno *in* Mackenzie, 1971, p. 491; Uyeno *in* Lenz and Pedder, 1972, p. 37).

The Lower *P. asymmetricus* Zone is present in the Calumet and basal Christina Members of the Waterways Formation, and probably in the upper 17 feet of the Swan Hills Formation in the Imperial Shell Burntwood 12-6 well (12-6-64-12W5th) (*see* Appendix). It is also represented in an unnamed formation at Mary's Mountain, Nevada, the Squaw Bay Limestone of Michigan, and the Genundewa Limestone of New York.

The Middle *P. asymmetricus* Zone, without *Palmatolepis punctata* (Hinde), is present in the upper part of the Christina through the Moberly Member. This interval is also represented in the lower part of the Snyder Creek Shale of Missouri. Possibly it may be present in the West River Shale Member of the Genesee Formation of New York (with *A. rotundiloba alata*) and in the Rock Grove Member of the Shell Rock Formation of Iowa (with *A. gigas* as the only diagnostic form found so far in it; Anderson, 1966, p. 399-400).

Pollock (1968, p. 428) recorded the lowest occurrence of *Palmatolepis punctata* in the Mildred Member of the Waterways Formation, and assigned this unit to the Middle *P. asymmetricus* Zone. This interval, with *P. punctata*, is also present in the Maligne Formation (= upper Flume, of de Wit and McLaren, 1950). In the upper beds of the Maligne Formation at the Saskatchewan Gap section, in an interval that is probably equivalent to the beds carrying the *Eleutherokomma jasperensis* fauna, *Ancyrodella rotundiloba* occurs with *Palmatolepis subrecta* Miller and Youngquist (Pollock, 1968, p. 425, 428; pers. com., 1972). This interval probably represents the upper part of the Middle *P. asymmetricus* Zone (Ziegler,

1958, Table 2). The basal Woodford Shale of Oklahoma also yielded this combination (Hass and Huddle, 1965, p. D126, loc. D).

The conodonts of the Flume Formation at its type section require detailed study. The type section at Roche Miette in Jasper National Park is 151.5 feet thick (de Wit and McLaren, 1950, p. 24).

The macrofauna of the Waterways in the past has been compared closely by some authors with that of the Tully Formation of New York. The Tully lies within the upper part of the *Polygnathus varcus* Zone, and is therefore dated as late Middle Devonian (Klapper and Ziegler, 1967, p. 71, 79). A Middle Devonian age assignment is supported by macrofaunal evidence (Cooper, 1968, p. 703–704; Oliver *et al.*, 1968, p. 1034). The goniatites reported from the Tully by House (1962, p. 272–274) are regarded by Kullmann and Zielger (1970, p. 75) to represent a form closely related to *Maenioceras* or a predecessor of true *Pharciceras* because of its archaic suture.

## SYSTEMATIC PALEONTOLOGY

The form-taxonomy has been employed in the following systematic paleontology. Ramiform and simple cone form-genera are omitted from this study, although their abundance and distribution are recorded on Table 4 (*in pocket*) in order to present all the data. Those form-species that are constituent elements of apparatuses as reconstructed by Klapper and Philip (1971, 1972) are so noted in the systematics and on the accompanying tables. The names of these apparatuses are listed alphabetically together with those of form-taxa.

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

### Genus *Ancyrodella* Ulrich and Bassler, 1926

*Ancyrodella* Ulrich and Bassler, 1926, p. 48.

*Ancyropenta* Müller and Müller, 1957, p. 1092–1093.

Type species. *Ancyrodella nodosa* Ulrich and Bassler, 1926.

*Remarks.* The Waterways collection includes juvenile specimens of *Ancyrodella rotundiloba binodosa* Uyeno, which, in possessing only incipiently developed platforms, exhibit forms similar to those described herein, and by Uyeno (1967, p. 11, Pl. 2, figs. 2, 3), as *Spathognathodus*? sp. The latter, however, morphologically more closely resembles a *Spathognathodus*, similar to *S. insitus* (Stauffer). It lacks the platform of *Ancyrodella*, and possesses nodes as outgrowths of the lateral sides. *Spathognathodus*? sp. occurs in the upper part of the Firebag Member, whereas *Ancyrodella rotundiloba binodosa* occurs in the middle part of the Calumet Member through basal Christina Member. Their morphological similarities and relative stratigraphic positions suggest a possible phylogenetic relationship between them.

Klapper and Philip (1972, p. 99) regarded this genus in multielement taxonomy as belonging to family Polygnathidae, and composed of six elements.

### *Ancyrodella gigas* Youngquist

#### Plate 1, figures 1, 8, 9

*Ancyrodella gigas* Youngquist, 1947, p. 96–97, Pl. 25, fig. 23; Anderson, 1966, p. 403, Pl. 48, figs. 10, 14; Szulczewski, 1971, p. 12, Pl. 2, fig. 3, Pl. 4, fig. 1.

*Polygnathus rotundiloba* Bryant, Youngquist, 1947, p. 110, Pl. 26, fig. 6.

*Ancyrodella rugosa* Branson and Mehl, Pollock, 1968, p. 428, Pl. 61, fig. 1.

*Description.* Triangular platform of nearly symmetrical to somewhat irregular outline. Upper surface of the platform with coarse, rounded nodes set in semiregular arrangement. Secondary carinae not prominent; secondary keels, however, well developed, extending to the anterior end of the platform.

*Remarks.* In his discussion of the evolution of *Ancyrodella*, Ziegler (1962a) demonstrated that *A. gigas* was the postgenitor of *A. rotundiloba*. The secondary keels of *A. gigas* are more

advanced, and exhibit forms characteristic of the genus, as illustrated by Ziegler (1962a, p. 151, text-fig. 4b).

*Range.* In Germany, Ziegler (1958, 1962b) recorded the range of this species as the Middle *P. asymmetricus* Zone to the Upper *P. gigas* Zone.

*Figured specimens.* GSC Nos. 20694, 24062, and 24063, GSC locs. 63317, 63356, and 64010, respectively.

#### *Ancyrodella rotundiloba* (Bryant)

*Polygnathus rotundilobus* Bryant, 1921, p. 26–27, Pl. 12, figs. 1–6, p. 26, text-fig. 7 [Pl. 12, fig. 1, is lectotype designated by Ziegler, 1958, p. 44].

*Ancyrodella rotundiloba rotundiloba* (Bryant), Glenister and Klapper, 1966, p. 799, Pl. 85, figs. 9–13.

*Diagnosis.* See Glenister and Klapper (1966, p. 799) and Uyeno (1967, p. 4).

*Remarks.* Müller and Clark (1967, p. 906) noted that with their specimens of this species, the size of the pit remains more or less constant through various growth stages. While this is true, greater variations in the initial pit size are exhibited by the Waterways specimens.

*Range.* The range of this species is from the Lower through Middle *P. asymmetricus* Zones (Ziegler, 1971).

#### *Ancyrodella rotundiloba alata* Glenister and Klapper

##### Plate 1, figures 3, 7

*Ancyrodella rotundiloba alata* Glenister and Klapper, 1966, p. 799–800, Pl. 85, figs. 1–8, Pl. 86, figs. 1–4; Pollock, 1968, p. 424, Pl. 61, figs. 2, 3; Pölsler, 1969, p. 404, Pl. 4, figs. 1–4; Seddon, 1970b, Pl. 7, fig. 4, Pl. 9, figs. 5, 6; Szulczewski, 1971, p. 15–16, Pl. 1, figs. 1, 2.

*Ancyrodella rotundiloba* (Bryant), Müller and Clark, 1967, p. 908, Pl. 115, fig. 8 [not Pl. 116, figs. 1–5 = *A. rotundiloba rotundiloba*].

*Ancyrodella rotundiloba rotundiloba* (Bryant), Pölsler, 1969, p. 404, Pl. 4, figs. 5–8; Klapper and Philip, 1972, p. 99, Pl. 2, fig. 6 [not figs. 7–13].

*Diagnosis.* See Glenister and Klapper, 1966, p. 799.

*Remarks.* The specimen from the Squaw Bay Limestone illustrated by Müller and Clark (1967, text-figs. 5d, 6r) may be referable to this subspecies. Unlike the Western Australian and the Waterways specimens, the drawings of their specimen show both secondary keels well developed, extending to the margins of the platform, and the upper surface of the platform ornamented with coarse nodes. Specimens with similarly well-developed secondary keels are reported by Pollock (1968) and Szulczewski (1971).

Representatives of this form-species constitute the P element of Type 1 apparatus, *A. rotundiloba alata* of family Polygnathidae (Klapper and Philip, 1972, p. 99).

*Figured specimens.* GSC Nos. 24064 and 24065, GSC locs. 63356 and 64010.

#### *Ancyrodella rotundiloba binodosa* Uyeno

##### Plate 1, figures 2, 4–6; Plate 2, figures 2, 3, 5

*Ancyrodella rotundiloba binodosa* Uyeno, 1967, p. 4–5, Pl. 1, figs. 2, 4, 5; Coen and Coen-Aubert, 1971, p. 16.

*Ancyrodella rotundiloba* (Bryant), Clark and Ethington, 1967, p. 29–30, Pl. 2, fig. 7 [not figs. 4, 6, 8–10. 13–15 = *A. rotundiloba alata*]; Seddon, 1970a, Pl. 16, fig. 1.

*Spathognathodus swanhillensis* Pollock, 1968, p. 440–441, Pl. 63, figs. 1–7.

*Ancyrodella* cf. *A. rotundiloba* (Bryant), Seddon, 1970b, Pl. 7, fig. 5.

*Description.* Triangular platform with a pair of large nodes, one on each side of the carina. Platform otherwise free of ornamentation, although a few incipient nodes may occur. Carina composed of a few short, stubby denticles. Free blade high, composed of a few denticles. Pit relatively large, occupying most of the lower surface of the platform, especially of smaller specimens. Secondary keels developed only incipiently.

*Remarks.* The pit of *A. rotundiloba binodosa* is consistently relatively larger than that of *A. rotundiloba alata* or *A. rotundiloba rotundiloba* (the latter from comparison with illustrations and dimensions given by others, e.g., Glenister and Klapper, 1966; Müller and Clark, 1967). The last two subspecies have a diamond-shaped pit, whereas the pit of *A. rotundiloba binodosa* is more oval-shaped. The pit of *A. rotundiloba* subsp. A is even larger, with bifurcation in some (see description of the latter subspecies).

Two juvenile specimens were obtained from the base of the Christina Member (illustrated on Pl. 1, fig. 4; Pl. 2, fig. 3). These individuals exhibit a platform with the upper surface mostly occupied by large nodes. Most of the lower surface of the platform is occupied with a relatively large pit. In mature individuals, the platform attained a relatively larger size in proportion to the free blade, and the pit and the two nodes, although still large, occupied a relatively smaller area. The juvenile specimens are morphologically similar to *Spathognathodus?* sp. [described herein].

Pollock (1968, p. 441, and pers. com., 1972) recorded this subspecies from two wells, both occurring within the Waterways Formation, in the Moberly and Calumet Members. Coen and Coen-Aubert (1971, p. 16) noted it in the unit F2a (=Schistes calcaireux à *Cyrtospirifer orbelianus*; Lecompte, 1968, Pl. 7; 1970, Table 3) at Durbuy and Ny, Dinant Basin, and at Dourbes, in Belgium. These authors also noted that it is a rare subspecies, and that it has affiliation with *Spathognathodus*.

*Types.* Holotype, GSC No. 22819, GSC loc. 29089; paratypes, GSC Nos. 22820 and 22821, GSC locs. 63115 and 63382.

*Figured specimens.* GSC Nos. 24066 through 24069, from GSC locs. 80247, 63382, 63100, and 63118, respectively.

#### *Ancyrodella rotundiloba* subsp. A

##### Plate 2, figures 1, 4, 6–9

*Ancyrodella rotundiloba* subsp. A Uyeno, 1967, p. 5, Pl. 1, figs. 1, 3, 6.

(?) *Ancyrodella rotundiloba rotundiloba* (Bryant), Szulczewski, 1971, p. 15, Pl. 1, fig. 4 [not Pl. 1, fig. 3 = *A. rotundiloba rotundiloba*].

*Description.* Platform triangular to oval, sculptured with extremely coarse nodes; some specimens with a pair of larger nodes, one on each side of the platform. Free blade composed of a few high denticles. Pit small, diamond-shaped (e.g., illustrated on Pl. 2, fig. 8A), or large with flaring lips, in some specimens, bifurcating at the termini (e.g., illustrated on Pl. 2, fig. 6A). Secondary keels only incipiently developed. Lower surface of platform almost flat to highly undulating.

*Remarks.* Some specimens included in this subspecies are similar to the nominate subspecies in their platform outline and the shape of the pit. Others have a more oval platform with a large pit. All, however, bear the extremely coarse nodes in contrast to the finer ornamentation of the nominate subspecies.



Three juvenile specimens of this subspecies (one illustrated on Pl. 2, fig. 4) exhibit forms somewhat similar to those of *A. rotundiloba binodosa*. In addition to the prominent pair of nodes, a few small nodes are already present on the platform.

Szulcowski (1971) considered this subspecies as synonymous with the nominate subspecies. The basis for this was that Müller and Clark (1967) regarded Squaw Bay forms with similar platform outline and upper ornamentation as integral variations within the ontogeny of *A. rotundiloba*. Some of these Squaw Bay specimens may also fall within the present subspecies. That they are not juvenile representatives is attested by their large size, similar in dimensions to those given by Müller and Clark (1967).

*Figured specimens.* GSC Nos. 22822, 22823, 22824, 24070, 24071, and 24137, from GSC locs. 62691, 63119, 62828, 80428, 29282, and 63306, respectively.

### Genus *Diplododella* Bassler, 1925

Type species. *Diplododella bilateralis* Bassler, 1925.

*Remarks.* See Huddle, 1968, p. 12 for diagnosis and revised description of this genus.

#### *Diplododella aurita* (Sannemann)

##### Plate 8, figures 3, 6

*Roundya aurita* Sannemann, 1955, p. 153, Pl. 5, fig. 11 [not Pl. 2, fig. 3 = *Hibbardella* sp.].

(?) *Roundya aurita* Sannemann, Glenister and Klapper, 1966, p. 834, Pl. 96, fig. 18.

*Diplododella aurita* (Sannemann), Huddle, 1968, p. 12; Norris and Uyeno, 1972, p. 215, Pl. 3, fig. 13.

*Hibbardella plana* Thomas, Pollock, 1968, p. 430, Pl. 61, figs. 4, 5.

*Polygnathus asymmetricus* Bischoff and Ziegler, Klapper and Philip, 1971, p. 434, 449, fig. 3, illus. A<sub>3</sub> [not illus. P, O<sub>1</sub>, N, A<sub>1</sub>, A<sub>2</sub>].

*Mesotaxis asymmetrica asymmetrica* (Bischoff and Ziegler), Klapper and Philip, 1972, p. 100, Pl. 1, fig. 23, [not figs. 20–22, 24–27].

*Remarks.* Klapper (pers. com., 1972) kindly brought to my attention that one specimen illustrated by Sannemann (1955, Pl. 2, fig. 3) exhibits a large basal cavity and, therefore, is a hibbardellan, rather than a diplododellan. However, the holotype specimen (Pl. 5, fig. 11) is a diplododellan (written com., Dr. S. Rietschel of the Senckenberg Natural Museum and Research Institute, Frankfurt, to Dr. P. Bender, 2 October, 1972).

The specimen assigned to this species by Glenister and Klapper (1966, p. 834, Pl. 96, fig. 18) is illustrated only by a lateral view. No indication of the size of its basal cavity is given in the text. Klapper (pers. com., 1972) informed me however, that in the RS 205 collection (Bureau of Mineral Resources collections, Gogo Formation, Canning Basin, *ibid.*, p. 838; the collection from which the illustrated specimen was obtained), there are at least three specimens of hibbardellan elements.

Pollock (oral com., 1972) informed me that the specimens from the Mildred Member, Beaverhill Lake Group, and Duvernay Formation, illustrated by him (1968, Pl. 61, figs. 4, 5) are diplododellan elements.

See also remarks under *Mesotaxis asymmetrica* of family Polygnathidae. Representatives of this form-species constitute the A<sub>3</sub> element of this Type 1 apparatus.

*Figured specimens.* GSC Nos. 24118 and 24119, GSC locs. 62958 and 29314.

Genus *Enantiognathus* Mosher and Clark, 1965

Type species. *Apatognathus inversus* Sannemann, 1955.

*Enantiognathus lipperti* (Bischoff)

Plate 6, figure 9

*Apatognathus lipperti* Bischoff, 1956, p. 121–122, Pl. 9, figs. 27, 31.

*Gnamptognathus lipperti* (Bischoff), Lindström, 1964, p. 155.

*Gnamptognathus? lipperti* (Bischoff), Glenister and Klapper, 1966, p. 803–804, Pl. 96, figs. 10–12.

*Enantiognathus lipperti* (Bischoff), Szulcowski, 1971, p. 20, Pl. 7, fig. 9.

*Diagnosis.* See Bischoff, 1956, p. 122.

*Remarks.* Like the type specimen from the Kellwasser Kalk of the Rhenish Schiefergebirge, one of the Waterways specimens possesses a large denticle developed on one bar. The other Waterways specimen appears to be bicuspid, but this is difficult to confirm owing to its fragmentary nature. Ziegler (1958, Pl. 12, figs. 10, 22) reported both monocuspid and bicuspid forms, these forms being regarded as intraspecific variants.

*Range.* Bischoff and Ziegler (1957, Table 4) and Ziegler (1958, Table 2) recorded the range of *Enantiognathus lipperti* as Lower *P. asymmetricus* Zone to a position within the Upper *P. gigas* Zone.

*Figured specimen.* GSC No. 24075, GSC loc. 63406.

*Enantiognathus* cf. *E. lipperti* (Bischoff)

Plate 6, figure 8

*Gnamptognathus?* cf. *G.? lipperti* (Bischoff), Glenister and Klapper, 1966, p. 804, Pl. 96, fig. 13.

*Enantiognathus lipperti* (Bischoff), Müller and Clark, 1967, p. 911–912, Pl. 117, fig. 5.

*Apatognathus* n. sp. Pollock, 1968, p. 429, Pl. 61, fig. 39.

*Remarks.* A single Waterways specimen lacks the alternation in the size of the denticles on the two processes, a feature which characterizes *E. lipperti*. Glenister and Klapper (1966, p. 804) reported a similar form from the Gogo Formation of Western Australia, and noted a possibility of it being a transitional form between a species of *Lonchodina* and *E. lipperti*. A similar form was reported by Pollock (1968, p. 429) from the Maligne Formation, and the Mildred Member, Waterways Formation, of Alberta.

*Figured specimen.* GSC No. 24076, GSC loc. 62970.

Genus *Falcodus* Huddle, 1934

Type species. *Falcodus angulus* Huddle, 1934.

*Falcodus?* cf. *F.? tortus* Huddle

Plate 7, figures 10, 17, 18

(cf.) *Falcodus tortus* Huddle, 1934, p. 88, Pl. 7, fig. 4; Bischoff and Ziegler, 1956, p. 146, Pl. 14, fig. 7.

*Polygnathus asymmetricus* Bischoff and Ziegler, Klapper and Philip, 1971, p. 434, 449, fig. 3, illus. A<sub>1</sub> [not illus. P, O<sub>1</sub>, N, A<sub>2</sub>, A<sub>3</sub>].

*Mesotaxis asymmetrica asymmetrica* (Bischoff and Ziegler), Klapper and Philip, 1972, p. 100, Pl. 1, figs. 26, 27 [not figs. 20–25]; Pl. 2, fig. 17 [not figs. 14–16].

*Description.* Laterally compressed blade with thin, sharply terminated denticles, confluent almost to their apices. Lower margin of posterior part of blade gently arched, with no downward flexure ("posterior deflection" of Huddle, 1934, p. 25) at the posterior end. Posterior part of blade laterally twisted with denticles close to the main cusp pointed upright and those at the posterior end inclined posteriorly and outward. Ridge on inner side of posterior part of blade slightly arched, and not extending to the extreme posterior edge. Anterior part of blade projected downward at about 60 degrees to the posterior part, and incurved with denticles on it pointing inward. Other than the main cusp, largest denticles at the posterior end of the posterior portion of the blade.

*Remarks.* The present species is questionably referred to the form-genus *Falcodus*. Downward projection of the posterior end of the posterior portion of the blade, herein considered a diagnostic feature of *Falcodus*, is absent.

Huddle's (1934) specimen from the upper New Albany Shale of Indiana differs from the Waterways individuals in exhibiting a straight, rather than arched, ridge on the inner side of the posterior portion of the blade.

See also remarks under *Mesotaxis asymmetrica* of family Polygnathidae. Representatives of this form-species constitute the A<sub>1</sub> element of this Type 1 apparatus.

*Figured specimens.* GSC Nos. 24072, 24073, and 24074, from GSC locs. 63984, 64010, and 64010, respectively.

### Genus *Hibbardella* Bassler, 1925

Type species. *Prioniodus angulatus* Hinde, 1879.

*Hibbardella* sp. A

Plate 8, figure 13

(?)*Roundya* sp. D Pollock, 1968, Pl. 64, fig. 3.

*Description.* Main cusp large and inclined, and of circular cross-section. Posterior bar broken in all specimens, but the part remaining is straight and bar-like, of ovate cross-section, with strongly inclined denticles of various sizes on its upper surface. Lateral limbs wide, extending downward and posteriorly, and forming an angle of about 60 degrees. Denticles on lateral limbs long, widely spaced, of circular cross-section, and curve posteriorly. Lower surface of limbs flat to gently convex. Triangular basal cavity beneath cusp, with grooves extending along the lower surfaces of lateral limbs and posterior bar.

*Remarks.* The present specimens differ from *Roundya* sp. c reported by Bischoff and Ziegler (1957, p. 113, Pl. 21, fig. 13) from the *P. varcus* Zone, in having lateral limbs that curve posteriorly rather than being in a plane. In other respects, the two forms are similar. A form reported by Pollock (1968, illustrated but undescribed) appears to be similar to the present Waterways individuals. Pollock's specimen is from the Firebag Member, Waterways Formation.

*Figured specimen.* GSC No. 24120, GSC loc. 63246.

*Hibbardella* sp. B

## Plate 8, figure 7

**Description.** Inclined main cusp of circular cross-section, and of extremely large size. Posterior bar broken in all specimens, but remaining part suggests it to be robust and straight, and of ovate to circular cross-section. Denticles on upper surface of posterior bar small, of circular cross-section, widely spaced, and posteriorly inclined. Lateral limbs robust, of ovate to circular cross-section, extending downward and posteriorly, and forming an angle of 80 to 90 degrees. Denticles on upper surfaces of lateral limbs slender, of circular cross-section, widely spaced and curving posteriorly. Lower surfaces of lateral limbs strongly convex. Lower side of the cusp with triangular basal cavity, with grooves extending to lower surfaces of lateral limbs and posterior bar.

**Remarks.** The present specimens differ from *Roundya* sp. b reported by Bischoff and Ziegler (1957, p. 113, Pl. 21, fig. 27) from the Lower *P. asymmetricus* Zone, in having lateral limbs that form an angle of 80 to 90 degrees, rather than 60 degrees. In other respects, the two forms are similar.

**Figured specimen.** GSC No. 24121, GSC loc. 29314.

Genus *Icriodus* Branson and Mehl, 1938

*Icriodus* Branson and Mehl, 1934, p. 225 [*nomen nudum*].

*Icriodus* Branson and Mehl, 1938, p. 159.

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

**Remarks.** Klapper and Philip (1972, p. 101) regarded this genus in multielement taxonomy as belonging to family Icriodontidae, and composed of two elements.

*Icriodus brevis brevis* Stauffer

## Plate 6, figures 3, 11, 12

*Icriodus brevis* Stauffer, 1940, p. 424, Pl. 60, figs. 36, 43, 44, 52.

*Icriodus brevis brevis* Stauffer, Seddon, 1970a, p. 735–736, Pl. 12, figs. 12–15.

(cf.) *Icriodus brevis angustulus* Seddon, 1970a, p. 736, Pl. 11, figs. 19–21 [not Pl. 11, figs. 13–18, 22–24].

**Description.** Unit small, of generally delicate construction. Middle row with 7 to 9 discrete denticles of which the posteriormost 2 are slightly elongated in axial plane and, in some specimens, partly fused and high. Lateral rows parallel or subparallel, with 3 to 6 discrete denticles which alternate with those of middle row. In lower view, basal cavity symmetrical, and widely to only slightly laterally flared at posterior end.

**Remarks.** The Waterways specimens match the illustrations and description given by Seddon (1970a, p. 735–736, Pl. 12, figs. 12–15) in most respects. The only difference is in the two posteriormost denticles of the median row which, in most specimens, are not as prominently high as those from the Canning Basin (Sadler Limestone and basal Virgin Hills Formation). In some Waterways specimens (e.g., one illustrated on Pl. 6, fig. 11C), however, these posterior denticles are relatively high and partly fused. These are transitional between the nominate subspecies and Seddon's (1970a, p. 736) new subspecies, *I. brevis angustulus*. The latter differs from the nominate subspecies by its posterior denticles which are fused into a high

thin blade. Seddon acknowledged that there is some variation in the degree of fusion of the posterior denticles, although they are always higher than the surrounding denticles. For this reason, of the two subspecies, Waterways specimens may be more preferably referable to *I. brevis angustulus*.

Seddon (1970a, p. 729, 735) found this subspecies restricted to his *I. angustulus* horizon which was tentatively correlated with the  $doI\beta/doI\gamma$  (Upper *P. asymmetricus* Zone–*A. triangularis* Zone) boundary interval.

*Figured specimens.* GSC Nos. 24077, 24078, and 24079, from GSC locs. 80420, 62743, and 64058, respectively.

### *Icriodus expansus* Branson and Mehl

#### Plate 6, figures 1, 2, 5

*Icriodus expansus* Branson and Mehl, 1938, p. 160–161, Pl. 26, figs. 18–21; Seddon, 1970a, p. 736, Pl. 11, figs. 30–32, Pl. 12, figs. 1, 2; Orr, 1971, p. 34–35, Pl. 3, figs. 14–17 [includes synonymy through 1971]. (non) *Icriodus expansus* Branson and Mehl, Clark and Ethington, 1966, p. 680, Pl. 83, fig. 9 [= *I. latericrescens* group].

*Icriodus* n. sp. Pollock, 1968, p. 431–432, Pl. 61, figs. 13–15, 17, 18, [not figs. 6–9, 16 = *I. nodosus*?].

*Description.* Unit straight to slightly incurved. Denticles of middle and lateral rows discrete. Lateral rows diverge posteriorly from the median axis. Posterior denticles of lateral rows sometimes elongated transversely, extending almost to the middle row. Two or three denticles of middle row at the extreme posterior end sometimes fused to produce a cusp. In lower view, basal cavity with a wide flare of circular outline at posterior end, tapering gradually anteriorly.

*Remarks.* *Icriodus nodosus* (Huddle) sensu lato may be distinguished from *I. expansus* by possessing a spur on the inner side of the posterior expansion of the basal cavity. The upper surfaces of the representatives of these two species are indistinguishable.

The specimen illustrated by Clark and Ethington (1966, p. 680) appears to be a fragmentary form of *I. latericrescens* Ziegler with one or more of its lateral processes missing.

Some Waterways specimens included herein (one illustrated on Pl. 6, fig. 5) possess a basal cavity with very widely flaring, almost circular lower margin. Their general lower and upper configuration is that of *I. expansus*, however.

*Range.* In North America and Europe, *I. expansus* has been reported previously from various Middle and Upper Devonian strata. Müller and Müller (1957, p. 1106) reported its range as Middle Devonian through middle Frasnian.

*Figured specimens.* GSC Nos. 24080, 24081, 24082, from GSC locs. 62833, 80424, and 29209, respectively.

### *Icriodus nodosus* (Huddle) sensu lato

#### Plate 6, figures 4, 10

*Gondolella? nodosa* Huddle, 1934, p. 94, Pl. 8, figs. 24, 25.

*Icriodus nodosus* (Huddle), Branson and Mehl, 1938, p. 160, Pl. 26, figs. 15, 22 [not fig. 14 = *I. symmetricus*?]; Freyer, 1961, p. 47–48, Pl. 2, fig. 35; Seddon, 1969, p. 27, Pl. 1, figs. 4–6; Seddon, 1970a, p. 736, Pl. 11, figs. 27–29, 33–35; Szulcowski, 1971, p. 22–23, Pl. 7, fig. 1; Orr, 1971, p. 38–39, Pl. 2, figs. 20–23.

(non) *Icriodus* cf. *I. nodosus* (Huddle), Lys, Serre, and Deroo, 1957, p. 801, Pl. 9, fig. 4 [= *I. symmetricus*?].

(non) *Icriodus nodosus* (Huddle), Spassov, 1964, p. 273, Pl. 2, figs. 8, 8a, [= *I. expansus*].

*Figured specimens.* GSC Nos. 24083 and 24084, GSC locs. 62794 and 63315.

## Family POLYGNATHIDAE Bassler, 1925

Genus *Mesotaxis* Klapper and Philip, 1972

Type species. *Polygnathus asymmetricus* Bischoff and Ziegler, 1957.

*Mesotaxis asymmetrica* (Bischoff and Ziegler)

**Remarks.** This is a Type 1 apparatus of Klapper and Philip (1971, p. 434, fig. 3, p. 449; 1972, p. 100). It consists of six elements, and the form-species herein assigned to these elements are as follows: P, *Polygnathus asymmetricus* Bischoff and Ziegler; O<sub>1</sub>, *Nothognathella klapperi* Uyeno; N, *Palmatodella? paridens* Huddle, or an undescribed synprioniodinan; A<sub>1</sub>, *Falcodus? cf. F.? tortus* Huddle; and A<sub>3</sub>, *Diplododella aurita* (Sannemann). The A<sub>2</sub> and synprioniodinan N elements are not described herein. Five elements (A<sub>2</sub> missing) are present in the Mildred Member (Shell Swæn Hills 6-31 well, 6-31-67-12W5th, depth = 9,353 feet, GSC loc. 77128) and all six are in the Moberly Member (Imperial Judy Creek 6-7 well, 6-7-63-10W5th, depth = 8,451.8-8,454.3 feet and 8,516.3-8,518.7 feet, GSC locs. 63984 and 64010). As noted under *Pandorinellina insita*, the A<sub>3</sub> (diplododellan) element of this apparatus and of *P. insita* may be close morphologically. Under form taxonomy, therefore, this entire element may be identified as *Diplododella aurita*. This may explain the apparent discrepancy in the range of the A<sub>3</sub> element when compared with those of the remaining constituent elements of *Mesotaxis asymmetrica*.

This apparatus was described from the Gogo Formation of Western Australia, from a locality that was previously dated as Lower *P. asymmetricus* Zone (Klapper and Philip, 1971, p. 434, fig. 3, p. 449; 1972, p. 100; Glenister and Klapper, 1966, p. 836), and from the Dominik suite, Chut River, southern Timan, U.S.S.R. (Klapper and Philip, 1972, p. 100). The Waterways occurrence is in the Middle *P. asymmetricus* Zone.

The apparatus from the Dominik suite, U.S.S.R., contains a palmatodellan as the N element (Klapper and Philip, 1972, Pl. 1, figs. 21, 22), whereas that from the Gogo Formation of Western Australia has a synprioniodinan in this position (Klapper and Philip, 1971, p. 434, fig. 3, illus. N). In the Waterways Formation, the N element is a palmatodellan in samples where there is full complement of other elements (see Table 4(a), GSC locs. 63984 and 64010).

Genus *Lonchodina* Bassler, 1925

Type species. *Lonchodina typicalis* Bassler, 1925.

**Remarks.** Huddle (1968, p. 21) presented a revised diagnosis for this form-genus. He noted that, among other features, it has a small pit and a bar that is laterally bowed or with a sharp inward flexure. Included in Table 4 are both these morphological forms, i.e., ones with a bar that is gently bowed laterally, and with a bar that is sharply curved inward. Also included are forms termed the "aversiform element" by Klapper and Philip (1971, p. 433). Although these forms are not arched as strongly as the "usual" lonchodinian element, they possess a relatively small pit and a bar that is sharply curved inward, thus approaching the concept of *Lonchodina*. They cannot be assigned to *Prioniodina* (see Huddle, 1968, p. 43 for description of this form-genus).

Genus *Nothognathella* Branson and Mehl, 1934

Type species. *Nothognathella typicalis* Branson and Mehl, 1934.

**Remarks.** The type species of the genus, *Nothognathella typicalis*, exhibits an inward flexure near the posterior end of the blade. In addition, Branson and Mehl (1934, p. 227) noted that in *Nothognathella* "the longer series of teeth is sharply flexed outward at its posterior end," presumably referring to the denticles located posterior to the apical denticle. The Waterways specimens, with the exception of that assigned to *Nothognathella bicristata*, similarly exhibit this inward flexure of the posterior part, with an outward bending of posterior denticles. These features are prominent in *N. klapperi*.

Lindström (1964, p. 159, 177) noted that the genus *Nothognathella* cannot be distinguished from *Bryantodus* Bassler by the absence of an apical denticle, a criterion proposed by Branson and Mehl (1934, p. 227). Whether the degree of development of the platform can be used for a distinguishing criterion was also questioned by Lindström (*ibid.*). *Nothognathella*, however, possesses prominent platforms, very wide in certain species such as *N. klapperi*, which are distinct from lateral ledges of *Bryantodus*.

*Nothognathella* generally may be distinguished from *Elictognathus* Cooper by its possession of an apical denticle. Apex of a blade in *Elictognathus* is usually represented by a group of high denticles. Some specimens, such as those present in the Waterways collection, exhibit features characteristic of both genera.

**Range.** *Nothognathella* ranges from the Lower *P. asymmetricus* Zone to *doIV* in Germany (Helms, 1959, p. 645–646; Ziegler, 1958, Table 2). In the North American midcontinent, it has been reported as high as the Louisiana Limestone of Illinois, regarded by Scott and Collinson (1961, p. 117) to be *doVI* equivalent.

*Nothognathella bicristata* Youngquist and Miller

## Plate 7, figures 9, 16

*Nothognathella* sp. Miller and Youngquist, 1947, p. 512, Pl. 73, fig. 7.

*Nothognathella bicristata* Youngquist and Miller, 1948, p. 447, Pl. 68, fig. 7; Bischoff and Ziegler, 1957, p. 73–74, Pl. 14, fig. 11; Anderson, 1966, p. 407, Pl. 50, figs. 16–18.

**Remarks.** One of the figured Waterways specimens (Pl. 7, fig. 9) has broken denticles on the anterior part of the blade, but the relative sizes of the denticles may be estimated by the remaining stubs. Another Waterways specimen exhibits a short posterior part of the blade with small denticles, and is incurved near the posterior end. As noted by Youngquist and Miller (1948, p. 447), an unnamed Sweetland Creek Shale specimen previously described by them (Miller and Youngquist, 1947, p. 512), may be considered conspecific with *N. bicristata*.

**Range.** Ziegler (1958, Table 2) recorded this species from the Lower *P. asymmetricus* Zone through the Lower *P. gigas* Zone.

**Figured specimens,** GSC Nos. 24085 and 24086, GSC locs. 62809 and 62695.

*Nothognathella brevidonta* Youngquist

## Plate 7, figure 8

*Nothognathella brevidonta* Youngquist, 1947, p. 108, Pl. 25, fig. 1; Klapper and Furnish, 1962, p. 403, 404, 406.

**Description.** Blade strongly arched, with apical denticle about two-thirds the unit length from the anterior end. Denticles anterior to the apical denticles of even height but wider anteriorly. Upper edge of the posterior part of blade inclined about 45 degrees to the upper edge of the anterior part. Denticles posterior to the apical denticle diminishing in size to the terminus.

In upper view, both parts of the blade straight. Posterior part sharply flexed inward, forming an obtuse angle with the anterior part. Platform on the inner side wide, with round outline, extending from the posterior end to midpoint of the anterior part. Upper surface of platform nodose near margin. Outer side broken in the Waterways specimen.

Lower side with central keel and basal plate.

**Remarks.** The Waterways specimen differs in some features from the holotype of the species. However, some conodonts from the type Sweetland Creek Shale of Iowa, which may be assigned to *N. brevidonta*, are similar to the present specimen, and all are considered to be within intraspecific variation (Klapper, pers. com., 1966).

**Figured specimen.** GSC No. 24087, GSC loc. 63967.

*Nothognathella klapperi* Uyeno

## Plate 7, figures 1-6

*Nothognathella klapperi* Uyeno, 1967, p. 5-7, Pl. 1, figs. 7, 8, Pl. 2, fig. 1; Szulczewski, 1971, p. 24-25, Pl. 8, figs. 2, 5, 8.

*Nothognathella?* sp. C Pollock, 1968, p. 434, Pl. 62, figs. 3, 5, 6.

*Polygnathus asymmetricus* Bischoff and Ziegler, Klapper and Philip, 1971, p. 434, fig. 3, illus. O<sub>1</sub> [not illus. P, N, A<sub>1</sub>, A<sub>2</sub>, A<sub>3</sub>].

*Mesotaxis asymmetrica asymmetrica* (Bischoff and Ziegler), Klapper and Philip, 1972, p. 100, Pl. 1, fig. 24 [not figs. 20-23, 25-27]; Pl. 2, fig. 14 [not figs. 15-17].

**Diagnosis.** A species of *Nothognathella* whose representatives feature two apices: apical denticle located about two-thirds the blade length from the anterior end, and a group of high denticles occurring near the anterior end. Blade strongly incurved posteriorly with denticles inclined and almost in the plane of the platform. Platform widest posteriorly on the inner side of the unit.

**Description.** Blade only moderately arched, with two apices: the main apical denticle located about two-thirds of the blade length from the anterior end, and a group of high denticles occurring near the anterior end. Denticles numerous and fused almost to their apices; those on posterior part less robust than anterior ones. Denticles near the anterior end erect to only slightly inclined. The apical denticles, however, inclined at about 45 degrees to the plane of the platform. Denticles posterior to the apical denticle successively more inclined, so that, together with strong incurving of the blade, those at the extreme posterior end lie almost in the same plane as the platform.

In upper view, blade straight to only slightly incurved, but strongly incurved at the extreme posterior end. Platform on inner side widest posteriorly, gradually narrowing anteriorly. Outer platform much smaller, restricted to region around the apical denticle. In mature specimens, upper surfaces of platform ornamented with small nodes.



Lower side flat under platform, with moderately high keel extending the entire length of the blade. Keel straight with a point of deflection near the midlength, at the site of a small oval pit.

*Remarks.* *Nothognathella klapperi* differs from previously described species of this genus in having strongly incurved posterior end of the blade, and extremely inclined posterior denticles. Furthermore, the inner platform widens posteriorly unlike in other species. *N. brevidonta* differs in possessing small equal-size platforms restricted to the midlength of the blade on both sides, short stout denticles, and a straight lower keel which curves near the posterior end. The pit of the holotype specimen of *N. brevidonta* was not observed (Youngquist, 1947, p. 108).

Some specimens of *N. iowaensis* Youngquist previously reported elsewhere (e.g., Anderson, 1966, p. 407–408, Pl. 50, fig. 3) also possess two apices. This species, however, may be distinguished by its greater arching, short denticles, and lack of strong curvature.

*Nothognathella klapperi* is a homeomorph of a Lower Carboniferous genus, *Elictognathus*, and is superficially similar to *E. laceratus* (Branson and Mehl). Common features of these species are the inward curvature of the posterior end of the blade, and the two apices, although these features are not always present in *E. laceratus* (Klapper, 1966, p. 26).

The specimen illustrated by Pollock (1968), from the Mildred Member, Waterways Formation of Alberta, in all probability belongs to this species. It lacks platform ornamentation, but some of the smaller specimens of the Waterways (e.g., one illustrated on Pl. 7, fig. 4) have similar unornamented upper surface of the platform.

Szulczewski (1971, Pl. 8, fig. 8) illustrated a specimen exhibiting a more pronounced curvature. In all other features, however, this specimen conforms with the Waterways individuals.

See also remarks under *Mesotaxis asymmetrica* of family Polygnathidae. Representatives of this form-species constitute the O<sub>1</sub> element of this Type 1 apparatus.

*Types.* Holotype, GSC No. 22825, GSC loc. 64010; paratypes, GSC Nos. 22826 and 22827, GSC locs. 77128 and 64010.

*Figured specimens.* GSC Nos. 24088 through 24091, from GSC locs. 63309, 64016, 63984, and 63984, respectively.

### *Nothognathella* sp. A

#### Plate 7, figure 7

*Description.* Blade moderately arched, with apical denticle as the only apex. Denticles on either side of the apex rapidly diminishing in size to termini. Denticles few in number (5 anterior to the apex, 4 posterior to it), wide, bluntly pointed, and confluent almost to their apices. Lateral ridges on either side of the blade, with narrow platforms near midlength.

In upper view, blade straight except for a sharp inward flexure near the posterior end. Platforms on both sides narrow; inner one extending from the posterior end to about midlength, with outer one restricted to near the midlength area.

Lower surface irregular, with high offset keel extending from the anterior end to the pit, and low and diminishing posteriorly.

*Figured specimen.* GSC No. 24092, GSC loc. 63356.

Genus *Palmatodella* Bassler, 1925

Type species. *Palmatodella delicatula* Ulrich and Bassler, 1926.

*Palmatodella? paridens* Huddle

Plate 7, figures 14, 15

*Palmatodella? paridens* Huddle, 1934, p. 57, Pl. 11, fig. 3.

*Mesotaxis asymmetrica asymmetrica* (Bischoff and Ziegler), Klapper and Philip, 1972, p. 100, Pl. 1, figs. 21, 22 [not figs. 20, 23–27].

**Description.** Blade with numerous slender, acutely pointed denticles, fused about two-thirds of their length. Anterior process, except for slight tapering at its extremity, of uniform height, and with slight inward flexure from the plane of the main cusp and the anterior process. Posterior process gradually tapering from the cusp to its extremity, and its terminus slightly twisted outward. Main cusp relatively short, compressed, and inclined about 30 degrees to the anterior process, with denticles on both processes subparallel to it. Lower keels on both processes sharp, and meet beneath the main cusp at about 60-degree angle. Pit extremely small.

**Remarks.** As with the specimens from the upper New Albany Shale of Indiana (Huddle, 1934, p. 57), the Waterways specimens are also questionably referred to *Palmatodella* owing to the heavy anterior process and arching of less than 90 degrees. Hass (1962, p. W54) and Lindström (1964, p. 159) suggested that *Telumodina* Cooper be considered synonymous with *Palmatodella*. *Telumodina*, as defined by Cooper (1931, p. 241), exhibits an angle at the junction of the two processes of about 45 to 50 degrees. If the concept of *Palmatodella* is broadened to include *Telumodina* then, perhaps, the Waterways specimens may be referred to it without reservation.

See also remarks under *Mesotaxis asymmetrica* of family Polygnathidae. Representatives of this form-species constitute the N element of this Type 1 apparatus.

**Figured specimens.** GSC Nos. 24093 and 24094, GSC locs. 63984 and 63310.

## Family POLYGNATHIDAE Bassler, 1925

Genus *Pandorinellina* Müller and Müller, 1957

Type species. *Pandorina insita* Stauffer, 1940.

*Pandorinellina insita* (Stauffer)

**Remarks.** This is a Type 1 apparatus of Klapper and Philip (1971, p. 432, fig. 1, p. 448; 1972, p. 99). It consists of six elements, and the only form-species herein assigned to it is the P element, *Spathognathodus insitus* (Stauffer). The other elements (O<sub>1</sub>, N, A<sub>1</sub>, A<sub>2</sub>, and A<sub>3</sub>) are not described herein, with the possible exception of the A<sub>3</sub> (diplododellan) element (see below). Forms that may be identified with these undescribed elements are present in the Waterways collection. In the Calumet Member (GSC loc. 63080, Station 171) and the Moberly Member (GSC loc. 62905, Station 47), for example, all six constituent elements are present in the former, but the A<sub>3</sub> (diplododellan) element is missing in the latter [see Table 4(a)]. It is interesting to note that, although the P elements in these localities may perhaps be sufficiently different morphologically to warrant separate subspecific designations on a form-

taxonomic level, the remaining constituent elements are similar. (The P element of *P. insita* from GSC loc. 62905 is illustrated on Pl. 8, fig. 5; that from GSC loc. 63080 is similar to the one illustrated on Pl. 8, fig. 14.)

The A<sub>3</sub> element in the *Pandorinellina insita* apparatus may be close morphologically to its counterpart in another Type 1 apparatus, *Mesotaxis asymmetrica*, and both may be referred to *Diplododella aurita* (Sannemann). This may account for the apparent discrepancy in the stratigraphic range of the A<sub>3</sub> element of *M. asymmetrica* in relation to those of the remainder of its elements (see Tables 1 and 4).

### Genus *Playfordia* Glenister and Klapper, 1966

Type species. *Pelekysgnathus? primitivus* Bischoff and Ziegler, 1957.

*Diagnosis.* See Glenister and Klapper, 1966, p. 827.

*Remarks.* Glenister and Klapper (1966, p. 827) noted the similarity between *Playfordia* and a Lower Carboniferous genus, *Dinodus* Cooper. These genera are similar in the denticulation of carina and in having their surfaces covered with small pits. Lindström and Ziegler (1966) observed that this kind of surface ornamentation is also present in *Elsonella* Youngquist, and erected a multielement species composed of forms with this characteristic.

*Range.* In Germany (Bischoff and Ziegler, 1957, p. 83) and Western Australia (Glenister and Klapper, 1966, p. 827), *Playfordia* occurs in the Lower *P. asymmetricus* Zone. In Poland (Szulczewski, 1971, p. 45, Table 3) and Alberta, the range extends to the Middle *P. asymmetricus* Zone.

#### *Playfordia primitiva* (Bischoff and Ziegler)

##### Plate 6, figures 6, 7

*Pelekysgnathus? primitiva* Bischoff and Ziegler, 1957, p. 83, Pl. 21, figs. 5–9.

*Playfordia primitiva* (Bischoff and Ziegler), Glenister and Klapper, 1966, p. 827, Pl. 95, figs. 19, 20; Szulczewski, 1971, p. 44–45, Pl. 7, fig. 7.

*Diagnosis.* See Glenister and Klapper, 1966, p. 827.

*Range.* This species has been reported previously from the Padberger Limestone (Bischoff and Ziegler, 1957, p. 83), and from the Gogo Formation of the Canning Basin, Western Australia (Glenister and Klapper, 1966, p. 827), both in the Lower *P. asymmetricus* Zone. In the Holy Cross Mountains of Poland, Szulczewski (1971, p. 45, Table 3) reported it from the Lower and Middle *P. asymmetricus* Zones. In the Waterways Formation, it occurs in the Middle *P. asymmetricus* Zone.

*Figured specimens.* GSC Nos. 24095 and 24096, GSC locs. 63319 and 63310.

### Genus *Polygnathus* Hinde, 1879

Type species. *Polygnathus dubius* Hinde, 1879, by subsequent designation of Miller, 1889. Following Opinion 932 of the International Commission on Zoological Nomenclature, Huddle (1970) was free to designate the lectotype of *Polygnathus foliatus* Bryant, 1921, as the neotype specimen of *P. dubius*.

*Polygnathus asymmetricus* Bischoff and Ziegler

*Polygnathus dubius* Hinde, Bischoff and Ziegler, 1957, p. 88.

**Remarks.** See remarks under *Mesotaxis asymmetrica* of family Polygnathidae. Representatives of this form-species constitute the P element of this Type 1 apparatus.

*Polygnathus asymmetricus asymmetricus* Bischoff and Ziegler

Plate 3, figures 1, 3, 4, 6

*Polygnathus dubia* Hinde, Beckmann, 1949, p. 154–155, Pl. 1, figs. 3a, b, c, Pl. 4, fig. 4 [in part only].

*Polygnathus dubia asymmetrica* Bischoff and Ziegler, 1957, p. 88–89, Pl. 16, figs. 18, 20–22, Pl. 21, fig. 3; Clark and Ethington, 1967, p. 61, Pl. 7, fig. 18.

*Polygnathus asymmetrica asymmetrica* Bischoff and Ziegler, Ziegler, Klapper, and Lindström, 1964, p. 423; Flajs, 1966, p. 230–232, Pl. 26, figs. 1–9; Seddon, 1970b, Pl. 10, fig. 2.

*Polygnathus dubia dubia* Hinde, Clark and Ethington, 1967, p. 60–61, Pl. 82, fig. 14 [not fig. 15 = *P. dengleri* Bischoff and Ziegler].

*Polygnathus asymmetricus asymmetricus* Bischoff and Ziegler, Szulczewski, 1971, p. 45, Pl. 16, figs. 3–5 (includes synonymy).

*Polygnathus asymmetricus* Bischoff and Ziegler, Klapper and Philip, 1971, p. 434, 449, fig. 3, illus. P [not illus. O<sub>1</sub>, N, A<sub>1</sub>, A<sub>2</sub>, A<sub>3</sub>].

*Mesotaxis asymmetrica asymmetrica* (Bischoff and Ziegler), Klapper and Philip, 1972, p. 100, Pl. 1, fig. 20 [not figs. 21–27].

**Diagnosis.** See Bischoff and Ziegler, 1957, p. 89, under *P. dubius asymmetricus*.

**Remarks.** A fragmentary form, only questionably assignable to *P. asymmetricus*, was recovered in the lower part of the Firebag Member.

**Figured specimens.** GSC Nos. 24097 through 24100, from GSC locs. 64010, 64010, 77128, and 63306, respectively.

*Polygnathus asymmetricus ovalis* Ziegler and Klapper

Plate 3, figures 2, 5, 7; Plate 4, figures 1, 3

*Polygnathus dubia* Hinde, Beckmann, 1949, p. 154–155, Pl. 4, fig. 4 [in part only].

*Polygnathus dubia dubia* Hinde, Bischoff and Ziegler, 1957, p. 88, Pl. 16, figs. 18, 19, Pl. 21, fig. 1; Clark and Ethington, 1967, p. 60–61, Pl. 8, fig. 9 [not fig. 8 = *P. dengleri* Bischoff and Ziegler].

*Polygnathus asymmetrica ovalis* Ziegler and Klapper, Ziegler, Klapper, and Lindström, 1964, p. 422–423; Flajs, 1966, Pl. 25, figs. 1–3; Pölsler, 1969, p. 420, Pl. 4, figs. 17, 18; Seddon, 1970a, Pl. 13, figs. 16, 17; Seddon, 1970b, Pl. 10, fig. 1; Szulczewski, 1971, p. 45–46, Pl. 17, figs. 1, 2 (includes synonymy).

*Polygnathus dubius* Hinde, Müller and Clark, 1967, p. 916, Pl. 115, figs. 5, 6.

*Polygnathus nodocostata* Branson and Mehl, Loranger, 1965a, p. 16, Photograph 3, figs. 7, 8.

**Remarks.** Loranger (1965a) figured a specimen from the middle part of the Firebag Member in the Bear Westmount No. 2 well (8-36-88-8W4th) which appears to be identifiable with *P. asymmetricus ovalis*.

**Figured specimens.** GSC Nos. 24101 through 24105, from GSC locs. 62800, 63304, 63308, 64010, and 63984, respectively.

*Polygnathus brevilaminus* Branson and Mehl

Plate 5, figures 4, 5

*Polygnathus brevilamina* Branson and Mehl, 1934, p. 246, Pl. 21, figs. 3–6; Anderson, 1966, p. 411; Wirth, 1967, p. 224, Pl. 21, figs. 15–17; Anderson and Ozias, 1968, p. 266–268, Pls. 1–3.

*Polygnathus brevilaminus* Branson and Mehl, Szulczewski, 1971, p. 46–47, Pl. 18, figs. 5, 6, 10.

*Description.* Platform variable in length, extending almost to the posterior end in some specimens, and terminating before the end in others. Lateral edges of platform parallel and serrated, and separated by deep troughs on either side of carina. Free blade high and short, about half the length of the unit, and straight to slightly incurved posteriorly. In lateral view, lower margin of the free blade straight, but arched under the platform. Junction between the blade and platform geniculate, with pit of variable size at this site. Lower edge keeled throughout except at the site of pit.

*Remarks.* Anderson and Ozias (1968) made a detailed study of *P. brevilaminus*, in which they found a considerable wide range in morphological variation. Their 177 well-preserved specimens of this species came principally from the upper Sheffield Formation, and a few from the lower Aplington Formation, in Iowa. Conodonts from these units are indicative of *doIδ-doIIα*, and *doIV* or *doV*, respectively (Anderson, 1966, p. 400–401). The variations include the position of posterior termination of the platform, platform ornamentation, degree of arching of the unit, etc. Anderson and Ozias (1968) demonstrated that there is also a considerable variation in the size of the pit (e.g., their illustrations on Pl. 2, figs. 3 and 15), and in the relative length and height of the free blade (e.g., Pl. 3, figs. B and H). Given this wide range in morphology, the Waterways specimens are referable to this species.

The specimens illustrated by Wirth (1967, Pl. 21, figs. 15–17) from the Quinto Real (Spanish Western Pyrenees) similarly exhibit the high free blade as with the Waterways individuals.

One Waterways form (illustrated on Pl. 5, fig. 5) exhibits a large pit located at the junction between the platform and the free blade. This feature is more characteristic of *Polygnathus varcus* Stauffer or *P. rhenanus* Klapper, Philip, and Jackson. Whether this form also falls within the concept of *P. brevilaminus* is somewhat questionable.

*Figured specimens.* GSC Nos. 24106 and 24107, GSC locs. 80265 and 62836

*Polygnathus* cf. *P. decorosus* Stauffer

Plate 4, figures 2, 7; Plate 5, figure 2

*Description.* Platform sagittate, transversely shallow, and gradually tapering posteriorly. Unit straight to moderately incurved. Platform margin with distinct or subdued nodes. Carina of numerous denticles, and fused in some specimens. Free blade extremely high with largest and highest denticles at about central position of the free blade. Free blade about half the length of the unit. Lower margin of the entire unit forms a gentle and continuous arch. Lower edge keeled throughout. Pit small and narrow, or extremely large as in *Pseudopolygnathus*, and at the anterior end of the platform.

*Remarks.* Two morphological types are considered herein: forms with small narrow, slit-like pit (as illustrated on Pl. 5, fig. 2), and those with extremely large pit, almost as wide as the platform itself (Pl. 4, fig. 7). However, owing to their overall morphological similarities, except for the pit, and also to their contemporaneous occurrences, they are herein grouped together.

Those specimens considered here differ from *P. decorosus* in exhibiting extremely high free blade. The free blade in *P. decorosus* is of uniform height throughout its length (Klapper *et al.*, 1970, p. 653). In addition, the lower margin of the entire unit is gently and continuously arched, whereas in *P. decorosus* only the platform is arched. The large pit in some specimens also distinguishes the present species from *P. decorosus*.

*Polygnathus procerus* Sannemann also exhibits a high free blade, but differs in possessing extremely slender platform. It also has no representatives with large pit.

*Material* (in number of specimens). Mildred, 1 large; Moberly, 21 small, 15 large; Christina, 1 small; and Calumet, 2 large. Total, 18 large, 22 small (size refers to that of the pit).

*Figured specimens.* GSC Nos. 24110, 24111, and 24112, from GSC locs. 63310, 63984, and 63311, respectively.

*Polygnathus incompletus* Uyeno

Plate 4, figure 5; Plate 5, figure 1

*Polygnathus incompleta* Uyeno, 1967, p. 7, 10, Pl. 2, figs. 6, 7.

*Polygnathus incompletus* Uyeno, Szulczewski, 1971, p. 49, Pl. 18, fig. 9.

*Diagnosis.* A species of *Polygnathus* whose representatives feature smooth or weakly ornamented, elongated platform. Carina composed of fused denticles, not extending to posterior end. Two or three small nodes may occur posterior to ridge-like carina.

*Description.* Platform elongate, smooth, or indistinctly ornamented with vague ribs near the margins. Carina ridge-like, presumably resulting from fusion of a series of denticles. In some specimens, 2 or 3 extremely small nodes may occur posterior to the ridge-like structure. Deep troughs present on upper surface of the platform, one on either side of the carina, which unite and continue posterior to the carina. Free blade about half the length of the unit, and high anteriorly. Entire unit slightly to moderately incurved. In lateral view, free blade straight and platform gently arched. Lower side keeled throughout, except at the site of pit near anterior end of platform.

*Remarks.* The smooth to indistinctly ornamented platform of specimens of this species is a feature also common with *Polygnathus communis* Branson and Mehl, and *Polygnathus glaber* Ulrich and Bassler. A number of features differentiate it from these two species. In *P. communis* the platform is much wider with only shallow troughs adjacent to the carina, and the carina extends to the posterior end of the platform. In *P. glaber*, the platform has a round anterior outline with a pointed posterior end.

*Types.* Holotype, GSC No. 22828, GSC loc. 63389; paratype, GSC No. 22829, GSC loc. 63113.

*Polygnathus norrisi* Uyeno

Plate 5, figures 3, 6

*Polygnathus norris* Uyeno, 1967, p. 10, Pl. 2, figs. 4, 5; Uyeno in MacKenzie, 1971, p. 491; Norris and Uyeno, 1972, p. 215, Pl. 3, fig. 15.

*Diagnosis.* A species of *Polygnathus* whose representatives feature platform with subparallel sides and fluted margins. Upper surface of platform characterized by plates arranged in reversed chevron patterns.

*Description.* Platform about twice as long as wide, with posterior end abruptly pointed or somewhat smoothly tapering. Lateral margins of platform subparallel with possible slight constriction near midlength. Upper surface of platform with numerous thin plate-like projections. These projections of the holotype (illustrated on Pl. 5, fig. 6B) directed anteriorly at the anterior end, and posteriorly at the opposite end, creating reversed chevron patterns. Anterior margin of the inner platform directed posteriorly, at about 60 degrees to the

carina, whereas that of the outer platform merges into the free blade. In lateral view, these plates appear as a series of needle-like projections occurring in groups. Carina inconspicuous, composed of a series of fused nodes standing only slightly higher than the platform. Free blade short, one-third the length of the unit, with 6 to 10 denticles. Lower side with straight keel under platform and blade, and a shallow, slit-like pit near the anterior part of platform.

*Remarks.* Two slightly different morphological types are included in this species, but it is believed that the differences are due to preservation. Three of the five specimens available are deformed, the free blade bent and inclined against the platform, or the platform itself distorted.

A juvenile form of *Polygnathus diversus* Helms, illustrated by Helms (1959, Pl. 5, fig. 8), bears superficial resemblance to *P. norrisi*. *P. diversus*, however, has a carina and a free blade that are slightly offset and a platform with numerous, needle-like projections.

Shaffer (1963) reported a polygnathid from the Holts Summit Formation (Upper Devonian) of Missouri, which bears some resemblance to the Waterways individuals. The unnamed Missouri specimens, however, have the blade as an extension of the outermost longitudinal row of denticles on the platform; furthermore, no pit was observed in them. Owing to their small size, they were considered to be juvenile specimens, or even aberrant growth forms. The Waterways specimens are of "usual" polygnathid size, and are regarded as normal and mature.

*Distribution.* In the Waterways Formation, *P. norrisi* was found restricted to the Firebag Member, associated with the *Spathognathodus insitus* fauna. It is also associated with this fauna in the Souris River Formation of southwestern Manitoba (Norris and Uyeno, 1972, p. 215). In the "Allochthonous beds" overlying the Ramparts Formation of the Powell Creek section, western District of Mackenzie, *P. norrisi* occurs in the Lowermost *P. asymmetricus* Zone (Uyeno in MacKenzie, 1971, p. 491).

*Types.* Holotype, GSC No. 22830, GSC loc. 62737; paratype, GSC No. 22831, GSC loc. 77112.

*Polygnathus webbi* Stauffer

Plate 5, figure 7

*Polygnathus webbi* Stauffer, 1938, p. 439, Pl. 53, figs. 25, 26, 28, 29; Klapper, 1971, p. 66–67, Pl. 1, figs. 25–28 [includes synonymy].

*Polygnathus normalis* Miller and Youngquist, 1947, p. 515, Pl. 74, figs. 4, 5.

*Remarks.* Klapper (1971, p. 66) suggested that *P. webbi* and *P. normalis* are left- and right-curved specimens, respectively, of a pair of a type described as Class IIIb symmetry by Lane (1968, p. 1260).

*Figured specimen.* GSC No. 24113, GSC loc. 62713.

*Polygnathus xylus* Stauffer

Plate 4, figures 6, 8

*Polygnathus xylus* Stauffer, 1940, p. 430–431, Pl. 60, figs. 54, 66, 72–74 only; Klapper, Philip, and Jackson, 1970, p. 659–660, Pl. 1, figs. 4–6, 11, Pl. 2, figs. 4, 5, 7–12, 16–18; Seddon, 1970b, p. 62–63, Pl. 6, figs. 10–12; Norris and Uyeno, 1972, p. 215, Pl. 3, fig. 8.

*Remarks.* Klapper *et al.* (1970, p. 660) diagnosed *P. xylus* as having a free blade that is about half the length of the unit. This is true for most specimens from the Waterways Formation

that are assigned to this species (e.g., one illustrated on Pl. 4, fig. 6). Some juvenile specimens exhibit free blade which is slightly less than two-thirds the length of the unit (e.g., one illustrated on Pl. 4, fig. 8), and are superficially similar to *Polygnathus varcus* Stauffer.

The distribution of *P. xylus* is given by Klapper *et al.* (1970, p. 666). It also occurs in the Dawson Bay and Souris River Formations of southwestern Manitoba (Norris and Uyeno, 1972, p. 215).

*Figured specimens.* GSC Nos. 24114 and 24115, GSC locs. 63385 and 80425.

#### *Polygnathus* sp. A

Plate 4, figures 9, 10

*Description.* Platform symmetrical with constriction ("waist") near its anterior end, but degree of constriction variable. In some specimens upper margins of platform serrated, with wide, shallow ribs, normal to margins; in others, platform almost smooth. Upturned margins of platform higher than carina. Carina of partially or entirely fused denticles, straight, and extending to posterior end of platform. Deep troughs immediately adjacent to, and on either side of, the carina. Free blade short, about one-third the length of the unit, high at midpoint, and slightly incurved posteriorly. Lower side keeled throughout, except at the site of a small pit, located at midpoint between the centre and the anterior end of the platform. In lateral view, the entire unit nearly straight, with slight arching under platform.

*Remarks.* The "waist" of the platform is a feature in common with *Polygnathus webbi* Stauffer, but the Waterways specimens differ in most other aspects such as symmetrical platform and short free blade.

*Figured specimens.* GSC Nos. 24116 and 24117, GSC locs. 62794 and 62787.

#### *Polygnathus* sp. B

Plate 4, figure 4; Plate 5, figure 8

*Description.* Platform narrow, elongate and symmetrical, with free blade slightly less than half the length of the unit. The unit straight to slightly incurved. Free blade highest near the anterior end and rapidly declines in height posteriorly. Lower margin straight under free blade, but moderately to strongly arched (geniculate) under the platform. Lower edge keeled throughout, with large oval pit at the anterior end of platform. Margins of the platform with distinct or subdued nodes. Geniculation points are opposite and the anterior trough margins short.

*Remarks.* The free blade of this species is similar to that of *Polygnathus* cf. *P. decorosus* Stauffer. The platform is narrower, as opposed to the sagittate outline of the platform in *P. cf. P. decorosus*. Further, the size of the pit varies considerably in the latter.

*Figured specimens.* GSC Nos. 24108 and 24109, GSC locs. 62667 and 63406.



Genus *Spathognathodus* Branson and Mehl, 1941

Type species. *Spathodus primus* Branson and Mehl, 1933.

*Spathognathodus* cf. *S. brevis* Bischoff and Ziegler

Plate 7, figures 11–13; Plate 8, figures 4, 9

(cf.) *Spathognathodus brevis* Bischoff and Ziegler, 1957, p. 116–117, Pl. 19, figs. 24, 27–29; Wittekindt, 1966, p. 643, Pl. 3, figs. 23, 24.

**Diagnosis.** A species of *Spathognathodus* whose representatives feature a very short blade, and oval pit at or near the extreme posterior end of blade. Large denticle directly over the pit, followed posteriorly by a much smaller denticle.

**Description.** Blade very short, with 6 to 9 denticles. Denticles higher posteriorly, all upright but the posteriormost two inclined posteriorly. Denticle directly over the pit largest and highest, at least twice as wide as others, and followed posteriorly by a comparatively much smaller denticle. Lower margin straight and keeled throughout, with oval pit at or near the extreme posterior end of the blade. Pit twice as wide as long; slender grooves from the pit in either direction.

**Remarks.** Specimens included herein are very similar to *S. brevis* Bischoff and Ziegler. In *S. brevis*, however, the pit is situated at, and protrudes beyond, the posterior end of the blade. This feature is common to some, but not all, of the Waterways specimens. Further, in *S. brevis* all the denticles are about the same height, with that situated in the posteriormost position being wider than others.

**Range.** *S. cf. S. brevis* occurs in the Middle *P. asymmetricus* Zone in the Waterways Formation. *S. brevis* sensu stricto ranges from the *P. kockelianus*–*P. robusticostatus* assemblage zone and/or *P. varcus* Zone (Pedder *et al.*, 1970, p. 248, 249, 263) to the Middle *P. asymmetricus* Zone (Bischoff and Ziegler, 1957, Table 4).

**Figured specimens.** GSC Nos. 24122 through 24126, from GSC locs. 62789, 62693, 62831, 62832, and 62693, respectively.

*Spathognathodus gradatus* (Youngquist)

Plate 8, figures 1, 15–18

*Mehlina gradatus* Youngquist, 1945, p. 363, Pl. 56, fig. 3.

*Mehlina irregularis* Youngquist, 1945, p. 363, Pl. 56, fig. 2.

*Ctenognathus gradata* (Youngquist), Müller and Müller, 1957, p. 1083, Pl. 135, figs. 10, 11.

*Spathognathodus gradatus* (Youngquist), Szulcowski, 1971, p. 55, Pl. 20, figs. 1, 6–8 (includes synonymy).

**Description.** Blade slightly incurved. In lateral view, anterior part of blade straight, with posterior part slightly arched. Denticulation irregular but generally higher towards anterior end. Owing to arching, some denticles of the posterior part almost as high as those on the anterior end. Lower side keeled throughout, with small pit.

**Remarks.** Youngquist (1945, p. 363) erected two species, *Mehlina gradatus* and *M. irregularis*, based principally on the difference of regularity in denticulation. As noted by Müller and Müller (1957, p. 1083), this difference does not justify taxonomic separation. The Waterways specimens referred to this species exhibit the differences noted by Youngquist, but are considered conspecific.

The larger, mature specimens exhibit low, lateral ridges on either side of the blade, extending from the posterior to anterior end. This is in contrast to thinner blades with flat sides in smaller and younger individuals.

*Figured specimens.* GSC Nos. 24127 through 24129, GSC loc. 62841; GSC Nos. 24130 and 24131, GSC locs. 62829 and 62832.

*Spathognathodus insitus* (Stauffer)

Plate 8, figures 2, 5, 11, 12, 14

*Pandorina insita* Stauffer, 1940, p. 429, Pl. 59, figs. 23, 25.

*Pandorina brambona* Stauffer, 1940, p. 428, Pl. 59, figs. 34–36.

*Pandorina gratiosa* Stauffer, 1940, p. 428, Pl. 59, figs. 18–20, 24.

*Spathognathodus graciosus* (Stauffer), Youngquist, 1947, p. 111–112, Pl. 26, fig. 1; Clark and Ethington, 1967, p. 67, Pl. 6, fig. 4.

*Ctenognathus (Pandorinella) insita* (Stauffer), Müller and Müller, 1957, p. 1083, Pl. 142, figs. 2, 3.

*Spathognathodus brambosa* Stauffer, Loranger, 1965a, p. 13–14, Photograph 2, fig. 11.

*Spathognathodus (Pandorina) gratiosa* Stauffer, Loranger, 1965a, p. 14, Photograph 2, fig. 12.

*Spathognathodus insitus* (Stauffer), Coen and Coen-Aubert, 1971, p. 17, fig. 2; Norris and Uyeno, 1972, p. 215, Pl. 3, figs. 12, 16, 17.

*Ozarkodina insitus* (Stauffer), Klapper and Philip, 1971, p. 432, 448, fig. 1, illus. P [not illus. O<sub>1</sub>, N, A<sub>1</sub>, A<sub>2</sub>, A<sub>3</sub>].

*Pandorinellina insita* (Stauffer), Klapper and Philip, 1972, p. 99 [P element only].

*Description.* Blade with two distinct parts: an extremely high anterior part, and a highly arched posterior part. In lateral view, lower margin straight, slightly arched, or may extend downward from the anterior end to about one-third the length of the unit, and then arched posteriorly. The junction may be geniculate or more gently sigmoidal. In upper view, two parts aligned or anterior part of blade slightly offset ("right-sided" offset of Klapper, 1969, p. 16–17). Lower side keeled at anterior end. Large pit with broad lateral flare at, and posteriorly of, the junction of the two parts. Flare tapers to a point at the posterior end. In larger specimens, pit relatively small, and lower edge of posterior part keeled.

*Remarks.* The number of denticles of the two parts varies considerably. The high anterior part may consist of one large denticle, to 5 or more, with several smaller denticles, and the arched posterior part from 9 to 13 denticles.

Large specimens referred to this species (e.g., illustrated on Pl. 8, fig. 5; see also Pollock, 1968, Pl. 64, fig. 4) exhibit relatively small pit and keeled lower edge on anterior and posterior parts. Forms gradational between these and more "typical" forms (e.g., as illustrated on Pl. 8, figs. 11, 14) are present in the Waterways collection.

Four specimens with the general form of *S. insitus*, but with denticles on both sides of the blade, were recovered from the Firebag Member. They have been referred to as, and are herein discussed under, *Spathognathodus?* sp.

Comparison of *S. insitus* and *S. exiguus philipi* Klapper was given by Klapper (1969, p. 18). He noted the prominent "right-sided" offset (*ibid.*, p. 16–17) of the anterior part of some specimens of *S. insitus* (e.g., Pl. 8, figs. 5 and 11, herein), a feature in common with *S. exiguus philipi*.

*Spathognathodus primus* (Branson and Mehl) of Pridolian age, illustrated by Mashkova (1970, e.g., Pl. 13, figs. 2, 6) has a similar lateral outline. It may be readily distinguished, however, by the shape of the pit. *S. insitus* has a large pit with wide lateral flare that extends from a position immediately anterior to the geniculation point, to the posterior tip of the unit. *S. primus*, on the other hand, has a large pit but with lateral flare restricted to a position

immediately posterior to the geniculation point. *S. primus* similarly exhibits the "right-sided" offset of the anterior part of the unit.

*Distribution.* *Spathognathodus insitus* has been reported from an unnamed formation at Mary's Mountain, Nevada; upper part of the Callaway Formation, Missouri; upper part of the Coralville Member, Cedar Valley Limestone, and the State Quarry Limestone of southeastern Iowa; and the Coralville Member, Cedar Valley Limestone of Illinois (Klapper *et al.*, 1971, Fig. 3), the upper part of the Cedar Valley Limestone of Minnesota (Stauffer, 1940, p. 417, 428, 429; Youngquist, 1947, p. 112), the North Liberty beds of Iowa (Youngquist, 1947, p. 111–112; Müller and Müller, 1957, p. 1083), and the Souris River Formation of southwestern Manitoba (Norris and Uyeno, 1972, p. 215). Previously it was thought to be restricted to the North American continent (Klapper *et al.*, 1971, p. 299–300), and characteristic of the fauna of the same name. Subsequently, it has been reported from the Assise de Fromelennes (Fle) at Ny in the Dinant Basin (Coen and Coen-Aubert, 1971, p. 17).

*Figured specimens.* GSC Nos. 24132 through 24136, from GSC locs. 63197, 62905, 63076, 62829, and 63105, respectively.

*Spathognathodus?* sp.

Plate 8, figures 8, 10

*Spathognathodus?* sp. Uyeno, 1967, p. 11, Pl. 2, figs. 2, 3.

*Description.* Blade with form similar to that of *Spathognathodus insitus* (Stauffer) but with lateral denticles on both sides. Lateral denticles directly over the basal cavity, as outgrowths from sides of the blade rather than from a distinct platform. These denticles erect, some comparable in size to those on the posterior half of the blade, others smaller, and up to five in number. Two or more lateral denticles may fuse to form a short ridge.

*Remarks.* The Waterways collection includes juvenile specimens of *Ancyrodella rotundiloba binodosa* Uyeno which, in possessing only incipiently developed platforms, exhibit forms similar to those of the present species. The latter, however, is closer to *Spathognathodus* than to *Ancyrodella*. It lacks the distinct platform of *Ancyrodella*, and possesses denticles merely as outgrowths of the lateral sides. *Spathognathodus?* sp. occurs in the upper part of the Firebag Member, and *Ancyrodella rotundiloba binodosa* occurs from the middle part of the Calumet through the basal Christina Member. This succession suggests a possible phylogeny and origin of *Ancyrodella*, relating it with *Spathognathodus*.

*Figured specimens.* GSC Nos. 22832 and 22833, GSC locs. 77112 and 77110.

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## APPENDIX

### SAMPLES COLLECTED IN 1956 BY A. W. NORRIS OF THE GEOLOGICAL SURVEY OF CANADA, CALGARY

The following GSC localities yielded the specimens collected by Norris that are figured in this report. The conodont contents and number of specimens from these localities are listed in Table 5. GSC loc. 29089, Station 181, south bank, Clearwater River, 22.4 miles downstream from the mouth of High Hill River, Rock Unit 35, 2 to 4 feet above river level; Calumet Member, Waterways Formation.

GSC loc. 29209, Station 59, west bank, Athabasca River, 25.5 miles downstream from the Waterways' wharf, Rock Unit 34, 6 feet above river level; Moberly Member, Waterways Formation.

GSC loc. 29282, Station 81, west bank, Athabasca River, 34.6 miles downstream from the Waterways' wharf (=0.8 mile downstream from the mouth of Muskeg River), Rock Unit 34, 7 feet above river level; Moberly Member, Waterways Formation.

GSC loc. 29314, Station 203, south bank, Clearwater River, 6.1 miles downstream from the mouth of Christina River, Rock Unit 72, 1.5 to 2 feet above river level; Moberly Member, Waterways Formation.

### COLLECTING LOCALITIES OF WATERWAYS FORMATION ON ATHABASCA RIVER

Outcrop sites are designated by station numbers used by Norris (1963), and which are indicated in his Figures 4 and 7. Rock units are also those used in Norris' Memoir (*ibid.*), to which the reader is referred for detailed lithologic descriptions. Weight of each sample studied for conodonts ranges from about 1500 to 2000 grams. Asterisk (\*) denotes localities that yielded selected conodont form-species that are listed on Table 4(a).

#### Moberly Member

Eight sections of the Moberly Member on the Athabasca River were selected to give the most complete composite sequence. Columnar sections and correlations between stations are shown on Figure 4. Sections selected, and their sampling intervals, are as follows:

Rock Unit	GSC Loc.	Interval above river level (ft)
37	62696	31.8-34.8
	*62695	29.8-31.8
	*62694	27.8-29.8

Station 92: West bank, 0.6 mile downstream from Fort MacKay Settlement; collected along northern flank of anticline; base of section 14.3 feet above river level.

CONODONTS (form taxonomy)	GSC localities			
	29089	29209	29282	29314
<i>Ancyrodella rotundiloba binodosa</i>	1			
<i>Ancyrodella rotundiloba</i> subsp. A			1	
<i>Diplododella aurita</i>				4
<i>Hibbardella</i> sp. B				1
<i>Icriodus brevis brevis</i>	1	5	1	4
<i>Icriodus expansus</i>		9		
<i>Icriodus nodosus</i> s.l.	1	4		1
<i>Polygnathus brevilaminus</i>		3		
<i>Polygnathus incompletus</i>	4			
<i>Polygnathus webbi</i>				1
<i>Polygnathus xylus</i>	1			
<i>Polygnathus</i> sp. A				1
<i>Spathognathodus insitus</i>	2	24		6
<i>Acodina</i>			1	
<i>Angulodus</i>	1	12		14
<i>Hibbardella</i>		1		
<i>Hindeodella</i>		12	1	10
<i>Ligonodina</i>		1	4	1
<i>Lonchodina</i>	2	1	2	3
<i>Neopriodontus</i>	1			
<i>Ozarkodina</i>	3	24	2	3
<i>Synpriodontina</i>	1	3		10
Total: 188 specimens				
GSC				

Note: Collections from which specimens figured in this report were obtained are shown thus. . . . .4

TABLE 5. Locations and conodont contents of samples collected by A. W. Norris in 1956.

Rock Unit	GSC Loc.	Interval above river level (ft)
36	*62693	26.8–27.8
	*62692	26.2–26.8
	*62691	25.0–26.2
35	*62690	24.1–25.0
34	62689	23.3–24.1
	62688	22.3–23.3
	62687	20.3–22.3
	62686	18.3–20.3
	*62685	16.3–18.3
	*62684	14.3–16.3

*Station 79:* East bank, 0.7 mile upstream from the mouth of Muskeg River; collected along southern flank of anticline; base of section 7.5 feet above river level.

57	*62809	81.5–83.5
	*62808	79.5–81.5
	62807	77.5–79.5
	*62806	75.5–77.5
56	*62805	73.5–75.5
	*62804	71.5–73.5
55	*62803	69.5–71.5
	62802	67.5–69.5
	*62801	65.5–67.5
44	*62800	44.5–45.5
	*62799	39.5–41.5
	*62798	37.5–39.5
43	*62796	34.7–37.5
41	*62795	31.9–32.7
38	*62794	25.3–26.6
37	62793	20.6–22.5
	62792	18.6–20.6
	*62791	16.6–18.6
	*62790	14.1–16.6
36	*62789	13.0–14.1
34	*62788	10.3–13.0
	*62787	7.5–10.3

*Station 70:* East bank, 6.5 miles downstream from the mouth of Steepbank River; collected along anticlinal axis and its southern flank; base of section 1.1 feet above river level.

44	*62841	53.0–55.0
41	*62840	51.2–53.0
39	*62839	44.1–44.9
	*62838	41.7–42.1
37	62837	32.1–35.5
	*62836	30.1–32.1
	62835	28.1–30.1
36	*62834	26.8–28.1
35	*62833	25.0–26.8

Rock Unit	GSC Loc.	Interval above river level (ft)
34	*62832	21.7-25.0
	*62831	19.8-21.7
	*62830	17.8-19.8
33	*62829	16.4-17.8
32	*62828	14.6-16.4
31	*62827	13.5-14.6
30	62826	12.7-13.5
	62825	9.1-10.9
	*62824	7.1- 9.1
	*62823	5.1- 7.1
	62822	3.1- 5.1
	62821	1.1- 3.1

*Station 55:* West bank, opposite the mouth of Steepbank River; collected along southern flank of an eastward-plunging syncline; base of section 6 feet above river level.

43	*62882	8.5- 9.3
42	*62881	7.3- 8.5
41	*62880	7.1- 7.3
40	*62879	6.0- 7.1

*Station 47:* East bank, opposite the northern end of Tar Island; collected along anticlinal axis and its southern flank; base of section 8.8 feet above river level. Only those samples required to complement other sections were studied for conodonts.

47	*62907	45.2-46.0
46	*62906	44.8-45.2
45	*62905	44.6-44.8

*Station 23-1:* East bank, 11.6 miles downstream from Waterways' wharf; collected along synclinal axis; base of section 10 feet above river level.

51	*62965	19.6-20.3
50	62964	17.8-19.6
48	62963	15.8-17.8
	62962	13.8-15.8
	*62961	11.8-13.8
47	*62960	11.3-11.8
46	*62959	10.2-11.3
45	*62958	10.0-10.2

*Station 22-1:* East bank, 11.3 miles downstream from Waterways' wharf; base of section 3.2 feet above river level.

43	*62970	7.1- 8.0
42	*62969	6.1- 7.1
41	*62968	5.9- 6.1
40	*62967	4.6- 5.9
	*62966	3.2- 4.6

Rock Unit	GSC Loc.	Interval above river level (ft)
<i>Station 8a:</i> East bank, 0.5 mile downstream from northern end of McMurray Island; base of section 2.5 feet above river level.		
40	*63032	10.4–12.4
	63031	8.4–10.4
	*63030	6.4– 8.4
39	*63029	5.3– 6.4
	*63028	4.2– 5.3
	*63027	3.1– 4.2
38	*63026	2.5– 3.1

#### Christina Member

*Station 93:* East bank, opposite Haight Island; base of section 24.5 feet above river level.

22	*62683	27.5–28.7
	*62682	26.3–27.5
21	*62681	24.5–26.3

#### Calumet Member

*Stations 101 and 102:* West bank, 0.4 mile downstream from north end of Wheeler Island; collected along anticlinal axis and its northern flank; base of section at river level.

16	62680	24.2–27.2
	62679	21.2–24.2
	62678	18.2–21.2
14	62677	17.1–18.2
	62676	15.1–17.1
	*62675	13.1–15.1
13	*62672	8.4– 9.1
12	*62670	5.5– 7.1
11	*62669	4.6– 5.5
	*62668	3.6– 4.6
	*62667	2.6– 3.6
	*62666	1.6– 2.6
	*62665	1.1– 1.6
10	*62664	0 – 0.4

#### Firebag Member

*Station 103:* East bank, about 2 miles downstream from Daphne Island; collected along southern flank of a westward-plunging anticline; base of section at river level.

2	*62769	13.54–13.77
	62768	13.31–13.54
	*62767	13.18–13.31
	*62766	12.95–13.18

Rock Unit	GSC Loc.	Interval above river level (ft)
	62765	12.72-12.95
	*62764	12.49-12.72
	*62761	11.80-12.03
	*62757	10.88-11.11
	62754	10.19-10.42
	*62751	9.50- 9.73
	62747	8.58- 8.81
	*62743	7.89- 8.12
	62740	7.20- 7.43
	*62737	6.51- 6.74
	*62734	5.82- 6.05
	*62728	4.44- 4.67
	*62725	3.75- 3.98
	62722	3.06- 3.29
	62719	2.37- 2.60
	*62716	1.68- 1.91
	*62713	0.99- 1.22
	*62710	0 - 0.38

## COLLECTING LOCALITIES OF WATERWAYS FORMATION ON CLEARWATER RIVER AND ITS TRIBUTARIES

Outcrop sites are designated by station numbers used by Norris (1963), and which are indicated in his Figures 4 and 7. Rock units are also those used in Norris' Memoir (*ibid*), to which the reader is referred for detailed lithologic descriptions. Weight of each sample studied for conodonts ranges from about 1500 to 2000 grams. Asterisk (\*) denotes localities that yielded selected conodont form-species that are listed on Table 4(a).

### Moberly Member

*Station 205:* North bank, Clearwater River, 8.5 miles downstream from the mouth of Christina River; base of section at river level.

77	*63245	0.5 - 1.0
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*Station 203:* South bank, Clearwater River, 6.1 miles downstream from the mouth of Christina River; base of section at river level.

74	63243	12.3-13.8
73	*63240	9.3-10.3
	63239	8.3- 9.3
	63236	5.3- 6.3
	*63234	4.0- 4.3
	*63233	3.0- 4.0
72	63232	0 - 1.0



Rock Unit	GSC Loc.	Interval above river level (ft)
<i>Station 202:</i> North bank, Clearwater River, 5.7 miles downstream from the mouth of Christina River; base of section at river level.		
70	*63231	6.2– 7.2
	*63230	5.6– 6.2
	*63229	5.0– 5.6
69	*63227	3.0– 4.0
	*63224	0 – 1.0
<i>Station 194:</i> North bank, Clearwater River, 3.9 miles downstream from the mouth of Christina River; poorly exposed; base of section about 10 feet above river level.		
63	*63223	ca. 10.0–10.3
<i>Station 196:</i> Erosional outlier 0.2 mile north of Clearwater River, and 3.9 miles downstream from the mouth of Christina River. For this station only, interval is given as footage above the base of the exposure.		
67	*63222	15.3–16.3
	63219	12.3–13.3
	*63216	9.3–10.3
66	*63214	7.4– 8.3
65	*63212	5.0– 6.5
	*63207	0 – 1.0
<i>Station 193:</i> North bank, Clearwater River, 2.7 miles downstream from the mouth of Christina River; base of section 3 feet above river level.		
62	63206	15.0–16.5
	63203	12.0–13.0
	63199	8.0– 9.0
61	*63197	6.0– 7.0
	*63194	3.0– 4.0
<i>Station 192:</i> South bank, Clearwater River, 2.3 miles downstream from the mouth of Christina River; base of section 2 feet above river level.		
59	*63192	25.3–26.3
	*63189	22.3–23.3
58	63187	20.3–21.3
	63179	12.3–13.3
57	*63177	10.3–10.8
56	63175	8.3– 9.3
	*63170	3.3– 4.3

#### Christina Member

*Station 191:* Southwest bank, Christina River, 1.4 miles upstream from the confluence of Clearwater River; base of section 2 feet above river level.

51	63168	3.1– 4.3
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Rock Unit	GSC Loc.	Interval above river level (ft)
<i>Station 190:</i> Southwest bank, Christina River, 1.5 miles upstream from the confluence of Clearwater River; base of section 5 feet above river level.		
53	*63166	8.1– 8.9
	*63165	7.8– 8.1
	63163	6.0– 7.0
<i>Station 189:</i> Southwest bank, Christina River, 1.8 miles upstream from the confluence of Clearwater River; base of section 1.5 feet above river level.		
49	63160	6.8– 7.8
	63156	2.8– 3.8
48	63154	1.5– 1.8
<i>Station 187:</i> Northeast bank, Christina River, 2.3 miles upstream from the confluence of Clearwater River; base of section 4 feet above river level.		
46	63153	23.0–24.0
45	63151	21.0–22.0
	63146	16.0–17.0
	63141	11.0–12.0
	*63136	6.0– 7.0
44	63134	4.0– 5.0
<i>Station 184:</i> Southwest bank, Christina River, 2.8 miles upstream from the confluence of Clearwater River; base of section 2 feet above river level.		
Unassigned	*63132	14.2–15.2
43	63130	12.3–13.2
42	63128	10.6–11.4
41	63127	10.0–10.6
40	63126	9.0–10.0
	*63122	5.0– 6.0
	*63119	2.0– 3.0
Calumet Member		
<i>Station 182:</i> South bank, Clearwater River, 24.7 miles downstream from the mouth of High Hill River; base of section at river level.		
37	*63118	0.8– 1.5
<i>Station 181:</i> South bank, Clearwater River, 22.4 miles downstream from the mouth of High Hill River; base of section 1.5 feet above river level.		
35	*63115	5.5– 6.5
34	*63113	3.5– 4.5
	*63111	1.5– 2.5
<i>Station 45UA:</i> North bank, Clearwater River, 16.7 miles downstream from the mouth of High Hill River; base of section at river level. [This section was not recorded by Norris (1963)].		
Unassigned	*63110	0 – 1.0

Rock Unit	GSC Loc.	Interval above river level (ft)
<i>Station 178:</i> North bank, Clearwater River, 18.6 miles downstream from the mouth of High Hill River; base of section at river level.		
32	*63109	4.3– 5.1
	*63107	2.3– 3.3
31	*63105	0 – 1.3

*Station 176:* North bank, Clearwater River, 16.5 miles downstream from the mouth of High Hill River; base of section at river level.

Unassigned	*63104	2.0– 7.0
29	*63102	0 – 1.3

*Station 173:* North bank, Clearwater River, 13.7 miles downstream from the mouth of High Hill River; base of section 2 feet above river level.

26–27	*63100	9.7–10.7
25	*63095	5.6– 6.1
Unassigned	*63093	3.9– 4.9
24	*63091	2.0– 2.9

*Station 172:* North bank, Clearwater River, 13.5 miles downstream from the mouth of High Hill River; base of section 12 feet above river level.

Unassigned	*63089	14.1–15.1
	*63087	12.0–13.1

*Station 171:* North bank, Clearwater River, 13.3 miles downstream from the mouth of High Hill River; base of section 3 feet above river level.

18	*63086	12.0–13.0
	*63083	9.0–10.0
	*63080	6.0– 7.0
	*63076	3.0– 4.0

*Station 168:* North bank, Clearwater River, 9.2 miles downstream from the mouth of High Hill River; base of section 3 feet above river level.

16	*63074	4.0– 5.0
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#### Firebag Member

*Station 38UA:* South bank, Clearwater River, 0.6 mile downstream from the mouth of High Hill River; base of section at river level. [This section was not recorded by Norris (1963)].

Unassigned	*63072	11.6–13.1
	*63069	7.6– 8.8
	*63067	3.9– 4.9
	*63065	2.0– 2.9
	63063	0 – 1.0

Rock Unit	GSC Loc.	Interval above river level (ft)
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*Station 164:* North bank, High Hill River, 0.5 mile upstream from the confluence of Clearwater River; base of section about 20 feet above river level.

12	*63062	31.8–32.8
	*63059	28.8–29.8
Unassigned	*63058	28.0–28.8
	63057	27.0–28.0
	*63056	26.0–27.0
	*63054	24.0–25.0
	*63050	20.0–21.0

*Station 158:* West bank, Edwin Creek, 150 to 200 yards upstream from the confluence of Clearwater River; base of section 1.5 feet above creek level.

7	63048	7.2– 7.5
	63046	5.8– 6.9
	63042	3.0– 3.4

Depth (ft)	Stratigraphic Unit	Thickness (ft)	GSC Loc.
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### SUBSURFACE SECTION 1

Name: Alberta Government Salt Well No. 1

Location: Lot 8, McMurray townsite, tp. 89, rge. 9, W4th mer.

Elevation of surface: 795 feet Total depth: 685 feet

Commenced: October 1919 Completed: November 1920

See Carrigy (1959, p. 95-99) and Allan (1920, p. 104, 106-108) for core description.

A sample was obtained from each interval indicated below; the exact position within each interval is not known. Asterisk (\*) denotes the localities yielding selected conodont form-species (see Table 4). Weight of each sample about 150 to 200 grams. Material courtesy of Dr. R. Green, Research Council of Alberta.

### WATERWAYS FORMATION

#### Moberly Member (95-144 feet)

95- 96	1	*80236
96-105	9	80237
105-110	5	*80238
110-120	10	*80239
120-133	13	80240
133-135	2	80241
135-139	4	*80242
139-144	5	80243

#### Christina Member (144-223 feet)

144-155	11	80243
155-161	6	80244
161-164	3	*80245
164-223	59	80246

#### Calumet Member (223-315 feet)

223-230	7	*80247
230-240	10	*80248
240-260	20	80249
260-270	10	80250
270-292	22	*80251
292-296	4	—
296-315	19	*80252

#### Firebag Member (315-497 feet)

315-386	71	80253
386-402	16	*80254
402-406	4	80255
406-412	6	80256
412-419	7	80257

Depth (ft)	Stratigraphic Unit	Thickness (ft)	GSC Loc.
419-428		9	80258
428-435		7	80259
435-442		7	*80260
442-455		13	*80261
455-457		2	*80262
457-480		23	80263
480-490		10	*80264
490-497		7	*80265

Unconformity?

Slave Point Formation

## SUBSURFACE SECTION 2

Name: Industrial Minerals Limited Salt Well No. 1

Location: SE 1/4, sec. 10, tp. 89, rge. 9, W4th mer.

Elevation of surface: 825 feet Total depth: 898 feet

Commenced: 4 May 1936 Completed: No data

See Carrigy (1959, p. 105-109) for core description.

A sample was obtained from each interval indicated below; the exact position within each interval is not known. Asterisk (\*) denotes the localities yielding selected conodont form-species (see Table 4). Weight of each sample about 200 to 250 grams. Material courtesy of Dr. R. Green, Research Council of Alberta.

## WATERWAYS FORMATION

### Moberly Member (100-118 feet)

100-101	1	802676
101-105	4	*80268
105-110	5	80269
110-118	8	8026

### Christina Member (118-213 feet)

118-125	7	80270
125-130	5	80271
130-140	10	*80272
140-157	17	*80273
157-160	3	*80274
160-170	10	80275
170-213	43	80276

Depth (ft)	Lithology and Remarks	Thickness (ft)	GSC Loc.
Calumet Member (213-310 feet)			
213-249		36	*80277
249-277		28	*80278
277-285		8	*80279
285-294		9	*80280
294-304		10	*80281
304-306		2	80282
306-310		4	*80283
Firebag Member (310-490 feet)			
310-381		71	80284
381-416		35	80285
416-418		2	80286
418-419		1	80287
419-428		9	80288
428-432		4	80289
432-445		13	80290
445-447		2	*80291
447-484		37	80292
484-487		3	*80293
487-490		3	80294
Unconformity?			
Slave Point Formation			

### SUBSURFACE SECTION 3

Name: Richfield Oil Corporation Pony Creek No. 2

Location: Lsd. 9, sec. 1, tp. 80, rge. 8, W4th mer.

Elevation of surface: 2,041 feet (k.b.) Total depth: 1,802 feet

Commenced: 26 December 1958 Completed: 16 January 1959

Core description after R. Green and G. B. Mellon, Research Council of Alberta (pers. com. 1963), stratigraphic tops after Dr. H. R. Belyea, Geological Survey of Canada (pers. com. 1964).

A sample was obtained and studied for each interval indicated with an asterisk (\*); the exact position within that interval is not known. In some cases, the indicated intervals of a core and the sum total footage of parts comprising that core do not agree; no adjustments have been made, but the discrepancy can perhaps be considered as evenly distributed throughout. Sample designations are those used by the Research Council of Alberta. Weight of each sample about 150 to 200 grams; conodont specimens only were received for some intervals. Material courtesy of Dr. R. Green, Research Council of Alberta. "Barren" refers to absence of conodonts in samples studied.

Depth (ft)	Lithology and Remarks	Thickness (ft)	GSC Loc.
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## WATERWAYS FORMATION

[Core 31: 1,305–1,359 feet; recovery 45 per cent]

### Moberly Member (1,305–1,311 feet)

1,305–1,311	Limestone, light grey, aphanitic, hard, massive; scattered fossils	6	
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### Christina Member (1,311–1,405 feet)

1,311–1,314	Limestone, as above	3	
1,314–1,318	Shale, calcareous, hard, or argillaceous limestone	4	
1,318–1,321	Limestone, hard	3	
1,321–1,334	Limestone, argillaceous, with shale partings	13	
1,334–1,359	Shale, calcareous, hard, with argillaceous limestone beds	25	
	*1,336: M54		77104
	*1,352–1,359: M56; barren		77105
	[Core 32: 1,359–1,402 feet; recovery 100 per cent]		
1,359–1,364	Limestone, pale green to green-grey, nodular, very fine grained, massive; and calcareous shale in laminae up to 3/8 inch thick	5	
	*1,364: F59; barren		77106
1,364–1,369	Shale, calcareous, pale green, banded, and pale green aphanitic limestone	5	
1,369–1,379	Limestone, argillaceous, pale green, hard, fine grained, massive	10	
1,379–1,404	Limestone, as above, with traces of more calcareous laminae	25	
	[Core 33: 1,402–1,432 feet; recovery 100 per cent]		
1,402–1,403.5	Limestone, argillaceous, pale green	1.5	
1,403.5–1,405	Limestone, argillaceous, pale green; 6- to 8-inch gradational contact below	1.5	
	*1,403.5: L68; barren		77107
	*1,405: M69		77108

### Calumet Member (1,405–1,500 feet)

1,405–1,406	Limestone, pale brown-grey, hard, massive; fossiliferous	1	
1,406–1,411	Limestone, as above, with greenish shale blebs in upper 2 feet; fossiliferous	5	
1,411–1,421	Limestone, pale grey to brown and green-grey, very fine grained, hard, massive, fossiliferous	10	



Depth (ft)	Lithology and Remarks	Thickness (ft)	GSC Loc.
1,421-1,431	Limestone, as above, pale green to brownish grey; fossiliferous [Core 34: 1,432-1,492 feet; recovery 100 per cent]	10	
1,432-1,472	Limestone, as above, pale brown-grey, mostly aphanitic; fossiliferous	40	
1,472-1,474	Limestone, argillaceous, pale green, with shale partings	2	
1,474-1,475.5	Limestone, pale-brown-grey, hard, massive	1.5	
1,475.5-1,477	Limestone, argillaceous, green	1.5	
1,477-1,482	Limestone, pale brown-grey, hard, massive	5	
1,482-1,492	Limestone, pale green-grey to green; fossiliferous [Core 35: 1,492-1,550 feet; recovery 100 per cent]	10	
1,492-1,500	Limestone, as above	8	
Firebag Member (1,500-1,697 feet)			
1,500-1,502	Shale, calcareous, bright green; fossiliferous *1,500-1,502: M89	2	77109
1,502-1,530	Shale, calcareous, green; soft to harder, more massive, green calcareous shale or argillaceous limestone; fossiliferous *1,512-1,517: M94 *1,522-1,527: M97	28	77110 77111
1,530-1,532	Shale, calcareous, harder and more massive than above	2	
1,532-1,546	Limestone, pale to medium green, aphanitic, with alternating green calcareous shale; fossiliferous *1,541-1,542: F101	14	77112
1,546-1,552	Shale, calcareous, medium green; numerous fossils in upper part *1,546-1,552: M104 [Core 36: 1,550-1,610 feet; recovery 100 per cent]	6	77113
1,550-1,570	Shale, calcareous, medium green, softer than unit above *1,560-1,565: M109; barren	20	77114
1,570-1,580	Shale, as above, alternating with argillaceous limestone; few fossils	10	
1,580-1,610	Limestone, pale to medium green, hard, nodular, with numerous green calcareous shale partings; harder and more calcareous towards base of unit; fossiliferous *1,585-1,590: F116; barren *1,595-1,600: M119; barren *1,605-1,610: M123 [Core 37: 1,610-1,670 feet; recovery 100 per cent]	30	77115 77116 77117
1,610-1,640	Shale, calcareous, medium green, hard; more massive and calcareous in places; fossiliferous *1,615-1,620: M126; barren	30	77118

Depth (ft)	Lithology and Remarks	Thickness (ft)	GSC Loc.
	*1,620-1,625: F128		77119
	*1,625-1,630: M130		77120
	*1,630-1,635: F134; barren		77121
	*1,635-1,640: M136; barren		77122
1,640-1,670	Shale, as above, with nodular limestone bands; fossiliferous	30	
	*1,645-1,650: M139		77123
	*1,655-1,660: M142; barren		77124
	*1,665-1,670: M145		77125
	[Core 38: 1,670-1,722 feet; recovery 100 per cent]		
1,670-1,677	Shale, as above, with pale green-grey limestone bands up to 3/8 inch thick	7	
	*1,672-1,677: M148		77126
1,677-1,701	Shale, calcareous, green, fissile, becoming dark greyish green and laminated in the lower 3 feet; basal foot hard and massive	24	
	Unconformity?		
	Slave Point Formation		

## SUBSURFACE SECTION 4

Name: Union Red Earth 2-22

Location: Lsd. 2, sec. 22, tp. 88, rge. 8, W5th mer.

Elevation of surface: 1,855 feet (k.b.) Total depth: 4,926 feet

Cored intervals: 4,254-4,328 feet; 4,766-4,816 feet; 4,851-4,914 feet

Commenced: 30 January 1957 Completed: 3 March 1957

Stratigraphic tops after Dr. H. R. Belyea, Geological Survey of Canada (pers. com., 1964).

Samples were obtained at intervals of about 2.5 feet. Except at crucial intervals, such as at stratigraphic boundaries or at a distinct change in lithologies, generally only alternating samples were studied. Of the 29 samples studied from this well, only those intervals found to contain conodonts are listed below. Weight of each sample about 900 to 1200 grams. Elk Point Formation was also sampled in this well, but no conodonts were obtained.

## WATERWAYS FORMATION

Firebag Member (= basal limestone  
with *Ladogioides*)  
(4,254-4,296.5 feet)

4,254-4,264	Limestone, argillaceous, light brownish grey, cryptogained, almost conchoidal fracturing	10	63246
	4,254-4,256.5 feet		

Depth (ft)	Lithology and Remarks	Thickness (ft)	GSC Loc.
4,264-4,289	Limestone, similar to above, but more brown in colour, and not so argillaceous 4,265.9-4,268.3; 4,270.7-4,273.1 4,284.9-4,287.3 feet	25	63251 63253 63259
4,289-4,296.5	Limestone, similar to above, and limestone, lighter brown-grey, coarse-grained, crystalline, with echinoid stems; calcareous black-green shale partings common, with blebs of fine-grained limestone; fossiliferous 4,289.7-4,292.1; 4,294.5-4,296.5 feet	7.5	63261 63263
Unconformity?			
Slave Point Formation (4,296.5-4,328 feet)			
4,296.5-4,299	Limestone, crystalline, light grey, coarse-grained, bioclastic, with numerous echinoid stems	2.5	
4,299-4,306.5	Limestone, light grey near top and darker to almost black near bottom of unit, fine-grained, more argillaceous towards base, black shale partings throughout; fossiliferous 4,301.5-4,304 feet	7.5	63265
4,306-4,314	Limestone, light brown-grey, fine- to medium-grained, in places with clear calcite; echinoid stems, fossiliferous 4,306.5-4,309 feet	7.5	63268
4,314-4,328	Limestone, similar to above, no fossils observed; in places with very fine laminae of shale partings 4,314-4,316.5 feet [End of first cored interval]	14	63271

## SUBSURFACE SECTION 5

Name: Calstan Standard Oil of British Columbia House Mountain 2-6

Location: Lsd. 2, sec. 6, tp. 70, rge. 10, W5th mer.

Elevation of surface: 2,890 feet (k.b.) Total depth: 7,690 feet

Cored interval: 7,463-7,668 feet

Commenced: 12 August 1963 Completed: 6 September 1963

Samples were obtained at intervals of about 2.2 feet. Except at crucial intervals, such as at stratigraphic boundaries or at a distinct change in lithologies, generally only alternating samples were studied. Of the 30 samples studied, only those intervals found to contain conodonts are listed below. Weight of each sample from 7,463- to 7,508.8-foot interval about 800 to 1000 grams; others about 500 to 700 grams.

Depth (ft)	Lithology and Remarks	Thickness (ft)	GSC Loc.
Swan Hills Formation (7,463–7,595 feet)			
7,463–7,482.6	Limestone, dark brownish grey, fine-grained, hard; fractures along planes; in places vugs lined with calcite crystals 7,463–7,465.2; 7,467.4–7,469.5 7,471.7–7,473.9 feet	19.6	63402 63404 63406
7,482.6–7,495.7	Limestone, as above, with limestone, light brown, very finely granular, <i>Amphipora</i> and stromatoporoids scattered throughout calcarenite matrix	13.1	
7,495.7–7,502.2	Limestone, as above, with <i>Amphipora</i> also present in fine-grained, dark brownish grey limestones; <i>Amphipora</i> in places in white calcite matrix	6.5	
7,502.2–7,508.8	Limestone, light brown, very finely granular, with <i>Amphipora</i> and stromatoporoids	6.6	
7,508.8–7,513.1	Limestone, light brownish grey, fine-grained, hard; fractures along planes; in places black with bituminous matter	4.3	
7,513.1–7,525.7	Limestone, light brown, very finely granular with stromatoporoids; matrix fine-grained and hard in places	12.6	
7,525.7–7,550.1	Limestone, as above, but stromatoporoids absent	4.4	
7,530.1–7,534.5	Limestone, light brown, very finely granular with stromatoporoids	4.4	
7,534.5–7,547.9	Limestone, light grey, fine-grained, hard; in places like unit above	13.4	
7,547.9–7,561.2	Limestone, lithology similar to 7,482.6– to 7,495.7-foot interval	13.3	
7,561.2–7,595	Limestone, light grey, fine-grained, hard; in places limestone, light brown to dark grey, medium-grained 7,568–7,569; 7,571.3–7,573.6 7,575.9–7,578.2 feet	33.8	63448 63450 63452

#### Watt Mountain Formation

### SUBSURFACE SECTION 6

Name: Shell Swan Hills 6–31

Location: Lsd. 6, sec. 31, tp. 67, rge. 12, W5th mer.

Elevation of surface: 4,351 feet (k.b.) Total depth: 10,256 feet

Cored interval: No data

Commenced: 2 January 1958 Completed: 26 February 1958

Lithologic descriptions not available; material was received in residue form. Stratigraphic tops after Dr. H. R. Belyea, Geological Survey of Canada (pers. com., 1964).

Depth (ft)	Lithology and Remarks	Thickness (ft)	GSC Loc.
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A sample was obtained every 10 feet between 9,343- and 9,463-foot interval, and again between 9,534- and 9,574-foot interval; others are from 9,700- and 9,705-foot levels. Of the 20 samples, only 2 contained conodonts and are listed below. Weight of each sample estimated at about 100 grams. Material courtesy of Dr. U. Mayr, of J. C. Sproule and Associates, Ltd., Calgary.

#### WATERWAYS FORMATION

9,343-9,385	Mildred Member 9,353 feet	42	77128
9,385-9,510	Moberly Member 9,393 feet	125	77132
9,510-9,750	Swan Hills Formation	240	
	Unconformity?		
9,750+	Elk Point Formation		

#### SUBSURFACE SECTION 7

Name: Imperial Shell Burntwood 12-6

Locations: Lsd. 12, sec. 6, tp. 64, rge. 12, W5th mer.

Elevation of surface: 3,780 feet (k.b.) Total depth: 10,265 feet

Cored interval: No data

Commenced: 16 December 1957 Completed: 21 February 1958

Lithographic descriptions not available; material was received in residue form. Stratigraphic tops after Dr. H. R. Belyea, Geological Survey of Canada (pers. com., 1964).

Samples were obtained at intervals of 10 feet between 9,297 and 9,467 feet and again between 9,476 and 9,536 feet; others are from levels of 9,661, 9,671, 9,685, and 9,692 feet. Of the 29 samples, 16 contained conodonts and are listed below. Weight of each sample estimated at about 100 grams. Material courtesy of Dr. U. Mayr, of J. C. Sproule and Associates, Ltd., Calgary.

#### WATERWAYS FORMATION

9,285-9,350	Moberly Member 9,297 and 9,337 feet	65	80414 80418
9,350-9,450	(?) Moberly-Christina Members (dense limestone and shale) 9,347 through 9,447 feet at every 10-foot interval	100	80419 through 80429
9,450-9,630	Swan Hills Formation 9,457, 9,467, 9,476, 9,526, 9,536 feet	180	80430 80431 80432 80437 80438
9,630-9,674	Watt Mountain Formation	44	

Depth (ft)	Lithology and Remarks	Thickness (ft)	GSC Loc.
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## SUBSURFACE SECTION 8

**Name:** Imperial Judy Creek 6-7

**Location:** Lsd. 6, sec. 7, tp. 63, rge. 10, W5th mer.

**Elevation of surface:** 3,288 feet (k.b.) **Total depth:** 9,570 feet

**Cored interval:** 8,410-8,896 feet, with one-foot intervals missing in places.

**Commenced:** 15 March 1959 **Completed:** 10 May 1959

**Stratigraphic tops after Dr. H. R. Belyea, Geological Survey of Canada, (pers. com., 1964).**

Samples were obtained at intervals of about 2.5 feet. Except at crucial intervals, such as at stratigraphic boundaries or at a distinct change in lithologies, generally only alternating samples were studied. Of the 73 samples studied from this well, 13 were found to contain conodonts and are listed below. Weight of each sample about 300 to 500 grams. Elk Point Formation was also sampled and studied in this well, but no conodonts were found.

## WATERWAYS FORMATION

### Mildred Member

(8,410-8,440 feet)

8,410-8,424.8	Limestone, argillaceous, dark grey to black, cryptograined, finely laminated, hard and brittle; breakage into fine, sliver-like fragments 8,410-8,412.5 feet	14.8	63967
8,424.8-8,429.7	Limestone, as above, but splintering not as excessive 8,427.2-8,429.7 feet	4.9	63974
8,429.7-8,440	Limestone, similar to top unit of this Member 8,439.5-8,442 feet [may be partly Moberly]	10.3	63979

### Moberly Member

(8,440-8,510 feet)

8,440-8,444.4	Limestone, as above	4.4	
8,444.4-8,451.8	Limestone, as above, but splintering not as excessive	7.4	
8,451.8-8,464.1	Limestone, somewhat argillaceous, light brownish grey, almost conchoidal fracturing; lighter coloured granules, about $\frac{3}{4}$ inch long, common 8,451.8-8,454.3; 8,456.7-8,459.2 feet	12.3	63984 63986
8,464.1-8,510	Limestone, as above, but more argillaceous (?) Moberly-Christina Members (dense limestone and shale) (8,510-8,646 feet)	45.9	
8,510-8,516.3	Limestone, argillaceous, dark grey to black, cryptograined to fine-grained, splintery fracturing, hard, brittle	6.3	

Depth (ft)	Lithology and Remarks	Thickness (ft)	GSC Loc.
8,516.3-8,530.6	Limestone, somewhat less argillaceous and more massive; with fine shale partings in places; lighter coloured granules about 1 inch to 2 inches long common, with bent microlaminations	14.3	
	8,516.3-8,518.7; 8,521-8,523.4;		64010
	8,525.8-8,528.2; 8,530.6-8,532.9		64012
	8,535.3-8,537.7; 8,540.1-8,542.5 feet		64014
			64016
			64018
			64020
8,530.6-8,544.8	Limestone, as above, with more shale partings	14.2	
8,544.8-8,547.2	Limestone, similar to above, but tends to break along planes	2.4	
	8,544.8-8,547.2 feet		64022
8,547.2-8,565	Limestone, identical with top unit of the "dense limestone and shale" interval	17.2	
8,565-8,630.7	Limestone, as unit above	5.7	
8,630.7-8,632.9	Limestone, as above, with lighter coloured granules about 1 inch to 2 inches long common, with bent microlaminations	2.2	
8,632.9-8,651	Limestone, identical with top unit of this interval	18.1	
	8,632.9-8,635.1 feet		64058
Swan Hills Formation (8,646-8,807 feet)			
8,651-8,652.9	Limestone, light brownish grey, very finely granular; fossiliferous	1.9	
8,652.9-8,686	Limestone, as above, with <i>Amphipora</i> , stromatoporoids, brachiopods, and echinoid stems; stylolites common in places	33.1	
8,687-8,689.4	Limestone, somewhat argillaceous, cryptograined to fine-grained, with <i>Amphipora</i>	2.4	
8,689.4-8,694.3	Limestone, similar to top unit of this Member	4.9	
8,694.3-8,699.2	Limestone similar to above, but more argillaceous; breakage along planes in places	4.9	
8,699.2-8,745.6	Limestone, similar to top unit of this Member; with <i>Amphipora</i> especially common between 8,706.5 and 8,716.3 feet	46.4	
8,745.6-8,748	Limestone, dark brown, cryptograined; breakage along planes	2.4	
8,748-8,756.9	Limestone, as above, with <i>Amphipora</i> in places	17.9	
8,765.9-8,773.5	Limestone, light brownish grey, granular, fine- to medium-grained; <i>Amphipora</i> and stromatoporoids common at base of unit	7.6	
8,773.5-8,781.2	Limestone, not so granular and more argillaceous than the unit above; with numerous <i>Amphipora</i> and stromatoporoids in places	7.7	

Depth (ft)	Lithology and Remarks	Thickness (ft)	GSC Loc.
8,781.2-8,791.4	Limestone, light brownish grey, granular, fine- to medium-grained; <i>Amphipora</i> and stromatopora abundant in places	10.2	
8,791.4-8,804	Limestone, dark brown, cryptograined; breakage along planes; with <i>Amphipora</i> in places; near middle of unit lighter coloured granules about 1 inch to 2 inches long, with bent microlaminations	12.6	
8,804-8,807	Limestone, argillaceous, dark grey to black, breakage along irregular surfaces; <i>Amphipora</i> abundant	3	
Unconformity?			
Elk Point Formation			

## SUBSURFACE SECTION 9

Name: California Standard Cynthia SW 16-21

Location: Lsd. 16, sec. 21, tp. 49, rge. 13, W5th mer.

Elevation of surface: 3,297 feet (k.b.) Total depth: 12,492 feet

Cored interval: 11,535-11,810 feet

Commenced: 21 October 1956 Completed: 27 December 1957

Stratigraphic tops after Dr. H. R. Belyea, Geological Survey of Canada (pers. com., 1964).

Samples were obtained at intervals of about 2.3 to 2.5 feet. Except at crucial intervals, such as at stratigraphic boundaries or at a distinct change in lithologies, generally only alternating samples were studied. Of the 55 samples studied from this well, 35 were found to contain conodonts and are listed below. Weight of each sample about 900 to 1000 grams.

## WATERWAYS FORMATION

### Mildred Member (11,535-11,543 feet)

11, 535	Limestone, argillaceous, dark brown to black, cryptograined, irregular breaking surfaces; fragments of brachiopods	8	
	11,541.9-11,544.3 feet		63301

### Moberly Member (11,543-11,665 feet)

11,543	Limestone, as above	11	
11,554	Limestone, similar to above, but breaks along planes	6	
11,560	Limestone, combination of two types above; echinoid stems in places	25	



Depth (ft)	Lithology and Remarks	Thickness (ft)	GSC Loc.
11,585	Limestone, argillaceous, dark brown to black, cryptograined, irregular breaking surfaces; fragments of lingulid brachiopods	80	63302
	11,544.3–11,555.9 feet, at alternating 2.3-foot intervals;		through 63306
	11,558.2–11,567.4 feet, at every 2.3-foot interval;		63308
			through 63311
	11,576.8–11,581.4 feet, at 2.3-foot intervals		63316
			63317
	11,583.8–11,585; 11,589.8–11,592.2		63319
	11,613.8–11,616.2; 11,654.2–11,656.6 feet		63322
			63332
			63348
Christina Member (11,665–11,740)			
11,665	Limestone, as above; in places with echinoid stems; breakage along planes in places; echinoid stems, brachiopods	75	
	11,673.4–11,739.2 feet, at alternating 2.3-foot intervals		63356
			through 63382
	(11,687.8–11,690.2 feet, barren)		63362
	Dense limestone and shale [equivalent of Swan Hills Formation; probably also equivalent of about Calumet-Firebag Members]		
	(11,740–11,810 feet)		
11,740	Limestone, as above	7	
11,747	Limestone, argillaceous, dark brown to black, cryptograined; almost conchoidal fracturing	10	
11,757	Limestone, as above, but breakage along planes	17	
11,774	Limestone, argillaceous, dark brown to black, cryptograined, irregular breaking surfaces	36	
	11,739.2–11,766 feet, at alternating <i>ca.</i> 2.5-foot intervals; 11,770–11,774; 11,805–11,810 feet		63383
			through 63393
			63395
			63401

**PLATES 1 to 8**

## PLATE 1

All figures x45

Figures 1, 8, 9. *Ancyrodella gigas* Youngquist (PAGE 23)

1A, 1B, lower and upper views, GSC No. 20694, from Moberly Member, California Standard Cynthia SW 16-21 well, depth 11,579.1 to 11,581.4 feet, GSC loc. 63317.

8A, 8B, lower and upper views, GSC No. 24062, from Christina Member, California Standard Cynthia SW 16-21 well, depth 11,673.4 to 11,675.8 feet, GSC loc. 63356.

9A, 9B, lower and upper views, GSC No. 24063, from Moberly Member(?), Imperial Judy Creek 6-7 well, depth 8,516.3 to 8,518.7 feet, GSC loc. 64010.

Figures 2, 4-6. *Ancyrodella rotundiloba binodosa* Uyeno (PAGE 24)

2A, 2B, lower and upper views, GSC No. 24066, from Calumet Member, Alta. Govt. Salt Well No. 1, depth 223 to 230 feet, GSC loc. 80247.

4A, 4B, lower and upper views, GSC No. 24067, from Christina Member, California Standard Cynthia SW 16-21 well, depth 11,736.8 to 11,739.2 feet, GSC loc. 63382.

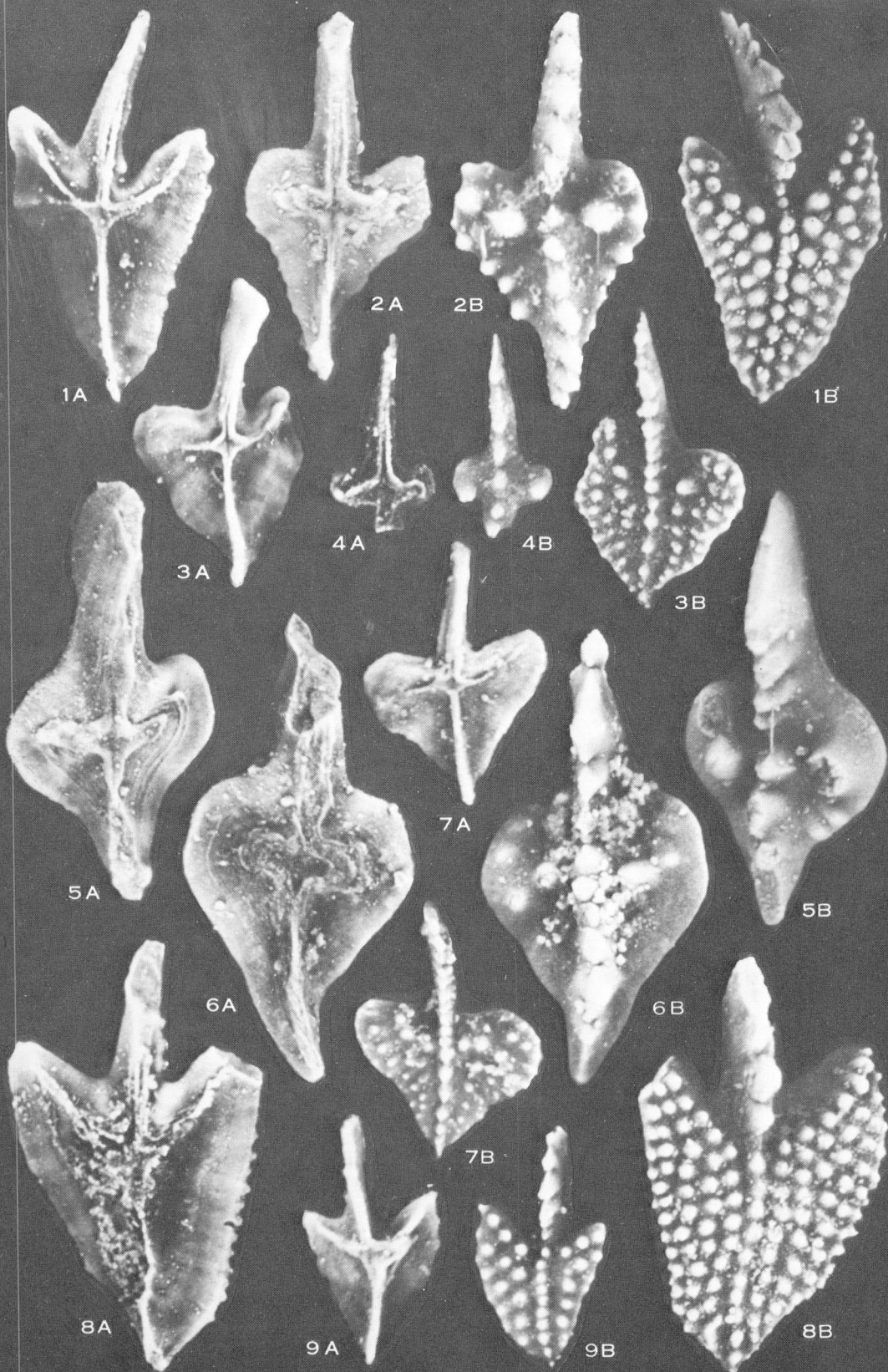
5A, 5B, lower and upper views, paratype, GSC No. 22820, from Calumet Member, Station 181, Clearwater River, Rock Unit 35, 5.5 to 6.5 feet above river level, GSC loc. 63115.

6A, 6B, lower and upper views, GSC No. 24068, from Calumet Member, Station 173, Clearwater River, Rock Units 26-27, 9.7 to 10.7 feet above river level, GSC loc. 63100.

Figures 3, 7. *Ancyrodella rotundiloba alata* Glenister and Klapper (PAGE 24)

3A, 3B, lower and upper views, GSC No. 24064, from Christina Member, California Standard Cynthia SW 16-21 well, depth 11,673.4 to 11,675.8 feet, GSC loc. 63356.

7A, 7B, lower and upper views, GSC No. 24065, from Moberly Member(?), Imperial Judy Creek 6-7 well, depth 8,516.3 to 8,518.7 feet, GSC loc. 64010.



## PLATE 2

All figures x45

Figures 1, 4, 6-9. *Ancyrodella rotundiloba* subsp. A (PAGE 25)

1A, 1B, lower and upper views, GSC No. 22822, from Moberly Member, Station 92, Athabasca River, Rock Unit 36, 25.0 to 26.2 feet above river level, GSC loc. 62691.

4A, 4B, lower and upper views, GSC No. 24137, from Moberly Member, California Standard Cynthia SW 16-21 well, depth 11,553.6 to 11,555.9 feet, GSC loc. 63306.

6A, 6B, lower and upper views, GSC No. 22823, from Christina Member, Station 184, Christina River, Rock Unit 40, 2.0 to 3.0 feet above river level, GSC loc. 63119.

7A, 7B, lower and upper views, GSC No. 24070, from Christina Member (?), Imperial Shell Burntwood 12-6 well, depth 9,437 feet, GSC loc. 80428.

8A, 8B, lower and upper views, GSC No. 22824, from Moberly Member, Station 70, Athabasca River, Rock Unit 32, 14.6 to 16.4 feet above river level, GSC loc. 62828.

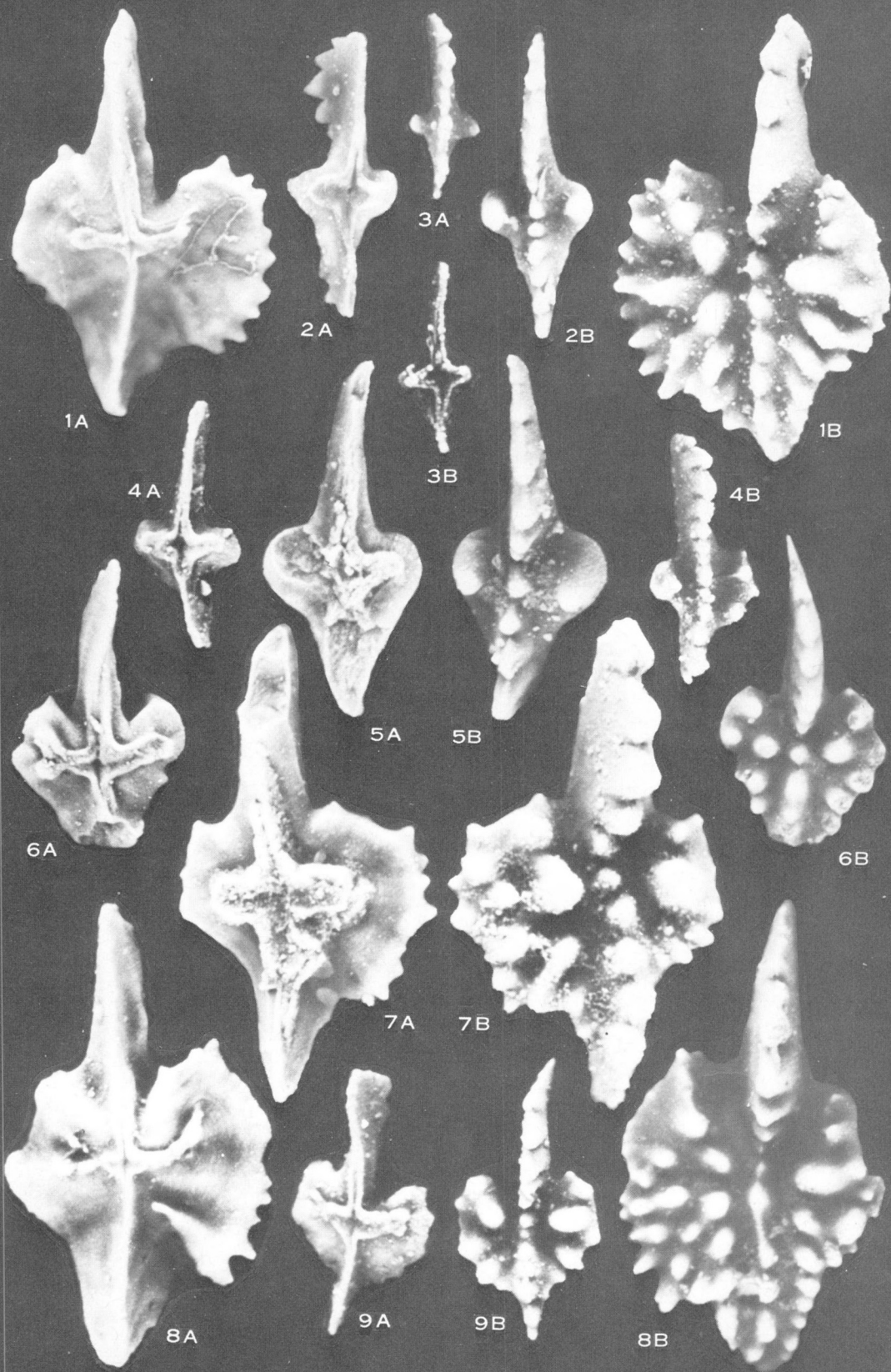
9A, 9B, lower and upper views, GSC No. 24071, from Moberly Member, Station 81, Athabasca River, Rock Unit 34, 7 feet above river level, collected by A. W. Norris, GSC loc. 29282.

Figures 2, 3, 5. *Ancyrodella rotundiloba binodosa* Uyeno (PAGE 24)

2A, 2B, lower and upper views, holotype GSC No. 22819, from Calumet Member, Station 181, Clearwater River, Rock Unit 35, 5.5 to 7.6 feet above river level, collected by A. W. Norris, GSC loc. 29089.

3A, 3B, upper and lower views, paratype, GSC No. 22821, from Christina Member, California Standard Cynthia SW 16-21 well, depth 11,736.8 to 11,739.2 feet, GSC loc. 63382.

5A, 5B, lower and upper views, GSC No. 24069, from Calumet Member, Station 182, Clearwater River, Rock Unit 37, from 0.8 to 1.5 feet above river level, GSC loc. 63118.



### PLATE 3

All figures x45

Figures 1, 3, 4, 6. *Polygnathus asymmetricus asymmetricus* Bischoff and Ziegler (PAGE 37)

1A, 1B, lower and upper views, GSC No. 24097, and 4A, 4B, lower and upper views, GSC No. 24098, both from Moberly Member (?), Imperial Judy Creek 6-7 well, depth 8,516.3 to 8,518.7 feet, GSC loc. 64010.

3A, 3B, 3C, upper, lower and outer lateral views, GSC No. 24099, from Mildred Member, Shell Swan Hills 6-31 well, depth 9,353 feet, GSC loc. 77128.

6A, 6B, lower and upper views, GSC No. 24100, from Moberly Member, California Standard Cynthia SW 16-21 well, depth 11,553.6 to 11,555.9 feet, GSC loc. 63306.

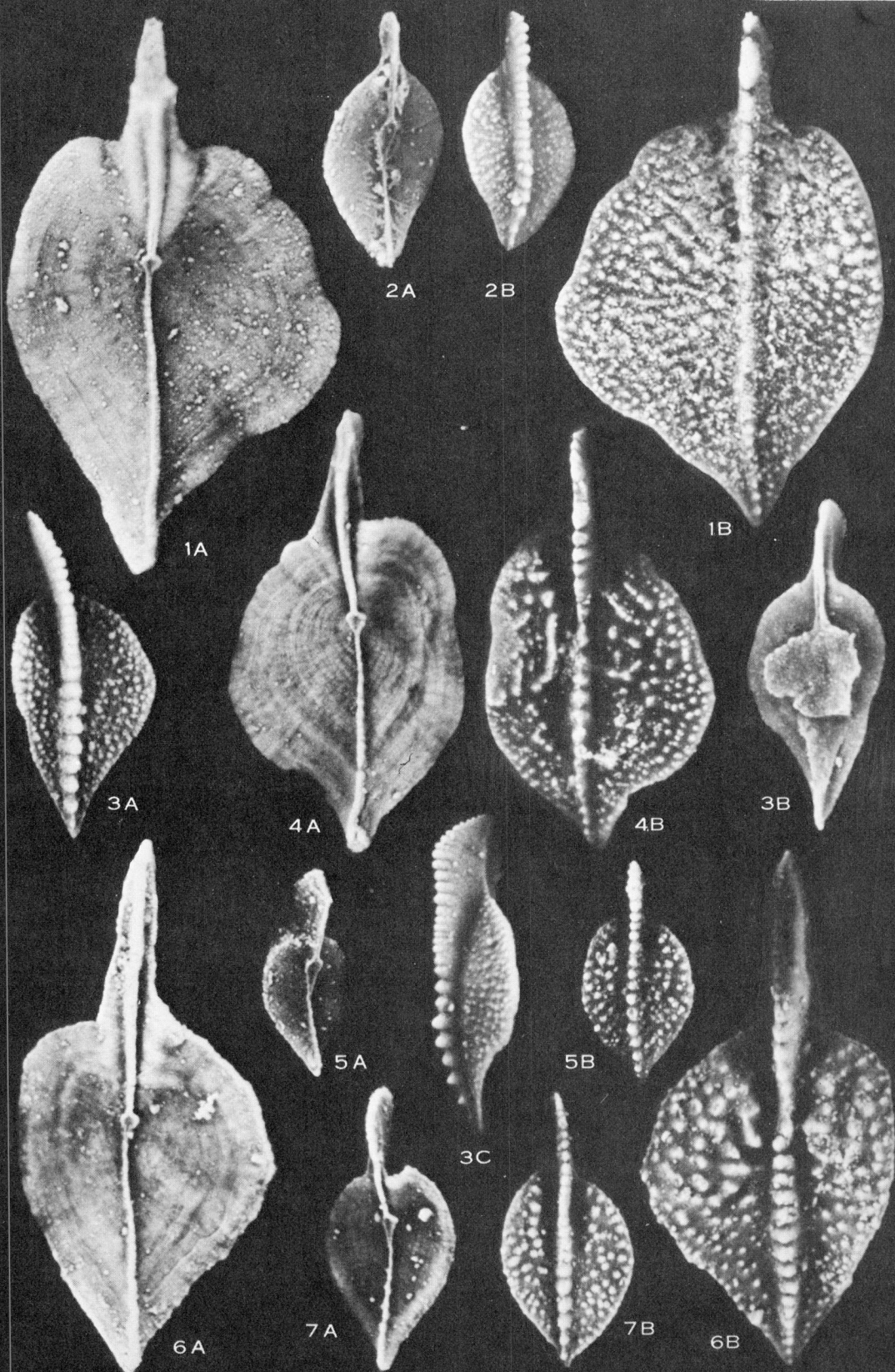
Figures 2, 5, 7. *Polygnathus asymmetricus ovalis* Ziegler and Klapper (PAGE 37)

2A, 2B, lower and upper views, GSC No. 24101, from Moberly Member, Station 79, Athabasca River, Rock Unit 44, 44.5 to 45.5 feet above river level, GSC loc. 62800.

5A, 5B, lower and upper views, GSC No. 24102, from Moberly Member, California Standard Cynthia SW 16-21 well, depth 11,548.9 to 11,551.2 feet, GSC loc. 63304.

7A, 7B, lower and upper views, GSC No. 24103, from Moberly Member, California Standard Cynthia SW 16-21 well, depth 11,558.2 to 11,560.5 feet, GSC loc. 63308.



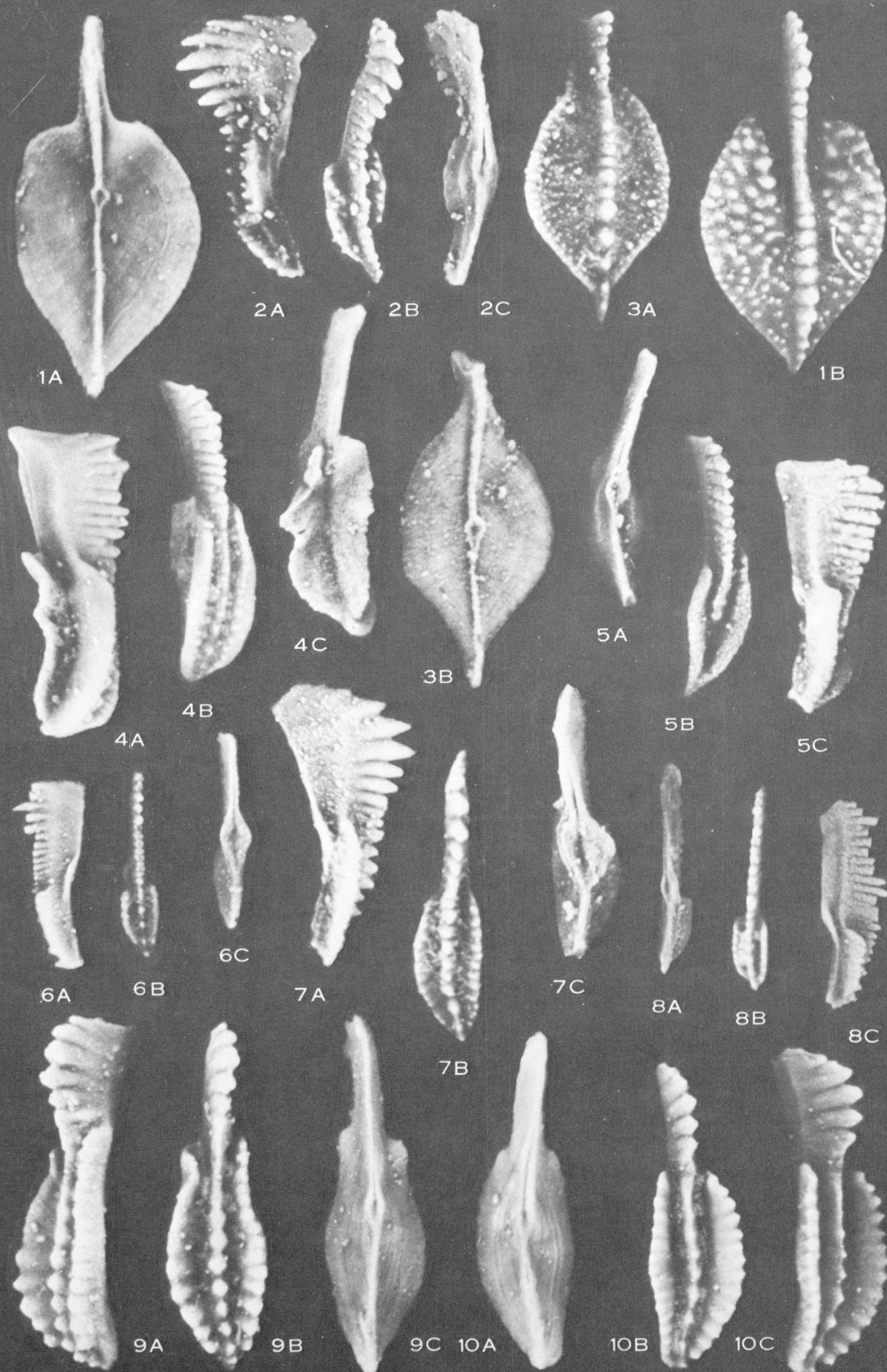




## PLATE 4

All figures x45

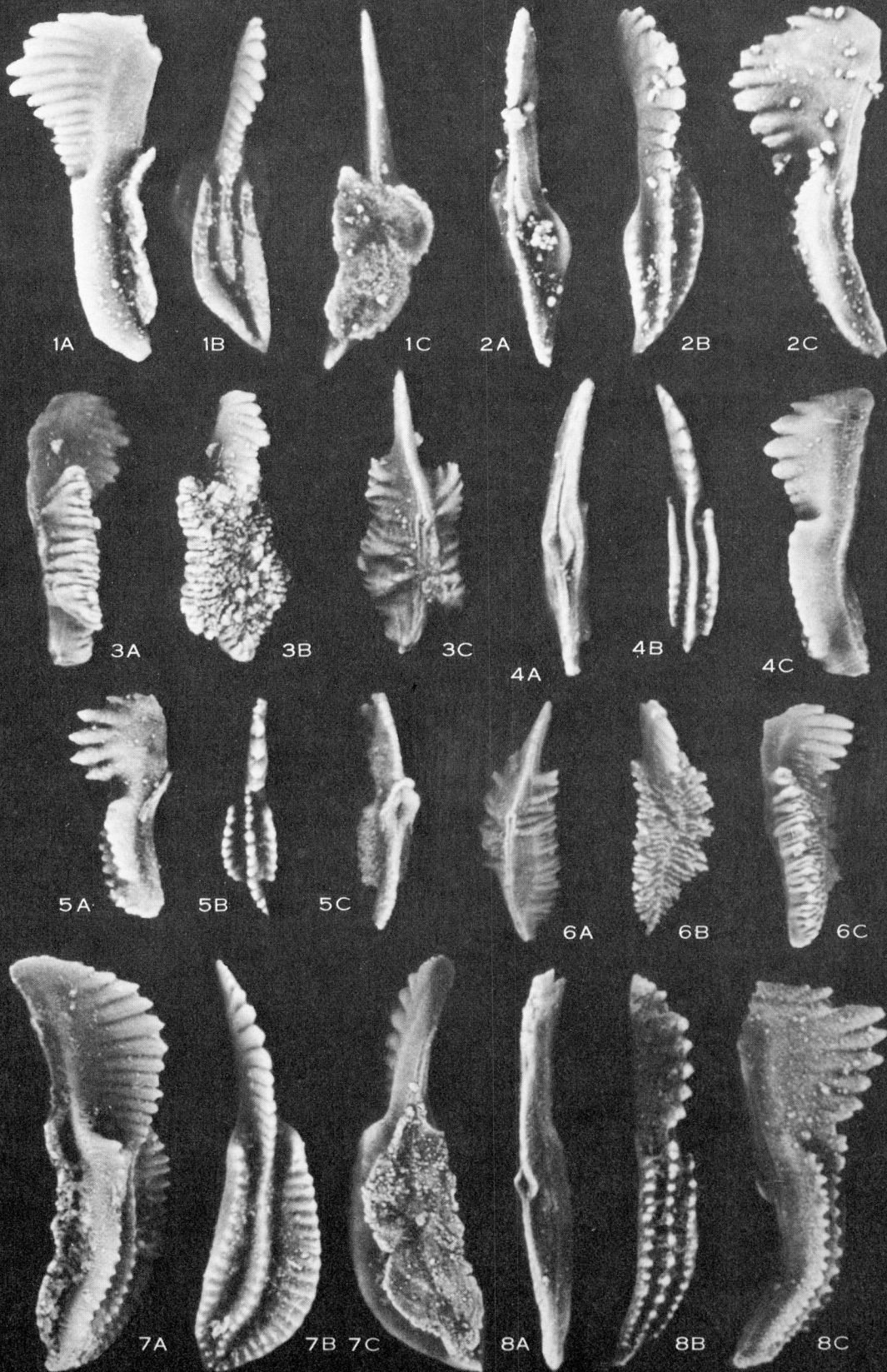
- Figures 1, 3. *Polygnathus asymmetricus ovalis* Ziegler and Klapper (PAGE 37)  
1A, 1B, lower and upper views, GSC No. 24104, from Moberly Member(?), Imperial Judy Creek 6-7 well, depth 8,516.3 to 8,518.7 feet, GSC loc. 64010.  
3A, 3B, upper and lower views, GSC No. 24105, from Moberly Member, Imperial Judy Creek 6-7 well, depth 8,451.8 to 8,454.3 feet, GSC loc. 63984.
- Figures 2, 7. *Polygnathus* cf. *P. decorosus* Stauffer (PAGE 38)  
2A, 2B, 2C, inner lateral, upper, and lower views, GSC No. 24110, from Moberly Member, California Standard Cynthia SW 16-21 well, depth 11,562.8 to 11,565.2 feet, GSC loc. 63310.  
7A, 7B, 7C, outer lateral, upper, and lower views, GSC No. 24111, from Moberly Member, Imperial Judy Creek 6-7 well, depth 8,451.8 to 8,454.3 feet, GSC loc. 63984.
- Figure 4. *Polygnathus* sp. B (PAGE 41)  
4A, 4B, 4C, inner lateral, upper and lower [showing large basal plate] views, GSC No. 24108, from Calumet Member, Station 101, Athabasca River, Rock Unit 11, 2.6 to 3.6 feet above river level, GSC loc. 62667.
- Figure 5. *Polygnathus incompletus* Uyeno (PAGE 39)  
5A, 5B, 5C, lower, upper, and inner lateral views, holotype GSC No. 22828, from Calumet Member(?), California Standard Cynthia SW 16-21 well, depth 11,754.1 to 11,756.6 feet, GSC loc. 63389.
- Figures 6, 8. *Polygnathus xylus* Stauffer (PAGE 40)  
6A, 6B, 6C, inner lateral, upper, and lower views, GSC No. 24114, from Calumet Member(?), California Standard Cynthia SW 16-21 well, depth 11,744.2 to 11,746.7 feet, GSC loc. 63385.  
8A, 8B, 8C, lower, upper, and outer lateral views, GSC No. 24115, from Moberly Member(?), Imperial Shell Burntwood 12-6 well, depth 9,407 feet, GSC loc. 80425.
- Figures 9, 10. *Polygnathus* sp. A (PAGE 41)  
9A, 9B, 9C, inner lateral, upper, and lower views, GSC No. 24116, from Moberly Member, Station 79, Athabasca River, Rock Unit 38, 25.3 to 26.6 feet above river level, GSC loc. 62794.  
10A, 10B, 10C, lower, upper, and inner lateral views, GSC No. 24117, from Moberly Member, Station 79, Athabasca River, Rock Unit 34, 7.5 to 10.3 feet above river level, GSC loc. 62787.



## PLATE 5

All figures x45

- Figure 1. *Polygnathus incompletus* Uyeno (PAGE 39)  
1A, 1B, 1C, inner lateral, upper, and lower [showing large basal plate] views, paratype, GSC No. 22829, from Calumet Member, Station 181, Clearwater River, Rock Unit 34, 3.5 to 4.5 feet above river level, GSC loc. 63113.
- Figure 2. *Polygnathus* cf. *P. decorosus* Stauffer (PAGE 38)  
2A, 2B, 2C, lower, upper, and outer lateral views, GSC No. 24112, from Moberly Member, California Standard Cynthia SW 16-21 well, depth 11,565.2 to 11,567.4 feet, GSC loc. 63311.
- Figures 3, 6. *Polygnathus norrisi* Uyeno (PAGE 39)  
3A, 3B, 3C, outer lateral, upper, and lower views, paratype, GSC No. 22831, from Firebag Member, Richfield Oil Corp. Pony Creek No. 2 well, depth 1,541 to 1,542 feet, GSC loc. 77112.  
  
6A, 6B, 6C, lower, upper, and inner lateral views, holotype, GSC No. 22830, from Firebag Member, Station 103, Athabasca River, Rock Unit 2, 6.51 to 6.74 feet above river level, GSC loc. 62737.
- Figures 4, 5. *Polygnathus brevilaminus* Branson and Mehl (PAGE 37)  
4A, 4B, 4C, lower, upper, and outer lateral views, GSC No. 24106, from Firebag Member, Alta. Govt. Salt Well No. 1, depth 490 to 497 feet, GSC loc. 80265.  
  
5A, 5B, 5C, inner lateral, upper, and lower views, GSC No. 24107, from Moberly Member, Station 70, Athabasca River, Rock Unit 37, 30.1 to 32.1 feet above river level, GSC loc. 62836.
- Figure 7. *Polygnathus webbi* Stauffer (PAGE 40)  
7A, 7B, 7C, inner lateral, upper, and lower [showing large basal plate] views, GSC No. 24113, from Firebag Member, Station 103, Athabasca River, Rock Unit 2, 0.99 to 1.22 feet above river level, GSC loc. 62713.
- Figure 8. *Polygnathus* sp. B (PAGE 41)  
8A, 8B, 8C, lower, upper, and inner lateral views, GSC No. 24109, from Swan Hills Member, Calstan SOBC House Mountain 2-6 well, depth 7,471.7 to 7,473.9 feet, GSC loc. 63406.

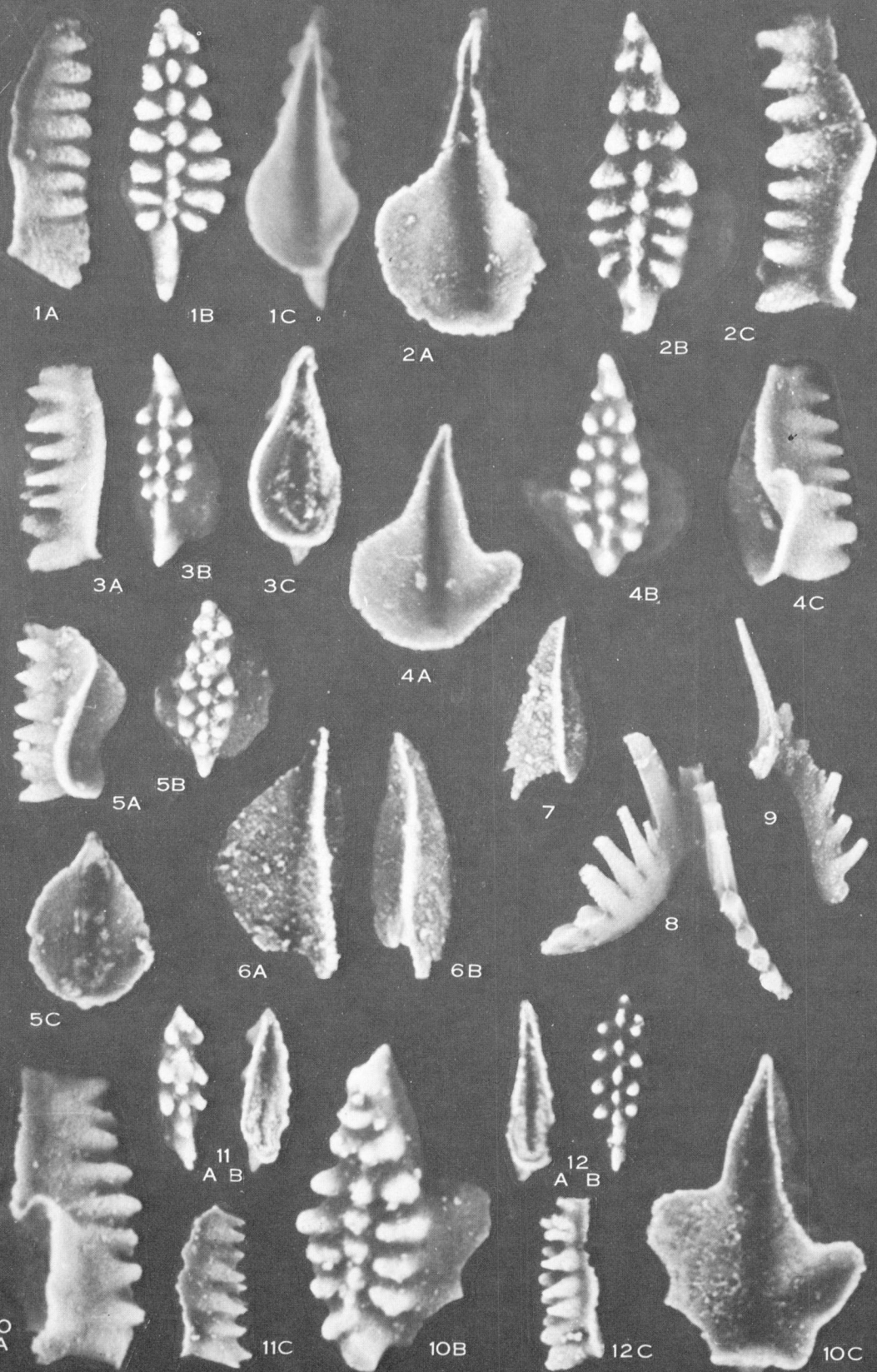


## PLATE 6

All figures x60, unless otherwise indicated

- Figures 1, 2, 5. *Icriodus expansus* Branson and Mehl (PAGE 30)  
1A, 1B, 1C, inner lateral, upper, and lower views, GSC No. 24080, from Moberly Member, Station 70, Athabasca River, Rock Unit 35, 25.0 to 26.8 feet above river level, GSC loc. 62833.  
  
2A, 2B, 2C, lower, upper, and outer lateral views, GSC No. 24081, from Moberly Member(?), Imperial Shell Burntwood 12-6 well, depth 9,397 feet, GSC loc. 80424.  
  
5A, 5B, 5C, outer lateral, upper, and lower views, GSC No. 24082, from Moberly Member, Station 59, Athabasca River, Rock Unit 34, 6 feet above river level, collected by A. W. Norris, GSC loc. 29209
- Figures 3, 11, 12. *Icriodus brevis brevis* Stauffer (PAGE 29)  
3A, 3B, 3C, outer lateral, upper, and lower views, GSC No. 24077, from Moberly Member(?), Imperial Shell Burntwood 12-6 well, depth 9,357 feet, GSC loc. 80420.  
  
11A, 11B, 11C, upper, lower, and outer lateral views, GSC No. 24078, from Firebag Member, Station 103, Athabasca River, Rock Unit 2, 7.89 to 8.12 feet above river level, GSC loc. 62743.  
  
12A, 12B, 12C, lower, upper, and inner lateral views, GSC No. 24079, from Christina Member(?), Imperial Judy Creek 6-7 well, depth 8,632.9 to 8,635.1 feet, GSC loc. 64058.
- Figures 4, 10. *Icriodus nodosus* (Huddle) sensu lato (PAGE 30)  
4A, 4B, 4C, lower, upper, and inner lateral views, GSC No. 24083, from Moberly Member, Station 79, Athabasca River, Rock Unit 38, 25.3 to 26.6 feet above river level, GSC loc. 62794.  
  
10A, 10B, 10C, inner lateral, upper, and lower views, GSC No. 24084, from Calumet Member, Station 181, Clearwater River, Rock Unit 35, 5.5 to 6.5 feet above river level, GSC loc. 63115.
- Figures 6, 7. *Playfordia primitiva* (Bischoff and Ziegler) (PAGE 36)  
6A, 6B, upper and lateral views, GSC No. 24095, from Moberly Member, California Standard Cynthia SW 16-21 well, depth 11,583.8 to 11,585.0 feet, GSC loc. 63319.  
  
7, lateral view, GSC No. 24096, from Moberly Member, California Standard Cynthia SW 16-21 well, depth 11,562.8 to 11,565.1 feet, GSC loc. 63310.
- Figure 8 (x45). *Enantiognathus* cf. *E. lipperti* (Bischoff) (PAGE 27)  
8, upper view, GSC No. 24076, from Moberly Member, Station 22-1, Athabasca River, Rock Unit 43, 7.1 to 8.0 feet above river level, GSC loc. 62970.
- Figure 9 (x45). *Enantiognathus lipperti* (Bischoff) (PAGE 27)  
9, lateral view, GSC No. 24075, from Swan Hills Formation, Calstan SOBC House Mountain 2-6 well, depth 7,471.7 to 7,473.9 feet, GSC loc. 63406.





## PLATE 7

All figures x45, unless otherwise indicated

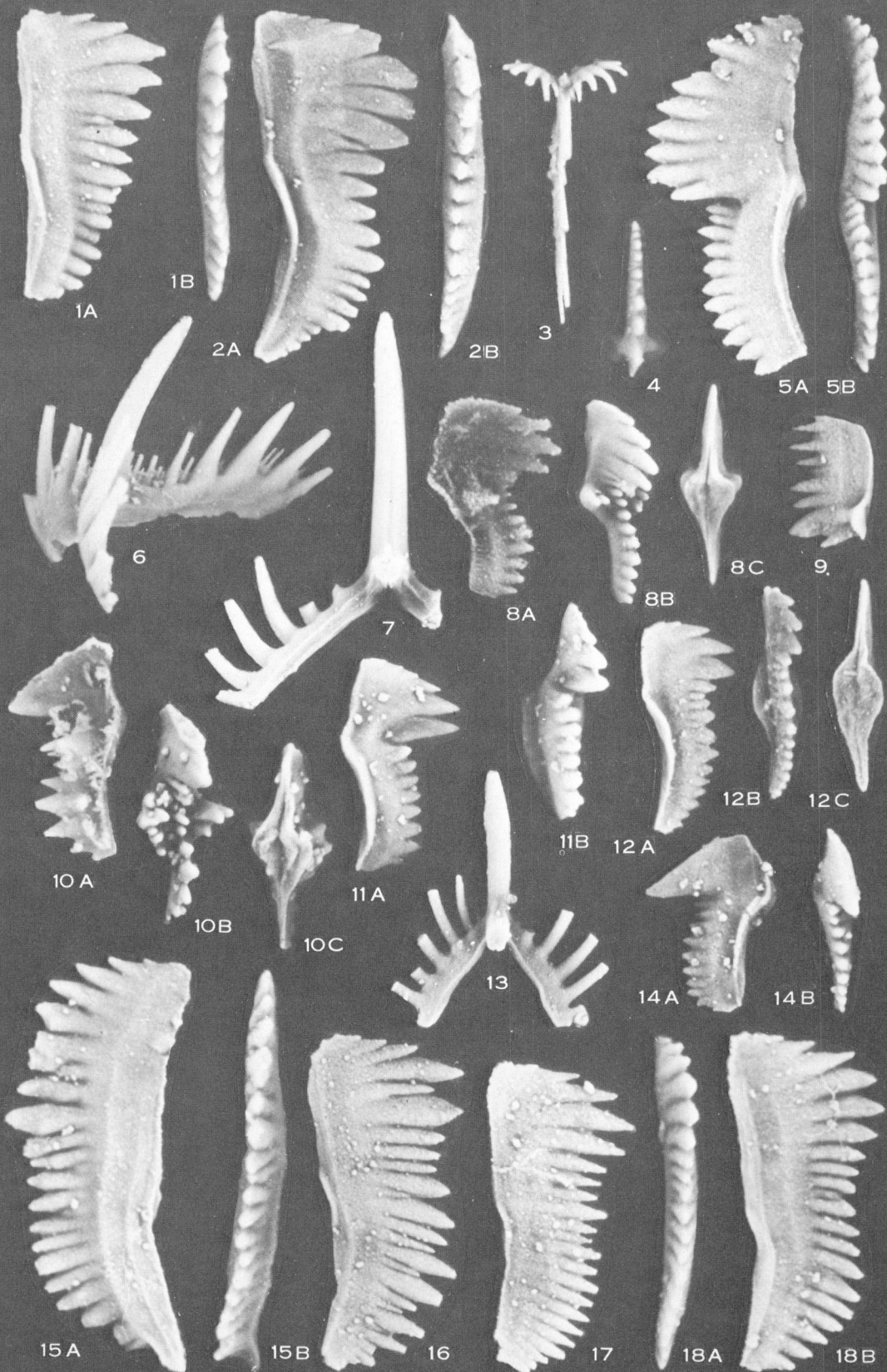
- Figures 1-6. *Nothognathella klapperi* Uyeno (PAGE 33)  
 1, oblique lateral view, holotype, GSC No. 22825, and 2, lower view, paratype, GSC No. 22827, both from Moberly Member(?), Imperial Judy Creek 6-7 well, depth 8,516.3 to 8,518.7 feet, GSC loc. 64010.  
 3, inner lateral view GSC No. 24088, from Moberly Member, California Standard Cynthia SW 16-21 well, depth 11,560.5 to 11,562.8 feet, GSC loc. 63309.  
 4, upper view, GSC No. 24089, from Moberly Member(?), Imperial Judy Creek 6-7 well, depth 8,530.6 to 8,532.9 feet, GSC loc. 64016.  
 5A, 5B, upper views, GSC Nos. 24090 and 24091, respectively, both from Moberly Member, Imperial Judy Creek 6-7 well, depth 8,451.8 to 8,454.3 feet, GSC loc. 63984.  
 6A, 6B, inner lateral and lower views, paratype, GSC No. 22826, from Mildred Member, Shell Swan Hills 6-31 well, depth 9,353 feet, GSC loc. 77128.
- Figure 7. *Nothognathella* sp. A (PAGE 34)  
 7A, 7B, outer lateral and inner lateral views, GSC No. 24092, from Christina Member, California Standard Cynthia SW 16-21 well, depth 11,673.4 to 11,735.7 feet, GSC loc. 63356.
- Figure 8. *Nothognathella brevidonta* Youngquist (PAGE 33)  
 8A, 8B, 8C, inner lateral, upper, and lower views, GSC No. 24087, from Mildred Member, Imperial Judy Creek 6-7 well, depth 8,410 to 8,412.5 feet, GSC loc. 63967.
- Figures 9, 16. *Nothognathella bicristata* Youngquist and Miller (PAGE 32)  
 (x30)  
 9A, 9B, 9C, inner lateral, upper, and lower views, GSC No. 24085, from Moberly Member, Station 79, Athabasca River, Rock Unit 57, 81.5 to 83.5 feet above river level, GSC loc. 62809.  
 16, inner lateral view, GSC No. 24086, from Moberly Member, Station 92, Athabasca River, Rock Unit 37, 29.8 to 31.8 feet above river level, GSC loc. 62695.
- Figures 10, 17, 18. *Falcodus?* cf. *F.?* *tortus* Huddle (PAGE 27)  
 10, inner lateral view, GSC No. 24072, from Moberly Member, Imperial Judy Creek 6-7 well, depth 8,451.8 to 8,454.3 feet, GSC loc. 63984.  
 17A, 17B, inner lateral and other lateral views, and 18A, 18B, outer lateral and inner lateral views, GSC Nos. 24073 and 24074, respectively, both from Moberly Member(?), Imperial Judy Creek 6-7 well, depth 8,516.3 to 8,518.7 feet, GSC loc. 64010.
- Figures 11-13. *Spathognathodus* cf. *S. brevis* Bischoff and Ziegler (PAGE 42)  
 11, lateral view, GSC No. 24122, from Moberly Member, Station 79, Athabasca River, Rock Unit 35, 13.0 to 14.1 feet above river level, GSC loc. 62789.  
 12, lateral view, GSC No. 24123, from Moberly Member, Station 92, Athabasca River, Rock Unit 36, 26.8 to 27.8 feet above river level, GSC loc. 62693.  
 13, lateral view, GSC No. 24124, from Moberly Member, Station 70, Athabasca River, Rock Unit 34, 19.8 to 21.7 feet above river level, GSC loc. 62831.
- Figures 14, 15. *Palmatodella?* *paridens* Huddle (PAGE 35)  
 14, inner lateral view, GSC No. 24093, from Moberly Member, Imperial Judy Creek 6-7 well, depth 8,451.8 to 8,454.3 feet, GSC loc. 63984.  
 15, inner lateral view, GSC No. 24094, from Moberly Member, California Standard Cynthia SW 16-21 well, depth 11,562.8 to 11,565.1 feet, GSC loc. 63310.





All figures x45, unless otherwise indicated

- Figures 1, 15-18. *Spathognathodus gradatus* (Youngquist) (PAGE 42)  
 1A, 1B, lateral and upper views, GSC No. 24127, 15A, 15B, inner lateral and upper views, GSC No. 24128, 18A, 18B, upper and inner lateral views, GSC No. 24129, all from Moberly Member, Station 70, Athabasca River, Rock Unit 44, 53.0 to 55.0 feet above river level, GSC loc. 62841.  
 16, inner lateral view, GSC No. 24130, from Moberly Member, Station 70, Athabasca River, Rock Unit 33, 16.4 to 17.8 feet above river level, GSC loc. 62829.  
 17, inner lateral view, GSC No. 24131, from Moberly Member, Station 70, Athabasca River, Rock Unit 34, 21.7 to 25.0 feet above river level, GSC loc. 62832.
- Figures 2, 5, 11, 12, 14. *Spathognathodus insitus* (Stauffer) (PAGE 43)  
 2A, 2B, inner lateral and upper views, GSC No. 24132, from Moberly Member, Station 193, Clearwater River, Rock Unit 61, 6.0 to 7.0 feet above river level, GSC loc. 63197.  
 5A, 5B, outer lateral and upper views, GSC No. 24133, from Moberly Member, Station 47, Athabasca River, Rock Unit 45, 44.6 to 44.8 feet above river level, GSC loc. 62905.  
 11A, 11B, lateral and upper views, GSC No. 24134, from Calumet Member, Station 171, Clearwater River, Rock Unit 18, 3.0 to 4.0 feet above river level, GSC loc. 63076.  
 12A, 12B, 12C, lateral, upper, and lower views, GSC No. 24135, from Moberly Member, Station 70, Athabasca River, Rock Unit 33, 16.4 to 17.8 feet above river level, GSC loc. 62829.  
 14A, 14B, lateral and upper views, GSC No. 24136, from Calumet Member, Station 178, Clearwater River, Rock Unit 31, 0 to 1.3 feet above river level, GSC loc. 63105.
- Figures 3, 6. *Diplododella aurita* (Sannemann) (PAGE 26)  
 3, upper view, GSC No. 24118, from Moberly Member, Station 23-1, Athabasca River, Rock Unit 45, 10 to 10.2 feet above river level, GSC loc. 62958.  
 6, oblique lateral view, GSC No. 24119, from Moberly Member, Station 203, Clearwater River, Rock Unit 72, 1.5 to 2 feet above river level, collected by A. W. Norris, GSC loc. 29314.
- Figures 4, 9. *Spathognathodus* cf. *S. brevis* Bischoff and Ziegler (PAGE 42)  
 4, upper view, GSC No. 24125, from Moberly Member, Station 70, Athabasca River, Rock Unit 34, 21.7 to 25.0 feet above river level, GSC loc. 62832.  
 9, lateral view, GSC No. 24126, from Moberly Member, Station 92, Athabasca River, Rock Unit 36, 26.8 to 27.8 feet above river level, GSC loc. 62693.
- Figure 7. (x23) *Hibbardella* sp. B (PAGE 29)  
 7, posterior view, GSC No. 24121, from Moberly Member, Station 203, Clearwater River, Rock Unit 72, 1.5 to 2 feet above river level, collected by A. W. Norris, GSC loc. 29314.
- Figures 8, 10. *Spathognathodus* ? sp. (PAGE 44)  
 8A, 8B, 8C, lateral, upper, and lower views, GSC No. 22833, from Firebag Member, Richfield Oil Corp. Pony Creek No. 2 well, depth 1,512 to 1,517 feet, GSC loc. 77110.  
 10A, 10B, 10C, lateral, upper, and lower views, GSC No. 22832, from Firebag Member, Richfield Oil Corp. Pony Creek No. 2 well, depth 1,541 to 1,542 feet, GSC loc. 77112.
- Figure 13. (x30) *Hibbardella* sp. A (PAGE 28)  
 13, posterior view, GSC No. 24120, from Firebag Member, Union Red Earth 2-22 well, depth 4,254 to 4,256.5 feet, GSC loc. 63246.





## Text Index to Form—Genera and—Species

	PAGE		PAGE
Ancyrodella.....	23, 44	typicalis.....	32
gigas.....	23	sp. A.....	34
rotundiloba.....	23, 24, 26		
rotundiloba alata.....	24, 25	Palmatodella.....	35
rotundiloba binodosa.....	24-26, 44	Palmatodella? paridens.....	31, 35
rotundiloba rotundiloba.....	25	*Pandorinellina.....	35
rotundiloba subsp. A.....	25	insita.....	31, 35, 36
Bryantodus.....	32	Playfordia.....	36
		primitiva.....	36
Dinodus.....	36	Polygnathus.....	36
Diplododella.....	26	asymmetricus.....	31, 37
aurita.....	26, 31, 36	asymmetricus asymmetricus.....	37
Elictognathus.....	32, 34	asymmetricus ovalis.....	37
laceratus.....	34	brevilaminus.....	37, 38
Elsonella.....	36	communis.....	39
Enantiognathus.....	27	cf. decorosus.....	38, 41
lipperti.....	27	diversus.....	40
cf. lipperti.....	27	dubius.....	36
Falcodus.....	27, 28	foliatus.....	36
Falcodus? cf. tortus.....	27, 31	glaber.....	39
Hibbardella.....	28	incompletus.....	39
sp. A.....	28	normalis.....	40
sp. B.....	29	norrisi.....	39, 40
Icriodus.....	29	procerus.....	39
brevis brevis.....	29, 30	rhenanus.....	38
expansus.....	30	varcus.....	38, 41
latericrescens.....	30	webbi.....	40, 41
nodosus sensu lato.....	30	xylus.....	40, 41
Lonchodina.....	27, 31	sp. A.....	41
Mehlina gradatus.....	42	sp. B.....	41
Mehlina irregularis.....	42	Prioniodina.....	31
*Mesotaxis asymmetrica.....	26, 28, 31, 34, 35, 37	Pseudopolygnathus.....	38
Nothognathella.....	32		
bicristata.....	32	Spathognathodus.....	23, 42, 44
brevidonta.....	33, 34	brevis.....	42
iowaensis.....	34	cf. brevis.....	42
klapperi.....	33-34	exiguus philipi.....	43
		gradatus.....	42
		insitus.....	23, 43, 44
		primus.....	43, 44
		Spathognathodus? sp.....	25, 43, 44
		Telumodina.....	35
		*multielement taxa	



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