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EARLY CRETACEOUS (ALBIAN) FORAMINIFERA IN
NORTHWESTERN AND CENTRAL ALBERTA,
CANADA:
BIOSTRATIGRAPHY AND
PALEOENVIRONMENTAL CHANGES

by

REBECCA A. STRITCH, Bsc. (Hons. Biology)

A thesis submitted to the Faculty of Graduate Studies and Research

in partial fulfilment of

the requirements for the degree of

Master of Science

Department of Earth Sciences

Carleton University

and the

Ottawa-Carleton Geoscience Centre

Ottawa, Ontario

May 15, 1997

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BIOSTRATIGRAPHY AND
PALEOENVIRONMENTAL CHANGES

submitted by Rebecca A. Stritch, B. Sc. (Hons Biology)
in partial fulfilment of the requirements for
the degree of Master of Science

A handwritten signature in black ink, reading "Ladia Idris-Aden", written over a horizontal line.

Thesis supervisor

A handwritten signature in black ink, reading "G. R. Smith", written over a horizontal line.
Chair, Department of Earth Sciences

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May 15, 1997

ABSTRACT

Albian-age foraminifera from three wells in northwestern and central Alberta provide the basis of a faunal comparison across the basin. The Albian was a time of fluctuating sea level in western Canada. Two global second order marine cycles are punctuated by higher frequency marine cycles expressed during the time of the Moosebar/Clearwater, Hulcross, Joli Fou and Mowry seas. The paleoenvironments of these seas are reflected in the foraminiferal faunas found throughout the succession. A total of 34 genera and 86 subgeneric taxa are recognised in Albian-age strata in central and northwestern Alberta. Foraminiferal abundance and diversity reflect and respond to changes in sedimentary facies. Re-evaluation of the foraminiferal subzonation of northwestern Alberta resulted in the addition of the lower Albian *Rectobolivina* sp. and *Trochammina mcmurrayensis* subzones of the *Gaudryina nanushukensis* Zone, and possibly the upper Albian *Haplophragmoides postis goodrichi* as well as the *Verneuilina canadensis* subzones of the *Miliammina manitobensis* Zone. Foraminiferal faunas from the Viking Formation in central Alberta plains and the correlative Paddy Member of the Peace River Formation in the northwestern plains are documented as the uppermost *Haplophragmoides gigas* subzone.

ACKNOWLEDGMENTS

I would like to thank my supervisor Dr. Claudia J. Schröder-Adams for her guidance and encouragement throughout the course of this work, and support of the research. Financial assistance was provided by an NSERC Strategic Grant to C. J. Schröder-Adams and by a Teaching Assistantship from the Department of Earth Sciences.

Amoco Canada is thanked for the donation of picked foraminiferal assemblages from the three study wells and various other data concerning this material. Thanks also to Dr. C. R. Stelck, Professor Emeritus at the University of Alberta in Edmonton, and to Dr. D. A. Leckie at the Geological Survey of Canada in Calgary for their helpful comments.

Sincere thanks and appreciation go to the SEM staff at Carleton University for their assistance (Peter Jones, Cheng Huang, and Lewis Ling); Dr. Chuck. E. Livingstone of the CCRS (Natural Resources Canada) for critically reviewing the manuscript; Deb Kliza, Sue Burbidge, Pat Brennan and Barbara Medioli for their stimulating discussions on the topic; and to Ivy Livingstone and Patrick Stritch for their love and support, and Liam for his cooperation.

This work is dedicated to my husband Patrick and our son William.

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INTRODUCTION

Cretaceous strata of the Western Interior Seaway were deposited in a series of transgressive and regressive marine cycles of varying magnitude. Ten Cretaceous cycles have been identified by Kauffman (1977, 1984) as global second order sea-level cycles (Caldwell *et al.*, 1993). Kauffman's fifth transgressive-regressive cycle (Kiowa-Skull Creek) and the beginning of cycle six (Greenhorn) lie within the Albian Stage of the Early Cretaceous (Kauffman, 1977) and established a marine connection between the Boreal and Tethys seas (Caldwell, 1984). The second order sea-level cycles in the Albian have been overprinted by several higher frequency cycles forming the Moosebar/Clearwater, Hulcross, Joli Fou, and Mowry seas (Figure 1) (Williams and Stelck, 1975; Caldwell, 1984; Leckie and Reinson, 1993) depositing variable strata of clastic sediments in the Western Canada Sedimentary Basin (WCSB) (Caldwell, 1984).

The sea-level history of the WCSB is associated with distinct micro- and macro-faunal assemblages. Paleontology has played an important role in establishing the paleogeography, paleoecology and sea-level history of the basin. Megafaunas such as ammonites are used as markers in regional correlation and have delivered a detailed zonation correlated with an absolute timescale (Warren and Stelck, 1969). However, macrofossils are generally rare in Lower Cretaceous marine rocks of the western interior and in core. Microfossils, however, have proven to be particularly useful in biostratigraphic correlation involving outcrop and subsurface sections due to their wide geographic distribution and high abundance. Index species with restricted stratigraphic range, such as the foraminifer *Haplophragmoides gigas*, are very useful for long range

Figure 1. Transgressive-Regressive couplets and cycles in the southern interior plains of Canada. Modified after Kauffman (1977) - global T-R cycles; Caldwell (1984) - T-R couplets; and Obradovich (1993) - ages at stage boundaries.

stratigraphic correlation (Caldwell *et al.*, 1978). Palynological studies can be useful for age dating and correlation, however the upper limit of the geologic range of a spore or pollen species may be deceptive due to reworking (Singh, 1964).

Foraminiferal assemblage zones and subzones associated with Albian marine cycles in the northern portion of the seaway were described by Nauss (1947), Wickenden (1951), Mellon and Wall (1956), Stelck *et al.* (1956), Tappan (1962), Guliov (1967), Wall (1967a), Sutherland and Stelck (1972), North and Caldwell (1975a), Stelck (1975), Koke and Stelck (1984, 1985), Stelck and Koke (1987) and Stelck (1991). Each work depicts different areas and as a result several Albian foraminiferal zonations have been proposed (Figure 2). Some have limited extent for regional correlation due to their association with local facies. Different taxonomic approaches can also cause taxonomic splitting hindering province-wide correlations. An attempt to synthesize published descriptions into a basin-wide foraminiferal zonal scheme for western Canada revealed that assemblage composition varies greatly between regions (Caldwell *et al.*, 1978).

This study compares the foraminiferal record from the Albian stage recovered from three wells in northwestern and central Alberta (Figure 3). All three Albian foraminiferal zones, *Gaudryina nanushukensis*, *Haplophragmoides gigas*, and *Miliammina manitobensis* are represented in the studied interval (Figure 2). Stratigraphic units in northwestern Alberta differ from central Alberta (Figure 4) and a faunal comparison allows a close examination of foraminiferal response to facies changes. Stratigraphic and biostratigraphic correlations are made between wells using mainly foraminiferal data, with lithostratigraphy and well log data as supporting evidence.

Reference	STAGE	SUBSTAGE	Stelck (1991)	Stelck and Leckie (1990) Caldwell et al. (1978)	Caldwell et al. (1978)	Mattison and Wall (1993) Caldwell et al. (1978)	North and Caldwell (1976b)	THIS STUDY		FORAMINIFERAL ZONE (After Caldwell et al. 1978)
								N. W. ALBERTA	CENTRAL ALBERTA	
ALBIAN	CENOM.	UPPER	NORTHEASTERN BRITISH COLUMBIA	NORTHWESTERN ALBERTA	CENTRAL ALBERTA	NORTHEASTERN ALBERTA	WESTERN SASKATCHEWAN			
			Haplophragmium swarini	Haplophragmium swarini						
			Haplophragmoides postis goodrichi	Haplophragmoides postis goodrichi						
			Verneuilina canadensis	Verneuilina canadensis	Verneuilina canadensis	Verneuilina canadensis	Zone III	Verneuilina canadensis ? H. postis goodrichi	Verneuilina canadensis	Millammina manitobensis
			Reophax troyeri					Reophax troyeri		
			Trochammina umlatensis							
			Trochammina depressa							
			Reophax tundraensis							
			Haplophragmoides gigas phaseolus							
			Haplophragmoides gigas gigas							
			Haplophragmoides unilobis							
			Ammobaculites wenonahae							
	MIDDLE		Ammobaculites sp.	Ammobaculites sp.						
			Haplophragmoides multiplex	Haplophragmoides multiplex						
			Margulinulopsis collinsi - Verneuilinoides cummingsensis	Margulinulopsis collinsi - Verneuilinoides cummingsensis	Margulinulopsis collinsi - Verneuilinoides cummingsensis	Margulinulopsis collinsi - Verneuilinoides cummingsensis	Zone I	Margulinulopsis collinsi - Verneuilinoides cummingsensis		
			Trochammina mcmurrayensis	Trochammina mcmurrayensis		Trochammina mcmurrayensis		Trochammina mcmurrayensis		
			Rectobolvinia sp.					Rectobolvinia sp.		
	LOWER									
APTIAN										

Figure 2. Correlation of the foraminiferal zones and subzones across the Western Canadian Sedimentary Basin.

Figure 3. Map showing localities of sampled wells (►). Circled numbers refer to correlation chart of figure 4. (1) Northeastern British Columbia Foothills, (2) Northwestern Alberta: Peace River Plains. (3) Central Alberta Plains. (4) Northeastern Alberta - Athabasca, (5) Northwestern Saskatchewan - Lloydminster.

Figure 4. Stratigraphic correlation chart of the upper Bullhead, Fort St. John, Mannville, and lower Colorado groups in the western portion of the WCSB showing microfaunal zonation. After 1. Hayes et al. (1994) and 2. Bloch et al. (1993). Circled numbers refer to appropriate geographical areas on the location map. Solid lines represent boundaries between formations; dashed lines denote boundaries between formations members. The dotted line in columns 1 and 2 denotes the top of the Mannville-equivalent strata in areas where deposition occurred without significant interruption into the overlying Colorado interval.

PREVIOUS STUDIES

Regional correlation of lithologic units in Alberta was first attempted by McLearn (1932, 1944). Since then an abundance of regional stratigraphic studies of strata in the central and northwestern plains have been published (Nauss, 1945; Badgley, 1952; Alberta Study Group, 1954; Gleddie, 1954; Glaister, 1959; Mellon and Wall, 1963; Stott, 1962, 1968). Most of these investigations were concerned with the correlation and distribution of gross lithologic units. Results of more recent investigations include micropaleontological evidence in stratigraphic studies. Numerous studies have been published describing Albian-age foraminifera throughout the American and Canadian portions of the basin, excluding Alberta. The majority of these studies have taxa common to central or northwestern Alberta making them useful for comparison with those taxa found in this study. Cretaceous foraminifera from the Boreal Sea were reported from northern Alaska by Tappan (1957, 1960, 1962) and Chamney (1978) investigated Albian foraminifera from the Yukon Territory. Albian foraminifera have been described from northeastern British Columbia (Sutherland and Stelck, 1972; Stelck, 1975; Stelck and Hedinger, 1983; Koke and Stelck, 1984, 1985; Stelck and Koke, 1987; Stelck and Leckie, 1988; Stelck, 1991); from the foothills of Alberta and British Columbia (Wall, 1967b), from southern Alberta and Saskatchewan (Schröder-Adams *et al.*, 1996), and from Saskatchewan and Manitoba (Guliov, 1967; North and Caldwell, 1975a, b; McNeil and Caldwell, 1981). Upper Albian faunas from Wyoming, Kansas and Texas have elements in common with Canadian faunas (Tappan, 1940, 1943; Loeblich and Tappan, 1946, 1950;

Eicher, 1960, 1965). Taxonomic and biostratigraphic work covering the Albian of Alberta has been published by Stelck *et al.* (1956) and Mellon and Wall (1956) who described Lower and Middle Albian foraminifera from northeastern Alberta and northeastern British Columbia. Wall (1967a) published a detailed study of foraminifera of the Alberta foothills. Foraminiferal biostratigraphy and paleoecology of southern Alberta, along the Montana border, was described by Lang and McGugan (1988). Various Albian microfaunal assemblages have been described within the plains of central and northwestern Alberta by Nauss (1947), Bahan (1951), Trollope (1951), Wickenden (1951) and Stelck and Leckie (1990) and biostratigraphic correlations have been made by Stelck (1958), Stelck and Leckie (1990), Bloch *et al.* (1993), and Schröder-Adams *et al.* (1996).

METHODS

This study is based on samples from three wells in northwestern and central Alberta: Imperial Spirit River 12-20-78-6W6, Anglo Home C&E Fort Augustus 7-29-55-21W4, and Amoco B1 Youngstown 6-34-30-8W4 (Figure 3). Picked foraminiferal assemblages were provided by Amoco Canada. The samples obtained represent a composite cross-section through the Albian. Sample intervals in each well cover mainly the shaley sections in the 1226.2 - 581.8 m (Spirit River), 1000 - 652.5 m (Fort Augustus) and 865.0 - 743.7 m (Youngstown) intervals. Formation boundaries were based on industry picks. Little microfossil data is available from the dominantly sandstone intervals. Foraminiferal faunas were identified within and compared between the three wells. Lithologic descriptions were based on core descriptions obtained from the original

geological reports for Spirit River and Fort Augustus, and from Bloch *et al.* (1997) for Youngstown. A gamma ray/sonic log was provided for the Youngstown well, and spontaneous potential/resistivity logs were provided for the Spirit River and Fort Augustus wells. Paleontological data were compared with lithology and wireline log signatures. The results illustrated in this study are based primarily on the foraminiferal data.

Well logs were photocopied on a microfiche reader/photocopier. Photocopies were digitally scanned using Desk Scan ®, and manipulated in Corel Draw 4.0.

Scanning electron micrographs of most identified species were prepared on a JOEL 6400 scanning electron microscope (SEM) at Carleton University Research Facility for Electron Microscopy. Video prints were obtained to aid with identification, and digital images were manipulated using Adobe Photo Shop 3.0 in preparation of the plates.

Taxonomic approach

192 microslides of picked foraminifera were received from Amoco Canada. A total of 38 genera and approximately 93 subgeneric taxa are identified. Whereas identification of genera was possible in most cases, poor preservation of foraminifera due to taphonomic processes such as crushing and fragmentation impeded identification at the species level. Occasionally samples contained well preserved pyritized specimens which were used in conjunction with original descriptions to make identifications. Some figured specimens of other studies did not resemble the original description of the species. In such cases I relied solely on the original description. In cases where there were no well preserved specimens

of a species, backlighting and/or wetting of the specimen appeared helpful. The classification follows Loeblich and Tappan (1987).

Microfossils contained on all 192 slides were identified and counted. Counts were entered into an Excel 5.0 spreadsheet. The species were arranged in order of first appearance, followed by alphabetical order. This information was then used to identify biofacies as well as compare with lithologies and well log signatures. Statistical analysis was not performed due to the lack of control over sample acquisition and picking.

GEOLOGICAL SETTING

The Albian of the Lower Cretaceous was a time of fluctuating sea level (Figure 2). The marine cycles overprinted on the global second order Kiowa-Skull Creek and Greenhorn marine cycles are not global in magnitude. The Early Albian Moosebar/Clearwater and Middle Albian Hulcross seas flooded only a portion of the Interior Seaway (Caldwell, 1984). The Late Albian Joli Fou Seaway, which represented the maximum transgression of the Kiowa-Skull Creek marine cycle, resulted in the connection of the Boreal and Tethys seas (Caldwell, 1984). The latest Late Albian Mowry Sea, intruding from the north, again flooded only a portion of the Western Interior Seaway and did not induce a connection with the Tethys Sea to the south (Williams and Stelck, 1975).

Stratigraphic position and age

The formations covered in this study are characterized in Tables 1 and 2. Stratigraphic positions of the formations are recorded in Figure 4.

<p>1. LOWER SHAFTESBURY FORMATION</p> <p>Uppermost Albian <i>Miliammina manitobensis</i> Zone Agglutinated foraminiferal assemblage Micro-micaceous shale Glaucinitic silt lenses Pyrite nodules Fish remains and algal cysts</p>	<p>5. SPIRIT RIVER FORMATION NOTIKEWIN MEMBER</p> <p>Lower Albian <i>Gaudryina nanushukensis</i> Zone Agglutinated foraminiferal assemblage Medium to coarse grained sandstone Interbedded sandstone-shale Calcareous Carbonaceous matter throughout Kaolinic</p>
<p>2. PEACE RIVER FORMATION PADDY MEMBER</p> <p>Upper Albian <i>Miliammina manitobensis</i> Zone Agglutinated foraminiferal assemblage Shale at base Fine to medium grained sandstone above Pyritic and highly quartzose Kaolinitic towards base</p>	<p>6. SPIRIT RIVER FORMATION FALHER MEMBER</p> <p>Lower Albian <i>Gaudryina nanushukensis</i> Zone Agglutinated and calcareous foraminiferal assemblage Carbonaceous shale interbedded with calcareous sandstone fine to coarse grained Kaolinitic Pyritic material and chert pebbles rare Occasional algal cysts</p>
<p>3. PEACE RIVER FORMATION CADOTTE MEMBER</p> <p>Middle Albian <i>Gaudryina nanushukensis</i> Zone Agglutinated foraminiferal assemblage Fine to medium grained sandstone Kaolinitic Top highly quartzose Some siderite glauconite and carbonaceous fragments towards base</p>	<p>7. SPIRIT RIVER FORMATION WILRICH MEMBER</p> <p>Lower Albian <i>Gaudryina nanushukensis</i> Zone Calcareous and agglutinated foraminiferal assemblage Carbonaceous silty shale Fine sandstone towards top Calcareous Some silt lenses Some kaolinite</p>
<p>4. PEACE RIVER FORMATION HARMON MEMBER</p> <p>Middle Albian <i>Gaudryina nanushukensis</i> Zone Agglutinated foraminiferal assemblage Carbonaceous shale with silty lenses Some pyritic material Coal near the base Occasional algal cysts</p>	<p>8. BLUESKY FORMATION</p> <p>Lowermost Albian <i>Gaudryina nanushukensis</i> Zone Dominantly agglutinated foraminiferal assemblage Fine to medium grained argillaceous sandstone Calcareous Finely disseminated pyritic material and carbonaceous partings Chert pebbles present</p>

Table 1. Characteristics of the Albian Fort St. John Group in northwestern Alberta, this study. Lithologic descriptions after Imperial Oil's Interim Geologic Report (1950). Descriptions are in descending order from 1-8.

<p>1. COLORADO GROUP FISH SCALES FORMATION Albian-Cenomanian boundary Barren of foraminifera Fish remains Abundant algal cysts Laminated claystone to mudstone Basal sandstone/conglomerate Bentonites</p>	<p>5. MANNVILLE GROUP UPPER MANNVILLE FORMATION (UNDIFFERENTIATED) Early Albian <i>Gaudryina nanushukensis</i> Zone Agglutinated and calcareous foraminiferal assemblage Lower 20 m dominantly calcareous shale Carbonaceous sandstone to shale interbedded Common carbonized plant remains</p>
<p>2. COLORADO GROUP WESTGATE FORMATION Late Albian <i>Miliammina manitobensis</i> Zone Agglutinated foraminiferal assemblage Fish remains and algal cysts Laminated claystone to siltstone Non-calcareous</p>	<p>6. MANNVILLE GROUP GLAUCONITIC SANDSTONE FORMATION Early Albian (?)<i>Gaudryina nanushukensis</i> Zone (?)Agglutinated and calcareous foraminiferal assemblage Medium grained sandstone Highly glauconitic Occasional interbedded shale</p>
<p>3. COLORADO GROUP VIKING FORMATION Late Albian <i>Haplophragmoides gigas</i> Zone Agglutinated foraminiferal assemblage Rare fish remains Abundant algal cysts Shale interbedded with fine to medium grained sandstone Glauconitic</p>	<p>7. MANNVILLE GROUP OSTRACODE BEDS (?)Aptian-Early Albian Barren of foraminifera Abundant ostracodes Fish remains Shale, siltstone, sandstone thinly interbedded Calcareous Some carbonaceous material</p>
<p>4. COLORADO GROUP JOLI FOU FORMATION Late Albian <i>Haplophragmoides gigas</i> Zone Agglutinated foraminiferal assemblage <i>Inoceramus</i> hinge lines Occasional fish remains Rare algal cysts Shale Thin bed of bentonite towards top</p>	<p>8. MANNVILLE GROUP ELLERSLIE FORMATION (?)Barremian to Aptian Barren of foraminifera Abundant fish remains Algal cysts Medium to fine grained sandstone interbedded with shale Some siltstone beds</p>

Table 2. Characteristics of the Albian Mannville and Colorado groups, this study. Lithologic descriptions based on the Anglo Canadian Interim Geological Report (1946), information from the Energy Resources Conservation Board, and the Westgate and Fish Scales formation descriptions of Bloch *et al.* (1997). Descriptions are in descending order from 1-8.

Microfloral evidence suggests an Aptian age for the Ellerslie Formation, overlain by the Early Albian Ostracode Beds (Singh 1964). The lower Mannville Group is approximately equivalent to the Bullhead Group which was dated using microfauna (predominantly foraminifera) as Barremian to Early Albian (Chamney, 1973). The Early Albian Bluesky Formation of the Ft. St. John Group correlates to the Glauconitic Sandstone of the Upper Mannville Group (Stott, 1973). Based on foraminiferal assemblages, the Clearwater Formation of the northeastern plains is equivalent to the Wilrich Member of the Spirit River Formation, northwestern plains, and the Upper Mannville (undifferentiated) is correlated to the Falher and Notikewin members of the Spirit River Formation (Caldwell *et al.*, 1978). A diachronous unconformity of regional extent exists above the Mannville Group and within the Peace River Formation (Hayes *et al.*, 1994). The Middle Albian Harmon and Cadotte members of the Peace River Formation have no equivalents in central Alberta. The Upper Albian Joli Fou Formation lies above the unconformity in the central plains, but has no equivalents in the plains of northwestern Alberta. The overlying Viking Formation has been correlated to the Paddy Member of the Peace River Formation (Stelck, 1958; Koke and Stelck, 1984). The correlation of Middle to Upper Albian strata in the WCSB has been the subject of controversy since the 1950's when the Harmon Shale (Middle Albian) was correlated with the Joli Fou Shale (Late Albian) by Workman (1959) but shown to be slightly older by Stelck (1958). Since the Cadotte (overlying the Harmon) carries an ammonite fauna of Middle Albian age whereas the Viking is Late Albian (Stelck and Koke, 1987) this study

adheres to the latest correlations of Stelck and Koke (1987). The recently named Westgate Formation of the central plains correlates with the Shaftesbury Formation which is of latest Albian age (Warren and Stelck, 1969; Bloch *et al.*, 1993).

Foraminiferal zonation

In western Canada, Caldwell *et al.* (1978) recognized three foraminiferal zones within the Albian stage (Figure 2). The *Gaudryina nanushukensis* Zone of Early Albian to early Late Albian age is found throughout northeastern British Columbia, northern and east-central Alberta, and west-central Saskatchewan. Of six subzones, *Trochammina mcmurrayensis*, *Marginulinopsis collinsi-Verneuilinoides cummingensis*, *Haplophragmoides multiplum*, and *Ammobaculites* sp. subzones have been recognized in the Alberta plains and the foothills of northwestern Alberta and northeastern British Columbia, whereas the *Rectobolivina* sp. subzone has been described from northern Alberta, and the *Trochammina mcmurrayensis* subzone has been recognized in northeastern Alberta. The *Ammobaculites wenonahae* subzone (sixth subzone) has only been recognized in northeastern British Columbia (Caldwell *et al.*, 1978). The *Rectobolivina* sp. subzone was described from the basal Loon River Formation on the lower Wabiskaw River (Wall, 1969). It is speculated that the *Trochammina mcmurrayensis* subzone may be present in the lower Wilrich Member of the Spirit River Formation of northwestern Alberta (Caldwell *et al.*, 1978). The *M. collinsi-V. cummingensis* subzone is recognized in the Wilrich, Falher, and Notikewin members of the Spirit River Formation. *Haplophragmoides multiplum* fauna is found in the Harmon

Member and *Ammobaculites* sp. fauna is found in the Cadotte Member, both part of the Peace River Formation. In central Alberta the *Marginulinopsis collinsi-Verneuulinoides cummingensis* subzone is distinguished in the Glauconitic Sandstone and Mannville (undifferentiated) formations, which are partly correlative to the Clearwater Formation of the northeastern plains (Figure 4). The zonal elements were originally described by Nauss (1947), Wickenden (1951), Mellon and Wall (1956), Stelck *et al.* (1956), Tappan (1962), Wall (1967a), and North and Caldwell (1975a).

The *Haplophragmoides gigas* Zone is widespread in western Canada and is found in strata of early Late Albian age from northeastern British Columbia to Manitoba (Caldwell *et al.*, 1978). The zone has its greatest expression in northeastern British Columbia where it has been divided into seven subzones by Stelck and Koke (1987) (Figure 2). *H. gigas* Cushman *sensu stricto* is found only in the lower part of the zone (*H. gigas gigas* subzone) and hence is not found in the Peace River area of northwestern Alberta, where the Joli Fou pinches out (Stelck, 1958). The *H. gigas gigas* and *H. gigas phaseolus* are the only two of the seven subzones recognized east of northeastern British Columbia (Caldwell *et al.*, 1993), and they have been identified in the Joli Fou and Viking formations and their equivalents of Saskatchewan and Manitoba (Guliov, 1967; McNeil and Caldwell, 1981). The zone is not identified in the Viking equivalent Paddy Member of the Peace River Formation in northwestern Alberta. The zonal elements were originally described by Stelck *et al.* (1956), Guliov (1967), North and Caldwell (1975a), Koke and Stelck (1985), Stelck and Koke (1987) and Stelck (1991).

The *Miliammina manitobensis* Zone is the most widespread Albian foraminiferal zone in western Canada and is found from the Rocky Mountain foothills in Alberta and

northeastern British Columbia to the Manitoba escarpment (Caldwell *et al.*, 1978). The *Verneuilina canadensis* subzone is the only one of the three subzones to be identified east of northeastern British Columbia (Caldwell *et al.*, 1978). The entire zone is of late Late Albian age and the *Verneuilina canadensis* subzone is recognized in the Shaftesbury Formation of northwestern Alberta below the Fish Scale Marker (Caldwell *et al.*, 1978), in the Westgate Formation of central Alberta and Saskatchewan (Bloch *et al.*, 1993; Schröder *et al.*, 1996) and in the Westgate Member of the Ashville Formation of Manitoba (McNeil and Caldwell, 1981). The zonal elements were originally described by Wickenden (1932), Wall (1967a), Sutherland and Stelck (1972), Stelck (1975), North and Caldwell (1975a, b) and Stelck and Hedinger (1976).

RESULTS

Foraminiferal faunas found in each well were subdivided into biofacies. Biofacies boundaries were defined on the basis of changes in foraminiferal abundance and taxal composition, and tend to coincide with formation boundaries and preexisting subzonal boundaries. Figured species are marked with an asterisk in the faunal lists on following pages. Most sandstone units were poorly sampled or not sampled at all. Actual foraminiferal counts are listed in appendices 1-3.

Imperial Spirit River Well (12-20-78-6W6)

The Imperial Spirit River well at 12-20-78-6W6 in northwestern Alberta lies on the Peace River Arch (PRA). The PRA is a northeast-trending Precambrian basement feature which is situated in northeastern British Columbia and northwestern Alberta (Stott, 1982; Cant, 1988). It was a structural high during the Paleozoic, but began subsiding during the Mississippian (Stott, 1982; Cant, 1988; O'Connell *et al.*, 1990). Depositional and preservational patterns of sediment overlying the PRA were influenced by subsidence of the Arch during the Cretaceous (Leckie *et al.*, 1990).

LITHOLOGY

The Albian succession at Spirit River (Figure 5) consists of the Bluesky, Spirit River (Wilrich, Falher and Notikewin members), Peace River (Harmon, Cadotte, and Paddy members), and Shaftesbury formations of the Fort St. John Group. The underlying

Gething Formation belongs to the upper Bullhead Group and is pre-Albian. The Gething Formation is dominated by medium grained sandstone. The Bluesky Formation is composed of medium to coarse grained sandstone which fines upward to fine sandstone. The Wilrich Member of the Spirit River Formation is dominated by two coarsening upwards successions of shale to fine or medium sandstone. The Falher Member contains mixed lithologies from shale to medium grained sandstone where sandstone dominates and is overlain by the Notikewin Member of shale and fine- medium grained sandstone. The Harmon Member of the Peace River Formation is a shale unit overlain by fine grained sandstone of the Cadotte Member. The Paddy Member contains shale and fine grained sandstone. The uppermost Shaftesbury consists of silty shale, with some fine beds of silt and fine sandstone. Lithology, wireline log signature, foraminiferal zonation and biofacies of the Spirit River locality are illustrated in Figure 5.

BIOFACIES CHANGES

The lowest sample in the Spirit River well lies within the Gething Formation and is barren of foraminifera. The Bluesky Formation contains biofacies SR1 (Figure 5). The Spirit River Formation is divided into three biofacies; SR2, SR3 and SR4. The stratigraphic boundaries of the members of this formation do not conform with the biofacies boundaries drawn in this study. The Peace River Formation is divided into three biofacies (SR5, SR6, and SR7) which do conform to the member boundaries. Long-ranging species which span the Albian of the Fort St. John Group are: *Ammobaculites fragmentarius* Cushman, *Bathysiphon brosgiei* Tappan, *Haplophragmoides linki* Nauss,

Haplophragmoides yukonensis Chamney, *Psammosphaera* sp. A, *Reophax troyeri* Tappan, and *Saccamina lathrami* Tappan.

Biofacies SR1

The lowest fauna in the sample set (SR1) spans the interval from 1173.7 - 1156.7 m (3851 - 3795 ft) which covers the Bluesky Formation. It is underlain by the Gething Formation. The Bluesky fauna has various elements in common with the *Rectobolivina* sp. subzone of the *Gaudryina nanushukensis* Zone, though the genus *Rectobolivina* is absent from the biofacies. The assemblage is dominated by *Glomospira reata*. The assemblage contains 10 subgeneric taxa which continue into the overlying biofacies (SR2) and one species (*Glomospira reata* Eicher) which is unique to SR1. The fauna of SR1 contains agglutinated and calcareous foraminifera. Foraminiferal abundances within samples representing SR1 range from about 35 to 250. Absolute counts of foraminiferal specimens are recorded in Appendix 1. The common and abundant taxa are listed below.

Ammödiscus rotalarius Loeblich and Tappan, 1949
 **Bathysiphon brosgiei* Tappan, 1957
Gaudryina tailleuri (Tappan), 1957
 **Glomospira reata* Eicher, 1960
 **Haplophragmoides yukonensis* Chamney, 1978
Hippocrepina barksdalei (Tappan), 1957
Psammosphaera sp. A
 **Textularia topagorukensis* Tappan, 1957
Verneuilinoides borealis Tappan, 1957

Biofacies SR2

The SR2 biofacies spans the interval from 1145.1 - 1111.6 m (3757 - 3664 ft) which covers the lower Wilrich Member of the Spirit River Formation. The Wilrich fauna

has various elements in common with the *Trochammina mcmurrayensis* subzone of the *Gaudryina nanushukensis* Zone. The assemblage is dominated by *Hyperammina strombotubulare*. SR2 contains 17 subgeneric taxa which continue into the overlying biofacies (SR3) and one species (*Trochammina mcmurrayensis* Mellon and Wall) which is unique to SR2. *T. mcmurrayensis* also serves as a subzonal marker of the lower Wilrich Member. The fauna of SR2 contains agglutinated and calcareous foraminifera and one distinct cycle of fluctuating foraminiferal abundance is observed which begins near the base of the Spirit River Formation. Foraminiferal abundances within samples representing SR2 range from about 10 to 165. The common and abundant taxa are listed below.

Bathysiphon brosgiei Tappan, 1957
Haplophragmoides linki Nauss, 1947
Haplophragmoides yukonensis Chamney, 1978
Hippocrepina barksdalei (Tappan), 1957
Hyperammina emacerata (Chamney), 1978
Hyperammina strombotubulare (Chamney), 1978
 **Quadriformina albertensis* Mellon and Wall, 1956
Trochammina sp. cf. *T. mcmurrayensis* Mellon and Wall, 1956

Biofacies SR3

The Spirit River Formation (above SR1) contains species of the *M. collinsi-V. cummingensis* subzone of the *G. nanushukensis* Zone. SR3 is defined between 1108.2 and 954.9 m (3636 - 3133 ft). The assemblage contains calcareous and agglutinated foraminifera and is recognized in the upper Wilrich and lower Falher members of the Spirit River Formation. SR3 is dominated by *Ammodiscus rotalarius* and *Haplophragmoides yukonensis*. The assemblage consists of 25 genera and 41 subgeneric taxa of which 14 longer ranging species continue into the overlying SR4 biofacies (upper Falher and

Notikewin members). Within SR3, six distinct cycles with increasing foraminiferal abundances ranging from a few to a few hundred specimens are observed over intervals of 5 to 20 m. The common and abundant taxa are listed below.

Ammobaculites fragmentarius Cushman, 1927a
Ammobaculites tyrrelli Nauss, 1947
 **Ammodiscus rotalarius* Loeblich and Tappan, 1950
 **Bathysiphon brosgiei* Tappan, 1957
 **Discorbis norrisi* Mellon and Wall, 1956
 **Gaudryina nanushukensis* Tappan, 1951
 **Globulina lacrima* Reuss ssp. *canadensis* Mellon and Wall, 1956
 **Gyroidina* sp. cf. *G. nitidi* (Reuss), 1844
Haplophragmoides sp. cf. *H. kirki* Wickenden, 1932
Haplophragmoides topagorukensis Tappan, 1957
Haplophragmoides uniorbis Eicher, 1960
 **Hippocrepina barksdalei* (Tappan), 1957
Hyperammina strombotubulare (Chamney), 1978
Miliammina subelliptica Mellon and Wall, 1956
Psammosphaera sp. A
Reophax deckeri Tappan, 1943
Reophax sikanniensis Stelck, 1975
Reophax troyeri Tappan, 1960
 **Saccamina globosa* Crespin, 1963
Saccamina lathrami Tappan, 1960
Textulariopsis minuta (Berthelin), 1880

Biofacies SR4

The SR4 fauna recognized in the Spirit River well is considered to be the dominantly agglutinated upper biofacies of the *M. collinsi*-*V. cummingensis* subzone (Caldwell *et al.*, 1978). It is found in the upper Falher and Notikewin members from 954.1 to 841.5 m (3130 - 2761 ft) and is based on the abundance of *Haplophragmoides gigas minor* throughout this interval. This assemblage is dominated by the genus *Haplophragmoides*. SR4 consists of 14 genera and 25 subgeneric taxa of which seven longer ranging species continue into the overlying biofacies (SR5) in the Harmon Member

of the Peace River Formation. Within SR4, three distinct cycles of increasing and decreasing foraminiferal abundances ranging from barren to 165 specimens are observed over intervals of 30 to 45 m. The common and abundant taxa are listed below.

Ammobaculites tyrrelli Nauss, 1947
Arenobulimina paynei Tappan, 1957
Discorbis sp. A
Gaudryina nanushukensis Tappan, 1951
Gravellina chamneyi Stelck, 1975
Haplophragmoides gigas Cushman ssp. *minor* Nauss, 1947
 **Haplophragmoides linki* Nauss, 1947
Haplophragmoides postis Stelck and Wall, 1956, in Stelck et al., 1956
 **Haplophragmoides yukonensis* Chamney, 1978
Haplophragmoides uniorbis Eicher, 1960
Lenticulina sp. A
 **Miliammina awunensis* Tappan, 1957
Miliammina manitobensis Wickenden, 1932
Reophax sikanniensis Stelck, 1975
Saccamina alexanderi (Loeblich and Tappan), 1950
Saccamina globosa Crespin, 1963
Textulariopsis minuta (Berthelin), 1880
Trochammina sp. cf. *T. depressa* Lozo, 1944
Trochammina sp. cf. *T. umiatensis* Tappan, 1957

Biofacies SR5

Biofacies SR5 spans the interval between 816.8 and 800.0 m (2680 - 2625 ft) and lies entirely within the Harmon Member of the Peace River Formation. This entirely agglutinated assemblage reflects the *Haplophragmoides multiplum* subzone of the *G. nanushukensis* Zone (Figure 2). SR5 is dominated by *H. gigas minor* and *H. postis*. SR5 consists of seven genera and 11 subgeneric taxa and is represented by three samples. Only one genus (*Haplophragmoides*) ranges into the overlying Cadotte Member. Foraminiferal abundance is moderately high ranging approximately from a few to 200 specimens. The common and abundant species of SR5 are listed below.

Haplophragmoides gigas Cushman ssp. *minor* Nauss, 1947
Haplophragmoides multiplum Stelck and Wall, 1956, in Stelck et al., 1956
Haplophragmoides postis Stelck and Wall, 1956, in Stelck et al., 1956

Biofacies SR6

The boundary between the Harmon and overlying Cadotte members is marked by a significant reduction in diversity. The sixth fauna (SR6) lies within the Cadotte Member of the Peace River Formation from 795.5 - 772.6 m (2610 - 2535 ft) and is represented by four samples. The fauna found in the Cadotte Member typically belongs to the *Ammobaculites* sp. subzone of the *G. nanushukensis* Zone (Figure 2) (Caldwell *et al.*, 1978). In the studied wells the lower portion contains only various unidentifiable *Haplophragmoides* species with moderate abundances of <100. The upper samples are barren of foraminifera.

Biofacies SR7

The seventh fauna (SR7) at the Imperial Spirit River locality lies within the Paddy Member of the Peace River Formation and is almost devoid of foraminifera. The Paddy Member in this study contains fauna from the *Verneuilina canadensis* subzone of the *M. manitobensis* Zone. All taxa found here range into the overlying Shaftesbury Formation (*M. manitobensis* Zone). There are two samples spanning the interval from 749.8 - 737.6 m (2460 - 2420 ft) which contain three genera and five species. All species are represented by singular occurrences.

Haplophragmoides gigas Cushman ssp. *minor* Nauss, 1947
Haplophragmoides postis Stelck and Wall, 1956, in Stelck et al., 1956
Haplophragmoides sp.

Psammosphaera sp. A
Saccamina sp.

Biofacies SR8

The uppermost fauna (SR8) is associated with the lower Shaftesbury Formation underlying the Fish Scale Marker and contains the highest abundance and species diversity in this well, though it is composed exclusively of agglutinated foraminifera. SR8 spans the interval between 728.4 and 605.9 m (2390 - 1988 ft). The Shaftesbury Formation typically contains the *V. canadensis* subzone (Caldwell *et al.*, 1978). SR8 can be divided into two faunules on the basis of subtle changes in species composition. In the lower faunule *Ammobaculites fragmentarius* dominates whereas in the upper faunule *Miliammina manitobensis* and *Reophax vasiformis* become the dominant taxa. Most samples contain >200 specimens, though a high proportion (up to 50%) are broken or deformed to the extent that they cannot be placed into genera with confidence. The abundance peaks at 550 (plus 442 fragments) specimens/sample in the 705.3-708.3m (2314-2324 ft) sample. The overlying Fish Scales Marker bed is barren of foraminifera. The SR8 biofacies consists of 19 genera and 47 species of which the common and abundant species are listed below.

**Ammobaculites fragmentarius* Cushman, 1927a
 **Ammobaculites petilus* Eicher, 1960
 **Ammobaculites tyrrelli* Nauss, 1947
 **Ammobaculites wenonahae* Tappan, 1960
 **Ammomarginulina cragini* Loeblich and Tappan, 1950
Bathysiphon brosgel Tappan, 1957
 **Gaudryina canadensis* Cushman, 1943
 **Gravellina chamneyi* Stelck, 1975
 **Haplophragmoides gilberti* Eicher, 1965
 **Haplophragmoides postis* Stelck and Wall, 1956, in Stelck et al., 1956
Haplophragmoides postis Stelck and Wall

ssp. *goodrichi* Sutherland and Stelck, 1972
Haplophragmoides yukonensis Chamney, 1978
 **Miliammina manitobensis* Wickenden, 1932
Psammosphaera sp. A
 **Reophax deckeri* Tappan, 1943
 **Reophax sikanniensis* Stelck, 1975
 **Reophax troyeri* Tappan, 1960
Reophax tundraensis Chamney, 1969
Reophax vasiformis Chamney, 1978
Saccammina alexanderi (Loeblich and Tappan), 1950
Saccammina globosa Crespin, 1963
Trochammina alcanensis Stelck, 1975
Trochammina gatensis Stelck and Wall, 1956, in Stelck et al., 1956
Trochammina rainwateri Cushman and Applin, 1946
 **Trochammina rutherfordi* Stelck and Wall, 1955
 **Verneuilina canadensis* Cushman, 1927a

Anglo Home C&E Fort Augustus Well (7-29-55-21W4)

LITHOLOGY

The Albian succession at Fort Augustus (Figure 6) consists of the Ellerslie, Ostracode Beds, Glauconitic, and Upper Mannville (undifferentiated) formations of the Mannville Group and the Joli Fou, Viking, and Westgate formations of the lower Colorado Group. The Ellerslie Formation contains a mixed lithology of shale to fine grained sandstone, with sandstone being dominant. The Ostracode Beds consist primarily of shale and are overlain by the Glauconitic Formation dominated by fine to medium grained sandstone with minor shale. The overlying Mannville (undifferentiated) Formation consists of mixed beds of shale to medium grained sandstone. The Joli Fou Formation is dominantly shale, whereas in the overlying Viking Formation shale is interrupted by some thin beds of silt and fine sandstone. The uppermost Westgate Formation is dominantly

shale. Lithology, wireline log signatures, foraminiferal zonation and biofacies are illustrated in Figure 6.

BIOFACIES CHANGES

The Ellerslie Formation underlying the Ostracode Beds is barren of foraminifera. The Glauconitic sandstone was not sampled. *Saccammina globosa* is the sole species to range throughout the foraminifera-bearing formations in this well.

Biofacies FA1

The lowermost biofacies encountered in the Ft. Augustus well (FA1) consists exclusively of fish remains and Ostracodes and is found within the Ostracode Beds of the Mannville Group between 914.7 and 895.5 m (3001 - 2938 ft). No taxonomic identification was performed on the Ostracodes.

Biofacies FA2

The lower Upper Mannville Formation is occupied by the *M. collinsi* - *V. cummingensis* subzone of the *G. nanushukensis*

Figure 6. Lithology, biostratigraphy, and environmental changes of the Mannville and lower Colorado Groups in central Alberta at 7-29-55-21W4. Lithologic descriptions based on Anglo Home Oil Company (1946).

located in the interval from 877.2 - 858.0 m (2878 - 2815 ft). FA2 is dominated by *Haplophragmoides gigas minor* and *Miliammina ischnia*. FA2 consists of 12 genera and 22 subgeneric taxa of which 14 taxa range into the overlying FA3 biofacies. The overall abundance of foraminifera is moderate, ranging from about 25 to 95 specimens per sample. Common and abundant taxa are listed below. Absolute counts of specimens per sample are recorded in Appendix 2.

Gaudryina nanushukensis Tappan, 1951
 **Haplophragmoides gigas* Cushman ssp. *minor* Nauss, 1947
 **Haplophragmoides linki* Nauss, 1947
Haplophragmoides yukonensis Chamney, 1978
Miliammina awunensis Tappan, 1957
Miliammina inflata Eicher, 1960
Miliammina ischnia Tappan, 1957
Miliammina manitobensis Wickenden, 1932
Miliammina subelliptica Mellon and Wall, 1956
Pseudonodosaria clearwaterensis Mellon and Wall, 1956
Reophax sp. A
Reophax sp. B

Biofacies FA3

Faunal trends of the third biofacies are discontinuous and inconsistent spanning the interval from 836.0 - 819.6 m (2743 - 2689 ft). The sandstone unit between FA2 and FA3 was not sampled (Figure 6). Contiguous samples contain vastly dissimilar diversities and abundances (changes from 0 to >100 specimens). FA3 differs from FA2 by the disappearance of calcareous taxa and the appearance of agglutinated species such as *Ammobaculites tyrrelli*, *Ammodiscus rotalarius*, *Arenobulimina paynei*, *Gaudryina canadensis*, *G. tailleuri*, *Psamminopelta bowsheri*, *P. subcircularis*, *Textulariopsis minuta* and *Verneulinoides borealis*. FA3 consists of 12 genera and 24 species of which

only *Saccamina globosa*, *G. canadensis* and *G. tailleuri* range into the overlying Joli Fou fauna (FA4). The overall abundance ranges from barren to >100 specimens per sample. Common and abundant species are listed below of which no species appears to be particularly dominant.

Gaudryina tailleuri (Tappan), 1957
Haplophragmoides gigas Cushman ssp. *minor* Nauss, 1947
Haplophragmoides linki Nauss, 1947
Haplophragmoides topagorukensis Tappan, 1957
Miliammina ischnia Tappan, 1957

The upper section of the Upper Mannville (undifferentiated) consists of dominantly sandstone and was not sampled for microfossils (Figure 6).

Biofacies FA4

Biofacies FA4 corresponds with the lower part of the Joli Fou Formation and is composed exclusively of agglutinated foraminifera. It occurs within the interval from 741.5 - 733.6 m (2433 - 2407 ft). The Joli Fou Formation typically contains species of the *H. gigas* Zone (Caldwell *et al.*, 1978), and in this study FA4 include taxa from the *H. gigas gigas* subzone. This subzone is dominated by the genus *Gaudryina*. The boundary between *H. gigas gigas* and the overlying *H. gigas phaseolus* subzone occurs at the disappearance of *H. gigas (sensu stricto)*. The subtle changes between FA4 and FA5 compare with the Guliov (1967) and North and Caldwell (1975b) studies in that *Ammobaculites petilus*, *Ammomarginulina asperata* and *H. gigas* (large) occur in the *H. gigas gigas* subzone but do not range into the overlying *H. gigas phaseolus* subzone

(FA5). FA4 consists of 11 genera and 19 subgeneric taxa of which 9 taxa range into the overlying *H. gigas phaseolus* subzone. Total foraminiferal numbers per sample vary between 175 and 300. Common and abundant species are listed below.

Ammobaculites tyrrelli Nauss, 1947
Ammomarginulina asperata Gulio, 1966
Gaudryina sp. A
Gaudryina canadensis Cushman, 1943
 **Gaudryina tailleuri* (Tappan), 1957
Haplophragmoides sp. A
Haplophragmoides gigas gigas Cushman, 1927a
Haplophragmoides gilberti Eicher, 1965
Haplophragmoides yukonensis Chamney, 1978

Biofacies FA5

Biofacies FA5 corresponds with the upper part of the Joli Fou Formation and is composed exclusively of agglutinated foraminifera. It occurs within the interval from 733.6 - 726.6 m (2407 - 2375 ft). In this study FA5 include taxa from the *H. gigas phaseolus* subzone. This subzone is dominated by the genus *Gaudryina*. The boundary between the Joli Fou and Viking faunas is characterized by a horizon of rare algal cysts. FA5 consists of seven genera and nine subgeneric taxa of which four taxa range into the overlying Viking Formation (FA6 biofacies). Total foraminiferal numbers per sample vary between 200 and 350. Common and abundant species are listed below.

Ammobaculites tyrrelli Nauss, 1947
Gaudryina canadensis Cushman, 1943
Gaudryina tailleuri (Tappan), 1957
Haplophragmoides gigas phaseolus Skolnick, 1958
 **Haplophragmoides gilberti* Eicher, 1965
Haplophragmoides yukonensis Chamney, 1978

Biofacies FA6

Biofacies FA6 corresponds to the Viking Formation and is also composed exclusively of agglutinated foraminifera. FA6 occurs in the interval from 723.9 - 701.9 m (2375 - 2303 ft). The upper four subzones of the *H. gigas* Zone (Figure 2) contain the faunas of the Viking Formation equivalents (Caldwell *et al.*, 1993). FA6 may belong to the *Reophax troyeri* subzone though it is missing several species found in abundance in northeastern British Columbia (Stelck and Koke, 1987). FA6 differs from FA5 by the reappearance of *Bathysiphon brosgiei* and *Gravellina chamneyi*, the appearance of *Miliammina ischnia*, *M. manitobensis*, and *Trochammina gatensis* and the disappearance of *Gaudryina canadensis*, *G. tailleuri*, *Haplophragmoides gilberti* and *H. yukonensis*. FA6 is dominated by *Gravellina chamneyi*. Above the Viking Formation lies a horizon of abundant fish remains and algal cysts. FA6 consists of 15 genera and 23 subgeneric taxa of which 15 taxa range into the overlying Westgate Formation (biofacies FA7). The Viking fauna has substantially more similarity with the overlying Westgate fauna than with the underlying Joli Fou fauna. Foraminiferal abundances range from a few to >200 specimens per sample. Common and abundant taxa are listed below.

Bathysiphon brosgiei Tappan, 1957
Gaudryina sp. A
Gravellina chamneyi Stelck, 1975
Haplophragmoides sp.
Psammosphaera sp. A
Reophax sp.
Saccammina lathrami Tappan, 1960
Textulariopsis minuta (Berthelin), 1880
Trochammina sp. A

Biofacies FA7

Biofacies FA7 reflects the *V. canadensis* subzone of the *M. manitobensis* Zone and is found within the Westgate Formation. This agglutinated assemblage is characterized by the highest species diversity within the Ft. Augustus well and is found in the interval between 699.2 and 652.5 m (2294 - 2141 ft). FA7 differs from FA6 by the disappearance of *Ammomarginulina asperata* and the appearance of *Ammobaculites pacalis pattersoni*, *Trochammina alcanensis*, *T. rainwateri* and *Verneuilina canadensis*. FA7 is dominated by *Miliammina manitobensis*. This assemblage consists of 17 genera and 38 species. Overall foraminiferal abundances range from 10 to 260 specimens per sample. Common and abundant species are listed below.

- Ammobaculites* sp. A
- Ammobaculites fragmentarius* Cushman, 1927a
- Ammobaculites pacalis* Stelck and Wall ssp. *pattersoni* Sutherland and Stelck, 1972
- Ammobaculites tyrrelli* Nauss, 1947
- Ammomarginulina cragini* Loeblich and Tappan, 1950
- Bathysiphon brosgiei* Tappan, 1957
- Gaudryina* sp. A
- **Gaudryina canadensis* Cushman, 1943
- **Gravellina chamneyi* Stelck, 1975
- Haplophragmoides postis* Stelck and Wall ssp. *goodrichi* Sutherland and Stelck, 1972
- Hippocrepina* sp. A
- Miliammina inflata* Eicher, 1960
- Miliammina ischnia* Tappan, 1957
- Miliammina manitobensis* Wickenden, 1932
- **Psammosphaera* sp. A
- Reophax sikanniensis* Stelck, 1975
- Reophax vasiformis* Chamney, 1978
- Textulariopsis minuta* (Berthelin), 1880
- **Trochammina alcanensis* Stelck, 1975
- Trochammina gatensis* Stelck and Wall, 1956, in Stelck et al., 1956
- Verneuilina canadensis* Cushman, 1927a

Amoco B1 Youngstown Well (6-34-30-8W4)

LITHOLOGY

The Albian succession at Youngstown (Figure 7) represented in micropaleontological samples, includes the Joli Fou, Viking, and Westgate formations. A lithologic description for the Joli Fou was not available. Gamma ray log signatures indicate a dominantly shaley succession. The Viking Formation consists predominantly of shale interbedded with silt and fine grained sandstone. The Westgate Formation contains primarily a finely interbedded silty shale and siltstone with a few medium grained sandstone beds. Lithology, wireline log signature, foraminiferal zonation and biofacies are illustrated in Figure 7.

BIOFACIES CHANGES

In the Youngstown well the sampled interval spans the upper part of the Joli Fou Formation and the Viking and Westgate formations. The *H. gigas* Zone is found in the Joli Fou and Viking formations and is subdivided into two biofacies based on subtle faunal differences (Figure 7).

Biofacies YT1

The lowest assemblage in this well (YT1) overlies the Mannville-Joli Fou unconformity and lies within the interval from 865 - 862 m (2840 - 2830 ft). The fauna contained within the Joli Fou and Viking formations exhibits a moderately diverse assemblage with a subtle shift of biofacies between the Joli Fou and Viking formations.

Figure 7. Lithology, biostratigraphy, and environmental changes of the Mannville and lower Colorado groups in central Alberta at 6-34-30-8W4. Lithologic descriptions courtesy of the Energy Resource Conservation Board. Descriptions of Westgate and Fish Scales formations after Bloch *et al.* (1993). X in lithology column represents missing core descriptions.

There are no dominant foraminifera species, though typical species include *Textulariopsis minuta* and *Gaudryina canadensis*. YT1 consists of 5 genera and 5 subgeneric taxa of which 2 taxa range into the overlying YT2 biofacies (Viking Formation). Abundance is low with a range of 20 to 30 specimens per sample. Absolute foraminiferal counts of specimens per sample are recorded in Appendix 3. The only common species is *Textulariopsis minuta* (Berthelin).

Biofacies YT2

Biofacies YT2 lies within the Viking Formation in the interval from 858 - 816 m (2818 - 2680 ft). *M. manitobensis* is the only common species. Other typical species include *Hippocrepina barksdalei*, *Miliammina ischnia*, *Miliammina manitobensis* and *Psammosphaera* sp. A. With respect to YT1, YT2 exhibits a decrease in *Gravellina*, *Gaudryina*, *Haplophragmoides*, *Textulariopsis* and *Trochammina*. *Ammobaculites* abundances remains roughly the same throughout this interval and there are increases in *Bathysiphon*, *Miliammina*, *Psammosphaera* and *Reophax*. *Trochammina gatensis* appears briefly near the base of the Viking. YT2 consists of 12 genera and 20 subgeneric taxa of which 17 taxa range into the overlying YT3 biofacies. Abundances are low with a range of 5 to 45 specimens per sample. Common and abundant species are listed below.

M. ischnia Tappan, 1957

M. manitobensis Wickenden, 1932

Psammosphaera sp. A

Biofacies YT3

Biofacies YT3 in the Youngstown well corresponds to the Westgate Formation in the interval from 813 - 768 m (2670 - 2520 ft). YT3 is dominated by *M. manitobensis* and towards the top by *Textulariopsis minuta* as well. This assemblage belongs to the *V. canadensis* subzone of the *M. manitobensis* Zone. YT3 differs from the underlying Viking fauna by the introduction of *Psamminopelta bowsheri*, *P. subcircularis*, *Trochammina bredini* and *V. canadensis*. The Westgate fauna consists of 16 genera and 33 species. Overall foraminiferal abundances range from a few to about 200 specimens per sample. All species disappear at the boundary of the overlying Fish Scales Formation which is barren of foraminifera. Common and abundant species are listed below.

Bathysiphon brosgei Tappan, 1957
Gaudryina canadensis Cushman, 1943
Gravellina chamneyi Stelck, 1975
Miliammina manitobensis Wickenden, 1932
Psammosphaera sp. A
Textulariopsis minuta (Berthelin), 1880
Verneuilina canadensis Cushman, 1927a

DISCUSSION

Foraminiferal response to sea level change

The Albian succession in the WCSB represents sedimentation of the global Kiowa-Skull Creek and Greenhorn marine cycles (so named in North America only (Kauffman, 1977)). These cycles were overprinted by higher frequency sea-level changes (Caldwell, 1984). A late Aptian sea-level lowstand was followed by a period of sea level rise during the Early Albian (Koke and Stelck, 1984) forming an embayment of the boreal sea which extended as far south as Peace River (Stott, 1984). This time is reflected in the non-marine sediments of the Gething Formation and the lower part of the Bluesky Formation at 12-20-78-6W6 and the Ellerslie Formation at 7-29-55-21W4. These intervals are barren of foraminifera. Later in the Early Albian boreal waters penetrated as far as southern Alberta forming the Moosebar/Clearwater Sea which deposited the shales of the Wilrich Member of the Spirit River Formation in northwestern Alberta and the Upper Mannville Formation (undifferentiated) in central Alberta (Figure 4) (Koke and Stelck, 1984). The Falher and Notikewin members of the Spirit River Formation record the retreat of the Moosebar/Clearwater Sea. Following this retreat, the Boreal Sea again advanced upon the WCSB forming the Hulcross Sea and depositing the shales of the Harmon Member and the sandstones of the Cadotte Member of the Peace River Formation in northwestern Alberta (Caldwell, 1984). Strata recording the sea-level history of the Middle Albian Hulcross Sea are missing in much of the WCSB due to a large regional unconformity. During the early Late Albian the Kiowa-Skull Creek cycle reached sea-level highstand resulting in the Joli Fou Seaway which connected the Boreal and Tethys seas for a brief

time. The connection was made at approximately the position of southern Colorado today. It is recorded in the strata of central Alberta as the Joli Fou Formation, but is missing in northwestern Alberta due to an unconformity (Figure 4). The Joli Fou Seaway was terminated by a major shallowing event depositing the sandstone-rich Viking Formation, reflecting a series of sea-level lowstands (Beaumont, 1984; Leckie, 1986; Reinson *et al.*, 1988). Near the end of the Early Cretaceous, in the latest Late Albian, the Boreal Sea began to advance once more forming the Mowry Sea and depositing the shales of the lower Shaftesbury Formation in northwestern Alberta and the Westgate Formation of central Alberta. This transgression marks the beginning of Kauffman's global Greenhorn marine cycle (Caldwell, 1984).

THE MOOSEBAR/CLEARWATER SEA

The foraminiferal fauna of the Bluesky/lower Spirit River formations reflect the shift from sandstone to shale with an increase in abundance, and a slight decrease in diversity (Figure 5). Abundance decreases within the Wilrich shale coinciding with deposition of slightly coarser sediment (Figure 5, biofacies SR2). The presence of calcareous taxa implies that the waters were not acidic, and that diagenetic effects were not sufficient to destroy the fossil record of calcareous foraminifera. There appears to be some cyclicity associated with the foraminiferal abundance. The cycles of waxing and waning overall abundance exhibited in the Spirit River Formation and throughout the strata at 12-20-78-6W6 (SR2, SR3, SR4 and SR8 biofacies) coincide with subtle lithologic changes and may indicate response to sea level change (Figure 5, biofacies SR4)

or a response to increased sedimentation rates. The SR4 biofacies of the upper Falher and Notikewin members begins with increasing foraminiferal abundance and diversity which tapers off towards the top of the Falher Member. The increases in abundance and diversity occur in fine grained lithologies which probably mark flooding surfaces according to the sequence stratigraphic definition (Van Wagoner *et al.*, 1988), though the highest abundances and diversities typically occur somewhat above these marine flooding surfaces and may represent maximum flooding surfaces. The low faunal abundance which occurs between these maximum flooding surfaces is accompanied by coarsening-upwards lithofacies (Figure 5).

The change from an open marine environment to a more restricted is expressed in the upper Falher-Notikewin fauna as the appearance of various *Haplophragmoides*, *Miliammina* and *Trochammina* species and the disappearance of most of the calcareous taxa. The Wilrich-lower Falher fauna represents an off-shore, open marine environment of the transgressive boreal sea, while the upper Falher-Notikewin fauna represents more restricted marginal-marine conditions during the regression of the Moosebar/Clearwater Sea (Caldwell *et al.*, 1978).

The Bluesky-lower Wilrich fauna (biofacies SR1) does not have a correlative fauna in central Alberta. The cyclicity observed in the faunas of the Spirit River well is also present at Fort Augustus in the Upper Mannville Formation (Figure 6, biofacies FA2). The high diversity of this biofacies indicates a favorable environment and the presence of calcareous taxa implies that the waters were not acidic.

In the fauna of the upper Upper Mannville the samples reflect more rapidly changing sedimentary facies. Over 13.4 (54 ft) m the lithology varies between shale and medium grained sandstone and foraminiferal abundances range from barren to moderately abundant (Figure 6 biofacies FA3, and appendix 2).

The faunas of the upper Wilrich-lower Falher and basal Upper Mannville (SR3 and FA2) are correlative, as are the upper Falher-Notikewin and upper Upper Mannville (SR4 and FA3) biofacies. The SR4 biofacies exhibits a cyclicity in overall abundance (Figure 5), which is not reflected by the FA3 biofacies (probably due to the lower sedimentation rates found in the distal portions of the basin). Despite the similarities between the Upper Mannville fauna in central Alberta and the Spirit River (Fm.) fauna in northwestern Alberta, it is difficult to make faunal comparisons over such distances due to facies-related faunal changes.

The initial transgression of the Moosebar/Clearwater Sea was interrupted by a series of regressive pulses which deposited the Bluesky Formation (O'Connell, 1988; Jackson, 1984). The Wilrich Member of the Spirit River Formation records the maximum transgression (Caldwell, 1984), and the withdrawal of the Moosebar/Clearwater Sea from the plains is recorded in the Falher and Notikewin members of the Spirit River Formation (McLean and Wall, 1981; Stott, 1982; MacDonald *et al.*, 1988).

THE HULCROSS SEA

There are no time equivalent strata to the Hulcross Sea to the east of northwestern Alberta. At 12-20-78-6W6 the Hulcross transgressive/regressive cycle resulted in the deposition of the Harmon and Cadotte members of the Peace River Formation.

The bottom of the Harmon Member (flooding surface) is marked by low foraminiferal abundance which increases and peaks (maximum flooding surface) about 10 m below the Cadotte Member before decreasing again (Figure 5, biofacies SR5). A low diversity species composition of robust, sturdy agglutinated foraminifera suggest a shallow, relatively high energy environment.

The overlying Cadotte fauna consists of one genus before becoming completely barren of foraminifera (Figure 5, biofacies SR6). The carbonaceous fragments (Table 1) and lack of foraminifera in the upper Cadotte Member supports the interpretation of this member as a regressive shoreline sequence (Rahmani and Smith, 1988). The Cadotte Member is located mainly on the Peace River Arch (Rahmani and Smith, 1988). It was deposited as an offshore to shoreline succession (Smith *et al.*, 1984). A thin coal caps the shoreline deposits and roots are present locally indicating a continental or marginal marine environment (Leckie, 1988; Rahmani and Smith, 1988; Leckie *et al.*, 1990). In northwestern Alberta the top of the Cadotte was subaerially exposed, truncated and incised by valleys leaving an unconformable surface between Cadotte and Paddy sediments (Leckie and Reinson, 1993).

THE JOLI FOU SEAWAY

The foraminiferal assemblage of the Joli Fou Formation at 7-29-55-21W4 is characterized by relatively high abundances and diversity indicating fully marine conditions (Figure 6). The dominance of benthic foraminifera suggests oxygenated bottom conditions, but the total lack of calcareous foraminifera is puzzling. A cycle of foraminiferal abundance in the Viking Formation is closely aligned with lithologic changes with the highest abundance accompanying the finest grained lithologies. Reduced salinities are indicated by a significant increase in the genus *Trochammina*.

Faunal results at 6-34-30-8W4 differ from the well further north. Foraminiferal abundances remain low throughout the Joli Fou and Viking formations but the diversity fluctuates substantially (Figure 7, biofacies YT1 and YT2, Figure 8). The change to an assemblage with more robust genera in the Viking indicates higher energy environments probably accompanied by lower salinities. This is supported by the lithology and gamma ray wireline signature which indicates that the Viking contains a much higher proportion of silt and fine sand. According to the low abundances seen throughout the Youngstown faunas, the water at this locality was not deep during the Late Albian. The Joli Fou Formation marks the time of sea-level highstand of the Kiowa-Skull Creek marine cycle and the initial connection of the Boreal and Tethyan seas. The connection was terminated by a series of sea-level lowstands resulting in deposition of the Viking Formation and its equivalents (Paddy) (Leckie and Smith, 1992).

The foraminiferal fauna of the Paddy Member of the Peace River Formation at Spirit River appears to be a reduced version of the overlying *Verneuilina canadensis*

subzone (Figure 9). However it lacks the diagnostic foraminifera of that subzone. In northwestern Alberta (near the town of Peace River) the Paddy Member represents a deepening event (Leckie and Reinson, 1993). A paleoestuary which resulted in Paddy sedimentation stretched from the estuary mouth north of Peace River to the paleo-bayline, east of the Alberta British Columbia border (Leckie and Singh, 1991; Zaitlin *et al.*, 1994). Paleosols developed between the tributaries until they were inundated by the transgressive estuarine sediments (Zaitlin *et al.*, 1994; Leckie *et al.*, 1989). As the sea level continued to rise, estuarine conditions gave way to a shallow bay environment (Zaitlin *et al.*, 1994). Based upon the foraminiferal content of the Cadotte and overlying Paddy members, the Spirit River locality possibly represented a position along the edge of the paleoestuary or one of its tributaries. The exact stratigraphic position of the Paddy Member of the Peace River Formation is still under debate (Stelck and Leckie, 1990).

THE MOWRY SEA

The lower Shaftesbury fauna is characterized by a rapidly expanding fauna forming the most abundant and diverse fauna in any of the wells (Figure 5, biofacies SR8). Foraminiferal abundance peaks near 1000 specimens per sample (Figure 5) (including a substantial proportion of fragments - Appendix 1). The tremendous abundance of foraminifera indicate that bottom waters were well oxygenated, though perhaps with reduced salinity (Stelck, 1975). The generally decreasing abundance towards the top of the Shaftesbury Formation, coupled with increasing fish remains may suggest that the bottom waters of this area were becoming dysoxic, heralding the anoxic conditions of the

Fish Scales Marker Beds (Leckie *et al.*, 1992). The decrease in abundance is accompanied by a shift in generic composition (Figure 9) which indicates decreasing salinity. Dominance of *Ammobaculites* has been interpreted as evidence of reduced salinity and shallow water (Stelck, 1975; Bandy and Arnal, 1960). The same trend in *Ammobaculites* is observed at Spirit River.

The Westgate Formation at Fort Augustus is substantially thinner than the correlative Shaftesbury (Figure 9) indicating that sedimentation rates were lower in distal regions of the basin. Changes in generic composition are not as pronounced as they are in the Spirit River well (Figure 9). The rich foraminiferal abundance observed in the Shaftesbury Formation is not duplicated in the upper Westgate Formation at Fort Augustus (Figure 6). This may also be a result of reduced oxygen.

The Westgate Formation at Youngstown has approximately the same thickness as Fort Augustus and the generic composition alters very little throughout this formation (Figure 9). The foraminiferal abundance exhibits a very different trend from that seen above. At Youngstown the general trend in abundance is an increase throughout the formation which ends abruptly (with the disappearance of all foraminifera) at the Fish Scales Formation. The increasing abundances of both *Gravellina* and *Textularia* in YT3 appear to indicate shallowing, though according to Schröder-Adams *et al.* (1996) the regression was slight. Schröder-Adams establishes the Westgate fauna at Youngstown as inner neritic to possibly mid-neritic depth. The Westgate fauna at Fort Augustus may be from a similar depth, but the Shaftesbury fauna is shallower as well as less saline as evidenced by *Ammobaculites* (see Stelck, 1975, p. 265).

Figure 9. Foraminiferal generic composition of the Shaftesbury and Westgate formations and the immediately underlying strata. Numbers in the Spirit River interval indicate total number of species below and above faunal break (denoted by dotted line). Vknng is the Viking Formation.

The strata of the Shaftesbury and Westgate formations represent the last major transgression of the Albian which culminated in the expansion of the Mowry Sea (Stelck, 1975). In central Alberta the transgression began with deposition of the basal Westgate Formation, and in northwestern Alberta at the base of the Shaftesbury Formation, though it is documented locally as occurring within the Viking-correlative Paddy Member of the Peace River Formation (Beaumont, 1984; Leckie, 1986; Stelck and Koke, 1987; Stelck and Leckie, 1990). During latest Albian time the Mowry sea extended from Wyoming to the Arctic and from the Rocky Mountain Foothills to eastern Manitoba (Stelck, 1975; Williams and Stelck, 1975).

The Mowry Sea was connected to the Boreal sea though the extent of the connection is unknown. In the Arctic, strata correlative to the Shaftesbury and Westgate formations are the Tuktu and Grandstand formations. Schröder-Adams (1996) stated that taxa common to both the Arctic and Alberta indicate a path for faunal exchange. In this study *Verneuilinoides borealis*, *Psamminopelta bowsheri*, *Ammobaculites fragmentarius*, *Miliammina manitobensis*, and *Haplophragmoides topagorukensis* are common with the correlative Arctic faunas of Tappan (1957, 1960, 1962).

FORAMINIFERAL RESPONSE TO FACIES CHANGES

Results have shown that foraminiferal diversity and abundance vary with changes in sedimentary facies. Within each well abundance is generally higher in the shaley strata

than in the sandy strata which tend to have low abundance or are barren. In northwestern Alberta foraminiferal abundance is seen to fluctuate without a substantial change in the corresponding diversity. This scenario occurs in the Lower Albian Wilrich Formation of the Spirit River Formation, and in the Upper Albian Shaftesbury Formation. Within both of these dominantly shale units, thin siltstone and sandstone beds coincide with the decreasing faunal abundance. The pulses of coarser sediments into the northwestern portion of the basin indicate locally higher sedimentation rates. These periods of decreasing abundance without a corresponding change in diversity appear to represent short term dilution of the faunas without major long-term environmental change caused by sea-level change. However in the Wilrich Member of the Spirit River Formation the faunal change is accompanied by a change in species composition resulting in the distinction between SR2 and SR3. The faunal changes in abundance and diversity seen in the Shaftesbury Formation are also accompanied by subtle changes in the species composition. These changes suggest major environmental change which causes disappearance of certain taxa.

Although assemblage composition can change with facies changes (see data representing the Hulcross Sea in Figure 5), certain less selective taxa responded with a change in size of the agglutinated grains forming their tests (Schröder-Adams *et al.*, 1996). Similar observations were made in this study. Species such as *Bathysiphon brosgiei* (Plate 1, Figures 1, 2), *Gaudryina nanushukensis* (Plate 5, Figures 3 - 5) and *Hippocrepina barksdalei* (Plate 1, Figures 12, 15) exhibit fine grained tests when found in fine grained substrates, and coarser grained tests when observed in sandier substrates.

Within the shales of the Shaftesbury Formation at Spirit River some foraminiferal taxa exhibit a preference for test grain size. Specimens of selected species of *Ammobaculites* (Plate 3, Figures 6, 7, 10 - 15), *Ammomarginulina* (Plate 4, Figure 4) and *Reophax* (Plate 1, Figures 17 - 19) are consistently much coarser grained than *Eggerella* (Plate 4, Figure 15), *Gaudryina* (Plate 5, Figure 1), *Gravellina* (Plate 5, Figure 11), *Haplophragmoides* (Plate 2, Figures 9, 15; Plate 3, Figure 3), *Miliammina* (Plate 2, Figures 3 - 6), *Saccamina* (Plate 1, Figures 5, 10), *Trochammina* (Plate 4, Figure 13) and *Verneuilinoides* (Plate 5, Figure 8). Similar preferences were encountered in the shales of the Wilrich Member of the Spirit River Formation. Tolerant taxa may have preferred fine grained substrates (such as *Gaudryina* and *Haplophragmoides*) or not (such as *Ammobaculites* and *Reophax*) but they were able to utilize coarser grained substrates for test construction, unlike *Eggerella* or *Verneuilina*, for example, which appear to have been unable to thrive in sandy substrates. This observation demonstrates that sedimentary facies have to be considered to explain the distribution of agglutinated foraminifera.

Biostratigraphic comparisons within the basin

THE GAUDRYINA NANUSHUKENSIS ZONE IN NORTHWESTERN AND CENTRAL ALBERTA

The *Rectobolivina* sp. subzone was recognized in the basal beds of the Loon River Formation along the lower Wabiskaw River in north central Alberta by Wall (1969). It was described as predating the *Marginulinopsis collinsi* fauna. The *Rectobolivina* sp. fauna may in part represent a deeper-water biofacies of the *Trochammina mcmurrayensis*

fauna (upper McMurray Formation), but is more likely to be the marine equivalent of the assemblage of pollen and spores found in the lower part of the McMurray Formation (Caldwell *et al.*, 1978). Wall described a diverse assemblage belonging to the *Rectobolivina* sp. fauna which contained both agglutinated and calcareous foraminifera. Elements of Wall's assemblage which are common to the SR1 biofacies include *Ammobaculites* sp. cf. *A. fragmentarius* Cushman, *Gaudryina tailleuri* (Tappan), *Lenticulina bayrocki* Mellon and Wall, *Quadriformina albertensis* Mellon and Wall, along with species of *Ammobaculites*, *Bathysiphon*, *Hippocrepina*, *Lenticulina*, *Saccamina*, *Saracenaria*, and *Trochammina*. However the Spirit River well contains no *Rectobolivina* sp. (which are dominant in Wall's fauna), and there is no mention in Wall (1969) or Caldwell *et al.* (1978) of biserial genera, *Glomospira*, or *Hyperammina* in the *Rectobolivina* sp. fauna. The lower SR1 fauna may simply represent a version of Wall's biofacies which is both shallower and more proximal to the sediment source. No comparable foraminiferal fauna was found in central Alberta.

The *Trochammina mcmurrayensis* subzone was described by Mellon and Wall (1956) from the uppermost beds of the McMurray Formation in northeastern Alberta (Athabasca). Caldwell *et al.* (1978) speculates that this fauna may be found in the lower Wilrich Member of the Spirit River Formation of northwestern Alberta. Elements from Mellon and Wall's assemblage which are common to the SR1 biofacies include *T. mcmurrayensis* Mellon and Wall, *Haplophragmoides* sp. plus *Ammodiscus*, *Trochammina*, and *Verneuilinoides*. The most important element is *T. mcmurrayensis* due to its short stratigraphic range: it is only found in the upper McMurray Formation. *T.*

mcmurrayensis is encountered within the lowest 25 m of the Wilrich Member and the lowest 45 m of the Wilrich Member correspond to the *T. mcmurrayensis* subzone. No comparable foraminiferal fauna was found in central Alberta.

The *M. collinsi-V. cummingensis* subzone is expressed in northwestern and central Alberta by the SR3, SR4, FA2 and FA3 biofacies (Figures 5 and 6). SR3 and FA2 correspond to the lower biofacies which contains abundant calcareous foraminifera (Stelck *et al.*, 1956). Many of the species found in SR3 are the same as those found by Stelck *et al.* (1956), though several remained unnamed in that report. SR4 and FA3 correspond to the dominantly agglutinated upper biofacies (Figures 5 and 6).

The fauna of the Harmon Member of the Peace River Formation (SR5) was first described by Wickenden (1951) and named by Stelck *et al.* (1956) the *H. multiplum* Zone. The fauna was given subzone status by Caldwell *et al.* (1978). The assemblage found in this study differs dramatically from that described by either of the earlier studies. The only common genus to the earlier studies and to the overlying Cadotte Member is *Haplophragmoides* (Figure 10).

Cadotte fauna (SR6) was originally described by Wickenden (1951) and by Stelck *et al.* (1956). The fauna was given subzone status and named the *Ammobaculites* sp. subzone by Caldwell *et al.* (1978). In this study the fauna consists exclusively of *Haplophragmoides* sp. and some *Ammobaculites* sp. fragments before becoming barren (Figure 10). In addition, the earlier reports also described *Eggerella*, *Miliammina*, *Glomospira*, *Nodosinella* and *Proteonina* (*Saccamina*).

THE *HAPLOPHRAGMOIDES GIGAS* ZONE IN NORTHWESTERN AND CENTRAL ALBERTA

The *Haplophragmoides gigas* Zone has been described and divided into 7 subzones in northeastern British Columbia by Koke and Stelck (1984, 1985), Stelck and Koke (1987) and Stelck (1991) (Figure 2). Most of these subzones have so far only been recognized in northeastern British Columbia in Joli Fou- and Viking-equivalent strata. North and Caldwell (1975b) described 2 distinct faunas as subzones IIa and IIb from the subsurface of Saskatchewan, whereas Guliov (1967) proposed the lower *Ammomarginulina asperata* and upper *Miliammina sproulei* subzones for eastern Saskatchewan. North and Caldwell's subzones coincide with Guliov's and both were found entirely within the Joli Fou Formation (North and Caldwell, 1975b) and correspond with the *Haplophragmoides gigas gigas* and *Haplophragmoides gigas phaseolus* subzones respectively (Caldwell *et al.*, 1993). The *Haplophragmoides gigas gigas* and *Haplophragmoides gigas phaseolus* subzones record the peak transgression of the Kiowa-Skull Creek global marine cycle and are typically the only two *Haplophragmoides gigas* subzones recognized east of northeastern British Columbia (Caldwell *et al.*, 1993) although elements of the uppermost *Reophax troyeri* subzone have been recognized in northwestern Alberta by Stelck and Leckie (1990).

In this study all three wells contain *Haplophragmoides gigas* faunas. In the Fort Augustus well the *Haplophragmoides gigas* Zone is divided into three biofacies. The lower faunas correspond to the *Haplophragmoides gigas gigas* (FA4) and *Haplophragmoides gigas phaseolus* (FA5) subzones. The contact between the

Haplophragmoides gigas gigas subzone and the overlying *Haplophragmoides gigas phaseolus* subzone is drawn at the disappearance of *Haplophragmoides gigas (sensu stricto)* (Figure 8) (Caldwell *et al.*, 1993). The faunal changes between the Joli Fou and Viking formations are expressed in Figure 8. Due to the proximity of the Viking and Westgate faunas, the Ft. Augustus Viking assemblage may belong to the uppermost *Reophax troyeri* subzone.

In the Youngstown well faunal changes between the Joli Fou and the Viking formations are expressed in Figure 8 and exhibit lower abundances in all genera during Viking deposition. The upper, sampled portion of the Joli Fou Formation lacks *Haplophragmoides gigas (sensu stricto)* suggesting that the fauna belongs to the *Haplophragmoides gigas phaseolus* subzone.

The Paddy Member at Goodfare Alberta contains a foraminiferal assemblage belonging to the *M. manitobensis* Zone (Stelck and Leckie, 1990). However 17 taxa known from the uppermost *Haplophragmoides gigas* subzone on Hasler Creek (Stelck and Koke, 1987) are present in the assemblage placing the Paddy Member at that locality stratigraphically slightly above the Viking Formation of central Alberta (Stelck and Leckie, 1990). The foraminifera of the Paddy Member are found immediately subjacent to the basal Shaftesbury Formation. The Paddy fauna appears to be a diminished version of the overlying *Miliammina manitobensis* Zone but it lacks the diagnostic elements. The few specimens composing this assemblage belong to taxa which range into the overlying *Miliammina manitobensis* Zone fauna. The close relationship between the Paddy and Shaftesbury faunas is also seen in central Alberta between the Viking and Westgate

faunas. In both central Alberta wells the Viking faunas lack the diagnostic *Miliammina manitobensis* fauna (such as *Verneuilina canadensis*) and so are placed in the *Haplophragmoides gigas* Zone.

THE MILIAMMINA MANITOBENSIS ZONE IN NORTHWESTERN AND CENTRAL ALBERTA

The *Miliammina manitobensis* Zone has been subdivided into 3 subzones (Figure 2) of which only the *Verneuilina canadensis* subzone is typically recognized throughout the WCSB as far east as Manitoba. The *Haplophragmoides postis goodrichi* and *Haplophragmium swarini* subzones have only been recognized from the foothills of northeastern British Columbia where species abundance and diversity are the highest in the WCSB (Caldwell *et al.*, 1993). This is probably due to the fact that in northeastern British Columbia the zone is associated with a much thicker succession of strata which might reflect several facies changes to which agglutinated taxa responded. The Shaftesbury and Westgate formations (which contain the zone) and underlying Viking Formation thin towards the southeast (Bloch *et al.*, 1993). Across the plains only the *Verneuilina canadensis* subzone is present. It was suggested that the plains do not exhibit a thinned version of all three subzones since the diagnostic *H. postis goodrichi* and *H. swarini* have not been found (Caldwell *et al.*, 1978). Schröder-Adams *et al.* (1996, appendix 2b), however, report both diagnostic species from the subsurface of central Alberta and Saskatchewan. In this study *Verneuilina canadensis* and *H. postis goodrichi* are reported

in abundance in all three locations and *H. swarini* is reported from the Spirit River well in northwestern Alberta and the Youngstown well in central Alberta.

The faunas of both central Alberta wells (FA7 and YT3) belong to the *Verneuilina canadensis* subzone. Neither can be divided into faunules on the basis of faunal differences. Both central Alberta wells exhibit faunas dominated by *Miliammina* and *Haplophragmoides*, and both contain *H. postis goodrichi* and *V. canadensis*.

In northwestern Alberta the affinity of the Shaftesbury fauna is uncertain. The fauna can be divided into two “faunules”. The break in assemblage composition occurs at about 675 m (approximately halfway through the lower Shaftesbury) and is characterized by the disappearance of *H. postis goodrichi* and *H. sp. cf. H. swarini* and the appearance of *V. canadensis* (Figure 9). *H. postis goodrichi* and *V. canadensis* are mutually exclusive. In the upper faunule, *Ammobaculites* and *Haplophragmoides* all but disappear. *Bathysiphon* numbers also dwindle above 675 m. *Trochammina* doesn’t appear to change dramatically in overall abundance but the species composition does: *T. alcanensis*, *T. bredini*, *T. gatensis*, *T. rainwateri* and *Trochammina sp. cf. T. rutherfordi* disappear and the genus becomes dominated by some uncertain species of *Trochammina*. *Gaudryina* and *Verneuilina*, in contrast, are scarce in the lower faunule but increase substantially in the upper faunule. The fauna is dominated by *Ammobaculites* below the break and *Haplophragmoides* above. The abundance of *H. postis goodrichi* in the lower faunule and *V. canadensis* in the upper faunule suggests both of those subzones may be present. However, the order of the two subzones is reversed (Caldwell *et al.*, 1978, Figure 2). This

reversal might be explained by the relationship observed in this study between agglutinated foraminiferal faunas and sedimentary facies.

The Joli Fou-Viking-Westgate problem

In central Alberta the faunal changes between the Joli Fou, Viking and Westgate formations reveal some interesting trends. At Youngstown the Joli Fou fauna (*H. gigas* Zone) is quite low in diversity as well as abundance (Figure 7) compared with Fort Augustus (Figure 6). The difference in abundance and diversity within the Joli Fou Formation between both wells could be interpreted as the result of reduced oxygen conditions further south at the Youngstown locality created by the connection between the northern and southern water masses. Tethyan derived calcareous fauna have migrated as far north as Kansas, Oklahoma and New Mexico (Caldwell *et al.*, 1993). Hay *et al.* (1993) suggest that the mixing of the Boreal and Tethyan water masses would produce a third water mass with density greater than one or both of the originating water masses. If this water mass reached the Youngstown locality, it could have created stratification inhibiting oxygen supply to benthic organisms.

The Viking Formation at both central Alberta localities appears to have a higher affinity with the overlying *M. manitobensis* Zone than the *H. gigas* Zone. The Viking assemblage is placed in the uppermost *Reophax troyeri* subzone of the *H. gigas* Zone because it is lacking specimens of the diagnostic species *V. canadensis*. However more taxa from the Viking Formation range into the overlying Westgate Formation than into the

underlying Joli Fou Formation. These results encourage further study of the relationships between these three formations.

The faunal changes between the Joli Fou, Viking and Westgate formations are gradational at Youngstown and are accompanied by a gamma ray log signature and lithology indicating sandstone beds. At Fort Augustus the faunal transition is rather abrupt and accompanied by an unrevealing spontaneous potential log signature and a lithology which also indicates sandstone beds. The abrupt faunal transition might be due to multiple unconformities occurring near the base and the top of the Viking Formation. A hypothetical unconformity would explain the abrupt changes in foraminiferal species composition between the Joli Fou and Viking formations and again between the Viking and Westgate formations.

CONCLUSIONS

This study was based on a comparison of Albian age foraminifera from three wells in northwestern and central Alberta.

1. The paleoenvironments of the Moosebar/Clearwater, Hulcross, Joli Fou and Mowry seas are reflected in the foraminiferal faunas as fluctuations in abundance, diversity and species composition.

2. The foraminifera throughout this study reflect coarsening-upwards cycles observed in the lithology and on the spontaneous potential or gamma ray log signatures. Shaley intervals tend to contain higher foraminiferal abundances than coarser grained substrates, though other factors such as salinity and oxygen content apply. Peaks in

foraminiferal abundance which appear above flooding surfaces are assumed to represent maximum flooding surfaces.

3. Foraminiferal taxa respond to changes in sedimentary facies. Some tolerant taxa prefer finer grained substrates while others utilize whatever grains are available for test construction. Intolerant taxa are unable to thrive on sandy (coarser grained) substrates.

4. The *Rectobolivina* sp. and *Trochammina mcmurrayensis* subzones of the *Gaudryina nanushukensis* Zone are documented at Spirit River in northwestern Alberta (12-20-78-6W6)

5. At all localities the Viking and correlative (Paddy) faunas have greater similarities with the overlying *Miliammina manitobensis* Zone than with underlying faunas, but lack the diagnostic elements of that Zone and hence are placed in the uppermost *Reophax troyeri* subzone of the *Haplophragmoides gigas* Zone. The faunal ranges indicate that the Viking fauna might be better placed as a new subzone of the *M. manitobensis* Zone or as a new zone altogether. Multiple local unconformities are a possible explanation for the abrupt microfaunal changes observed at the Joli Fou-Viking and Viking-Westgate formational boundaries at Fort Augustus (7-29-55-21W4).

6. Both the *Verneuilina canadensis* and the *Haplophragmoides postis goodrichi* subzones of the *Miliammina manitobensis* Zone may be present in the Shaftesbury Formation at Spirit River in northwestern Alberta (12-20-78-6W6).

7. Thermal stratification of the Boreal and Tethyan water masses may be responsible for the relatively low foraminiferal abundance and diversity observed in the Joli Fou Formation at Youngstown (6-34-30-8W4).

8. Multiple local unconformities are a possible explanation for the abrupt microfaunal changes observed at the Joli Fou-Viking and Viking-Westgate formational boundaries at Fort Augustus (7-29-55-21W4).

SYSTEMATICS

The supraspecific classification used for the foraminifera identified in the course of this study is based on Loeblich and Tappan (1987). New taxa listed herein are not to be considered as introduced into the literature, as a thesis does not constitute a publication within the International Code of Zoological Nomenclature (ICZN Article 9 (11)). In the following chapter the reference list includes the original reference and, if available, a more current publication with suitable figures. For extensive synonymy lists of many of the following species the reader is referred to McNeil and Caldwell (1981). Under *Occurrence* are listed formations in which species were found in this study. The *Remarks* indicate the formations in which species were originally found.

Family ASTRORHIZIDAE Brady, 1881

Genus *Bathysiphon* M. Sars in G. O. Sars, 1872

Bathysiphon brosgiei Tappan, 1957

Plate 1, figures 1, 2

Bathysiphon brosgiei Tappan, 1957. United States National Museum, Bulletin no. 215, p. 202, pl. 65, figs. 1-5.

Bathysiphon brosgiei Tappan. Stelck and Koke, 1987, Canadian Journal of Earth Sciences v. 24, pl. 1, figs. 1-3.

Occurrence. This species is recognized in the Bluesky Formation, the Wilrich and Falher members of the Spirit River Formation, the Harmon Member of the Peace River Formation, and the Shaftesbury Formation of the Ft. St. John Group of northwestern

Alberta. In central Alberta it occurs in the Joli Fou, Viking and Westgate formations of the Colorado Group.

Remarks. *B. brosgiei* differs from *B. vitta* Nauss in having a smaller diameter and coarser agglutination with a rough surface. *B. brosgiei* was originally described from the Topagoruk and Fortress Mountain formations of Alaska.

Family SACCAMMINIDAE Brady, 1884

Genus *Psammosphaera* Schultze, 1875

Psammosphaera sp.

Plate 1, figure 4

Genus *Saccammina* M. Sars in Carpenter, 1869

Saccammina alexanderi (Loeblich and Tappan), 1950

Proteonina alexanderi Loeblich and Tappan, 1950. University of Kansas Paleontological Contributions, Protozoa, art. 3, p. 5, pl. 1, figs. 1, 2.

Saccammina alexanderi (Loeblich and Tappan). Eicher, 1960, Peabody Museum of Natural History, Bulletin, no. 15, p. 55, pl. 3, figs. 1, 2.

Occurrence. This species is recognized in the Wilrich and Falher members of the Spirit River Formation and the Shaftesbury Formation of the Ft. St. John Group in northwestern Alberta, and in the Joli Fou, Viking and Westgate formations of the Colorado Group in central Alberta.

Remarks. *S. alexanderi* was originally described from the type Kiowa Shale, Lower Cretaceous, of Kansas.

Saccamina globosa Crespin, 1963

Plate 1, figures 6, 7

Saccamina globosa Crespin, 1963. Australia, Department of Natural Development, Bureau of Mineral Resources, Geology and Geophysics, Bulletin 66, p. 21, pl. 1, figs. 13-17.

Occurrence. This species is recognized in the Wilrich and Falher members of the Spirit River Formation, the Harmon Member of the Peace River Formation, and the Shaftesbury Formation of the Ft. St. John Group of northwestern Alberta. In central Alberta it occurs in the Upper Mannville (undifferentiated) and is ubiquitous in the lower Colorado Group.

Remarks. This species has been found in the Westgate Formation of central Alberta (Schröder-Adams *et al.*, 1996). *S. globosa* was originally described from the Cretaceous of Australia.

Saccamina lathrami Tappan, 1960

Plate 1, figures 5, 10, 11

Saccamina lathrami Tappan, 1960. Bulletin of the American Association of Petroleum Geologists, p. 289, pl. 1, fig. 1, 2.

Saccamina sp. cf. *S. lathrami* Tappan. Sutherland and Stelck, 1972, Bulletin of Canadian Petroleum Geology, p. 559, pl. 1, fig. 5.

Occurrence. This species is recognized in the Bluesky Formation, the Wilrich and Falher members of the Spirit River Formation, the Harmon Member of the Peace River Formation, and the Shaftesbury Formation of the Ft. St. John Group of northwestern Alberta. It occurs in the Upper Mannville (undifferentiated), Mannville Group, and the Viking and Westgate formations of the Colorado Group in central Alberta.

Remarks. *S. lathrami* was originally described from the Upper Albian Grandstand and Middle Albian Topagoruk formations, northern Alaska.

Family HIPPOCREPINIDAE Rhumbler, 1895

Genus *Hyperammia* Brady, 1878

Hyperammia emacerata (Chamney), 1978

Plate 1, figure 3

Bathysiphon emacerata Chamney, 1978, Geological Survey of Canada, Bulletin no. 253, p. 9, pl. 1, figs. 4, 5.

Hyperammia emacerata emacerata (Chamney). Stelck and Koke, 1987, Canadian Journal of Earth Sciences v. 24, pl. 1, figs. 4, 5.

Occurrence. This species is recognized in the Spirit River and (very rarely) in the Shaftesbury formations of the Fort. St. John Group at Spirit River.

Remarks. Originally described from the Lower Albian Martin House and Middle Albian Arctic Red formations of Yukon Territory.

Hyperammia strombotubulare, (Chamney), 1978

Bathysiphon strombotubulare, Chamney, 1978, Geological Survey of Canada, Bulletin no.

253, p. 9, pl. 1, figs. 6, 7.

Hyperammina strombotubulare (Chamney). Stelck and Koke, 1987, Canadian Journal of

Earth Sciences v. 24, pl. 1, fig. 14.

Occurrence. *H. strombotubulare* is recognized exclusively in the Wilrich Member of the Spirit River Formation at Spirit River.

Remarks. It was originally described from the Martin House Formation (Aptian to latest Early Albian).

Genus *Hippocrepina* Parker, in Dawson 1870

Hippocrepina barksdalei (Tappan), 1957

Plate 1, figures 12, 15

Hyperamminoides barksdalei Tappan, 1957, United States National Museum, Bulletin no.

215, p. 202, pl. 65, figs. 6 - 12.

Hippocrepina barksdalei (Tappan). Loeblich and Tappan, 1964, Treatise on Invertebrate

Paleontology, p. C-188.

Occurrence. This species occurs in the Bluesky and Spirit River formations at Spirit River and in the Westgate Formation at both Fort. Augustus and Youngstown.

Remarks. *H. barksdalei* was originally described from the Middle Albian Topagoruk and Upper Albian Grandstand formations, northern Alaska.

Family AMMODISCIDAE Reuss, 1862

Genus *Ammodiscus* Reuss, 1862

Ammodiscus kiowensis Loeblich and Tappan, 1950

Ammodiscus kiowensis Loeblich and Tappan, 1950. University of Kansas Paleontological Contributions, Protozoa, art. 3, p. 5-6, pl. 1, figs. 3a, b.

Ammodiscus kiowensis Loeblich and Tappan. Stelck and Wall, *in* Stelck *et al.*, 1956, Research Council of Alberta Report 75, p. 25, pl. 5, figs. 16, 17.

Occurrence. This species occurs in the Shaftesbury Formation at Spirit River, northwestern Alberta, and in the Viking Formation at Fort Augustus, central Alberta.

Remarks. There are only a few specimens of *A. kiowensis* found in the three wells. The species was originally described from the type Kiowa shale (Lower Cretaceous) of Kansas.

Ammodiscus sp. cf. *A. planus* Loeblich, 1946

Ammodiscus planus Loeblich, 1946, Journal of Paleontology, v. 20, p. 133, pl. 22, figs. 2a-b.

Ammodiscus planus Loeblich. Sutherland and Stelck, 1972, Bulletin of Canadian Petroleum Geology, p. 562, pl. 1, figs. 10, 11.

Occurrence. This species occurs in the Joli Fou Formation at Fort Augustus, central Alberta.

Remarks. Originally described from the type Pepper shale, Texas.

Ammodiscus rotalarius Loeblich and Tappan, 1949

Plate 1, figures 8, 9

Ammodiscus rotalarius Loeblich and Tappan, 1949, Journal of Paleontology, v. 23, no. 3, p. 247, pl. 46, fig. 1.

Ammodiscus rotalarius Loeblich and Tappan. Tappan, 1962, United States Geological Survey Professional Paper 236-C, p. 131-132, pl. 30, figs. 5-8.

Occurrence. This species is recognized in the Bluesky Formation, and the Wilrich and Falher members of the Spirit River Formation in northwestern Alberta and there are rare occurrences in the Viking Formation of central Alberta.

Remarks. *A. rotalarius* differs from *A. planus* in that it has overlapping chambers and does not have depressed sutures. It was originally described from the Middle Albian Walnut clay of Oklahoma. Tappan (1962) found *A. rotalarius* throughout the Albian in the Torok Formation and overlying Nanushuk Group.

Genus *Glomospira* Rzehak, 1885

Glomospira reata Eicher, 1960

Plate 1, figures 13a, b

Glomospira reata Eicher, 1960, Peabody Museum of Natural History, Bulletin, no. 15, p. 56-57, pl. 3, figs. 4a, b, 5.

Glomospira reata Eicher. Stelck and Leckie, 1990, Canadian Journal of Earth Sciences, pl. 1, figs. 5-8.

Occurrence. This species is recognized exclusively from the Bluesky Formation, at Spirit River, northwestern Alberta.

Remarks. Originally described from the Thermopolis shale in Wyoming.

Glomospira tortuosa Eicher, 1960

Plate 1, figures 14a, b

Glomospira tortuosa Eicher, 1960, Peabody Museum of Natural History, Bulletin, no. 15, p. 57 pl. 3, figs. 8a-b.

Glomospira tortuosa Eicher. Koke and Stelck, 1985, Canadian Journal of Earth Sciences, pl. 1, figs. 27, 28.

Occurrence. This species is only recognized in northwestern Alberta Bluesky and Shaftesbury formations.

Remarks. The Shaftesbury Formation contains a single specimen. *G. tortuosa* coils in random planes, differing from *G. reata* in which the initial random coil becomes roughly planispiral. *G. tortuosa* was originally described from the Thermopolis shale of Wyoming.

Family HORMOSINIDAE Haeckel, 1894

Genus *Reophax* de Montfort, 1808

Reophax deckeri Tappan, 1940

Plate 1, figures 16, 17a, b

Reophax deckeri Tappan, 1940, Journal of Paleontology, v. 14, no. 2, p. 94, pl. 14, figs. 3a-b.

Reophax deckeri Tappan. Sliter, 1981, Geological Survey of Canada Bulletin no. 300, p. 53, pl. 9, figs. 15, 16.

Occurrence. *R. deckeri* is recognized in the Shaftesbury Formation at Spirit River, northwestern Alberta, and in the Westgate Formation at Fort Augustus, central Alberta.

Remarks. Originally described from the Grayson Formation of Texas, Stelck (1991) reports *R. deckeri* from the Middle to Upper Albian Hasler Formation of the Fort St. John Group, northeastern British Columbia.

Reophax sp. cf. *R. densa* Tappan, 1955

Reophax densa Tappan, 1955, United States Geological Survey Professional Paper 236-B, p. 35, pl. 8, figs. 1-6.

Occurrence. This species occurs in the Shaftesbury Formation at Spirit River, northwestern Alberta.

Remarks. This species was originally described from the Jurassic of northern Alaska. Stelck and Hedinger (1983) reported it from the upper Albian Sully Formation of northeastern British Columbia (not figured).

Reophax sp. cf. *R. incompta* Loeblich and Tappan, 1946

Reophax incompta Loeblich and Tappan, 1946, Journal of Paleontology, v. 20, no. 3, p. 242, pl. 35, figs. 1a-b, text fig. 1.

Reophax incompta Loeblich and Tappan. McNeil and Caldwell, 1981, Geological Association of Canada Special Paper 21, p. 138, pl. 9, figs. 19, 20.

Occurrence. This species occurs in the Bluesky Formation at Spirit River, northwestern Alberta with a single specimen.

Remarks. This species was originally described from the Weno Formation of the Washita Group, north Texas. Chamney recognized *Reophax* sp. cf. *R. incompta* from the base of the Martin House Formation (Aptian) to the top of the Arctic Red Formation (late Albian).

Reophax sikanniensis Stelck, 1975

Plate 1, figure 18

Reophax sikanniensis Stelck, 1975, Geological Association of Canada Special Paper no. 13, p. 266, pl. 1, figs. 16-18.

Occurrence. This species occurs in the Wilrich and Falher members of the Spirit River Formation, and in the Shaftesbury Formation at Spirit River, northwestern Alberta; in the Viking and Westgate formations at Fort Augustus, central Alberta; and in the Joli Fou and Viking formations at Youngstown, central Alberta.

Remarks. *R. sikanniensis* is most abundant in the Shaftesbury Formation. The abundance decreases dramatically to the southeast and there are only a few specimens at Youngstown. It was originally described from the upper Albian Buckinghorse and Sikanni formations of the Fort. St. John Group, northeastern British Columbia. Schröder-Adams *et al.* (1996) has reported it from the Westgate Formation, central Alberta (not figured).

Reophax troyeri Tappan, 1960

Plate 1, figure 19; Plate 2, figures 1a, b

Reophax troyeri Tappan, 1960, American Association of Petroleum Geologists Bulletin, v. 44, no. 3, p. 291, pl. 1, figs. 10-12.

Reophax troyeri Tappan. Koke and Stelck, 1985, Canadian Journal of Earth Sciences v. 22, pl. 1, figs. 20-24.

Occurrence. This species occurs in the Bluesky, Spirit River, and Shaftesbury formations and in the Harmon Member of the Peace River Formation at Spirit River, northwestern Alberta; in the Viking and Westgate formations at Fort Augustus, central Alberta; and in the Viking Formation at Youngstown, central Alberta.

Remarks. Originally described from the Middle Albian Topagoruk Formation, northern Alaska.

Reophax tundraensis Chamney, 1969

Plate 2, figure 2

Reophax tundraensis Chamney, 1969, Geological Survey of Canada, Bulletin no. 185, p. 22-23, pl. 4, figs. 2-4.

Reophax tundraensis Chamney. Stelck, 1975, Geological Association of Canada Special Paper 13, pl. 1, figs. 19, 20, 23.

Occurrence. This species occurs in the Shaftesbury Formation at Spirit River, northwestern Alberta; and in the Viking Formation at Fort Augustus, central Alberta.

Remarks. Originally described from Barremian age strata, District of MacKenzie; Stelck (1975) recognized *R. tundraensis* in the Buckinghorse and Sikanni formations of northeastern British Columbia.

Reophax vasiformis Chamney, 1978

Reophax vasiformis Chamney, 1978, Geological Survey of Canada, Bulletin 253, p. 10-11, pl. 1, figs. 12-14.

Reophax vasiformis Chamney. Koke and Stelck, 1985, Canadian Journal of Earth Sciences v. 22, pl. 1, figs. 17-19.

Occurrence. This species is recognized in the Falher Member of the Spirit River Formation and in the Shaftesbury Formation at Spirit River, northwestern Alberta; in the Joli Fou, Viking and Westgate formations at Fort Augustus and Youngstown, central Alberta.

Remarks. *R. vasiformis* was originally described from the Middle to Upper Albian Arctic Red Formation, Yukon Territory.

Genus *Scherochorella* Loeblich and Tappan, 1984

Scherochorella minuta (Tappan), 1940

Reophax minuta Tappan, 1940, Journal of Paleontology v. 14, p. 94, pl. 14, figs. 4a-b.

Reophax minuta Tappan. Tappan, 1962, United States Geological Survey Professional Paper 236-C, p. 132-133, pl. 30, fig. 10.

Occurrence. This species occurs in the Bluesky Formation, the Wilrich Member of the Spirit River Formation, and the Harmon Member of the Peace River Formation at Spirit River, northwestern Alberta.

Remarks. This species was originally described from the Grayson Formation in Texas. Tappan (1962) recognized *S. minuta* in the Lower Albian Torok and Middle Albian Topagoruk formations, northern Alaska.

Family RZEHAKINIDAE Cushman, 1933

Genus *Miliammina* Heron-Allen and Earland, 1930

Miliammina awunensis Tappan, 1957

Plate 2, figure 3

Miliammina awunensis Tappan, 1957, United States National Museum, Bulletin no. 215, p. 210, pl. 67, figs. 19-21.

Miliammina awunensis Tappan, Stelck and Koke, 1987, Canadian Journal of Earth Sciences v. 24, pl. 2, figs. 23, 24.

Occurrence. This species occurs in the Falher Member of the Spirit River Formation and in the Shaftesbury Formation at Spirit River, northwestern Alberta; in the Upper Mannville (undifferentiated) and Westgate formations at Fort Augustus, central Alberta; and in the Joli Fou, Viking and Westgate formations at Youngstown, central Alberta.

Remarks. *M. awunensis* was originally described from the Middle Albian Topagoruk and Upper Albian Grandstand formations, northern Alaska.

Miliammina inflata Eicher, 1960

Miliammina inflata Eicher, 1960, Peabody Museum of Natural History, Bulletin 15, p. 70-71, pl. 5, figs. 13-14.

Miliammina inflata Eicher. Stelck and Koke, 1987, Canadian Journal of Earth Sciences v. 24, pl. 2, figs. 21, 22.

Occurrence. This species occurs in the Shaftesbury Formation at Spirit River, northwestern Alberta; in the Upper Mannville (undifferentiated) and Westgate formations at Fort Augustus, central Alberta; and in the Joli Fou, Viking and Westgate formations at Youngstown, central Alberta.

Remarks. *M. inflata* was originally described from the Upper Albian Thermopolis shale. Stelck and Koke (1987) report it from the Viking equivalent interval of the Hasler shale, northeastern British Columbia.

Miliammina ischnia Tappan, 1957

Plate 2, figures 5a, b

Miliammina ischnia Tappan, 1957, United States National Museum, Bulletin 215, p. 211, pl. 67, figs. 25-26.

Miliammina ischnia Tappan. North and Caldwell, 1975a, Geological Survey of Canada Paper 74-38, pl. 1, figs. 16a, b.

Occurrence. This species occurs in the Falher Member of the Spirit River Formation and in the Shaftesbury Formation at Spirit River, northwestern Alberta; in the Upper

Mannville (undifferentiated), Viking and Westgate formations at Fort Augustus, central Alberta; and in the Joli Fou, Viking, and Westgate formations at Youngstown, central Alberta.

Remarks. *M. ischnia* was originally described from the Upper Albian Grandstand Formation, northern Alaska.

Miliammina manitobensis Wickenden, 1932

Plate 2, figure 4, 6a, b

Miliammina manitobensis Wickenden, 1932, Royal Society of Canada Transactions, 3rd Serial, v. 26, sec. 4, p. 90, pl. 1, figs. 11a-c.

Miliammina manitobensis Wickenden. North and Caldwell, 1975a, Geological Survey of Canada Paper 74-38, pl. 1, figs. 12a-14b.

Occurrence. This species occurs in the Falher Member of the Spirit River Formation and in the Shaftesbury Formation at Spirit River, northwestern Alberta; in the Upper Mannville (undifferentiated), Viking and Westgate formations at Fort Augustus, central Alberta, and in the Joli Fou, Viking and Westgate formations at Youngstown, central Alberta.

Remarks. *M. manitobensis* was originally described from the Upper Albian Ashville Formation in Manitoba, and later was recognized by Nauss (1947) in the Lower Albian Lloydminster Member of the Cantuar Formation in central Alberta. It occurs in greatest abundance in the Shaftesbury and Westgate formations, though at Youngstown it also occurs in quantity in the Viking Formation.

Miliammina sproulei Nauss, 1947

Miliammina sproulei Nauss, 1947, Journal of Paleontology v. 21, no. 4, p. 339, pl. 48, figs. 13a-b.

Miliammina sproulei Nauss, Koke and Stelck, 1985, Canadian Journal of Earth Sciences v. 22, pl. 2, figs. 2, 3, 7, 8.

Occurrence. This species occurs in the Falher Member of the Spirit River Formation at Spirit River, northwestern Alberta; in the Upper Mannville (undifferentiated) at Fort Augustus, central Alberta; and in the Joli Fou and Westgate formations at Youngstown, central Alberta.

Remarks. *M. sproulei* was originally recorded in the Lower Albian Cummings Formation in the Vermilion area of Alberta. The specimens recorded at Youngstown are single occurrences.

Miliammina subelliptica Mellon and Wall, 1956

Miliammina subelliptica Mellon and Wall, 1956, Alberta Research Council Report no. 72, p. 22, pl. 1, fig. 6.

Miliammina subelliptica Mellon and Wall. Stelck and Koke, 1987, Canadian Journal of Earth Sciences v. 24, pl. 2, figs. 25, 26.

Occurrence. This species occurs in the Wilrich Member of the Spirit River Formation at Spirit River, northwestern Alberta; and in the Upper Mannville (undifferentiated) Formation at Fort Augustus, central Alberta.

Remarks. *M. subelliptica* was originally described from the Lower Albian Clearwater Formation, northeastern Alberta.

Genus *Psamminopelta* Tappan, 1957

Psamminopelta bowsheri Tappan, 1957

Plate 2, figures 7, 8

Psamminopelta bowsheri Tappan, 1957, United States National Museum, Bulletin no. 215, p. 211, pl. 67, figs. 11-18.

Psamminopelta bowsheri Tappan. Sutherland and Stelck, 1972, Bulletin of Canadian Petroleum Geology, v. 20, no. 3, p. 566-567, pl. 2, figs. 14-17, pl. 3, figs. 1-4.

Occurrence. This species occurs in the Falher Member of the Spirit River Formation and the Shaftesbury Formation at Spirit River, northwestern Alberta; in the Upper Mannville (undifferentiated) and Westgate formations at Fort Augustus, central Alberta; and in the Westgate Formation at Youngstown, central Alberta.

Remarks. *P. bowsheri* was originally reported from the northern Alaskan Albian succession of the Torok, Tuktu, Topagoruk and Grandstand formations and the paratypes encompassed a wide range of sizes. Most specimens of this study are large, but the figures illustrate the size range.

Psamminopelta subcircularis Tappan, 1957

Psamminopelta subcircularis Tappan, 1957, United States National Museum, Bulletin 215, p. 213, pl. 67, figs. 8-10.

Occurrence. This species occurs in the Upper Mannville (undifferentiated) and Westgate formations at Fort Augustus, central Alberta; and in the Westgate Formation at Youngstown, central Alberta.

Remarks. *P. subcircularis* was originally reported from the Middle Albian Topagoruk and Upper Albian Grandstand formations, northern Alaska.

Family LITUOLIDAE de Blainville, 1825

Genus *Haplophragmoides* Cushman, 1910

Haplophragmoides sp. cf. *H. collyra* Nauss, 1947

Haplophragmoides collyra Nauss, 1947, Journal of Paleontology v. 21, no. 4, p. 337-338, pl. 49, figs. 2a, b, 5.

Haplophragmoides collyra Nauss. Koke and Stelck, 1985, Canadian Journal of Earth Sciences v. 22, pl. 2, figs. 34-36.

Occurrence. This species occurs in the Bluesky and Shaftesbury formations at Spirit River, northwestern Alberta; and in the Upper Mannville (undifferentiated) and Joli Fou formations at Fort Augustus, central Alberta.

Remarks. *H. collyra* was originally reported from the Lloydminster Member of the Cantuar Formation in the Vermilion area of Alberta.

Haplophragmoides gigas gigas Cushman, 1927

Haplophragmoides gigas Cushman, 1927a, Transactions of the Royal Society of Canada, ser. 3, v. 21, sec. 4, p. 129-130, pl. 1, fig. 5.

Haplophragmoides gigas Cushman. Koke and Stelck, 1985, Canadian Journal of Earth Sciences v. 22, pl. 2, figs. 10-14.

Occurrence. This species occurs solely in the Joli Fou Formation at Fort Augustus, central Alberta.

Remarks. *H. gigas (sensu stricto)* was originally described from the subsurface of Alberta. In this study specimens are rare.

Haplophragmoides gigas minor Nauss, 1947

Plate 2, figures 10a, b, 13

Haplophragmoides gigas minor Nauss, 1947, Journal of Paleontology, v. 21, p. 338, pl. 49, fig. 10a, b.

Haplophragmoides gigas minor Nauss. Stelck and Wall, in Stelck *et al.*, 1956, Alberta Research Council Report 75, p. 35-36, pl. 2, figs. 29, 30.

Occurrence. This species occurs in the Spirit River, Harmon and Paddy members of the Peace River, and Shaftesbury formations at Spirit River, northwestern Alberta; and in the Upper Mannville (undifferentiated) Formation at Fort Augustus, central Alberta.

Remarks. *H. gigas minor* was originally reported from the Lower Albian Cummings Formation in the Vermilion are of Alberta (slightly west of area five on figure 2).

Haplophragmoides gilberti Eicher, 1965

Plate 2, figures 9a, b, 11a, b, 15a, b

Haplophragmoides gilberti Eicher, 1965, Journal of Paleontology v. 39, no. 5, p. 894, pl. 103, figs. 11, 13, 14.

Haplophragmoides gilberti Eicher. Sutherland and Stelck, 1972, Bulletin of Canadian Petroleum Geology, v. 20, p. 567-568, pl. 3, figs. 8, 9.

Occurrence. This species is recognized in the Shaftesbury Formation at Spirit River, northwestern Alberta; in the Joli Fou Formation at Fort Augustus, central Alberta; and in the Joli Fou and Westgate formations at Youngstown, central Alberta.

Remarks. *H. gilberti* was originally described from the Cenomanian Graneros shale in Colorado.

Haplophragmoides sp. cf. *H. kirki* Wickenden, 1932

Haplophragmoides kirki Wickenden, 1932, Transactions of the Royal Society of Canada, ser. 3, v. 26, sec. 4, p. 85, pl. 1, figs. 1a, b, c.

Haplophragmoides kirki Wickenden. McNeil and Caldwell, 1981, Geological Association of Canada, Special Paper no. 21, p. 152, pl. 11, figs. 10a, b.

Occurrence. This species is recognized in the Wilrich and Falher members of the Spirit River Formation and in the Shaftesbury Formation at Spirit River, northwestern Alberta; in the Upper Mannville (undifferentiated) and Joli Fou formations at Fort Augustus, central Alberta; and in the Joli Fou Formation at Youngstown, central Alberta.

Remarks. *H. kirki* was originally described from the Campanian Bearpaw Formation in Alberta. It has since been recognized in Albian age strata in northeastern British Columbia (Stelck *et al.*, 1956) and Saskatchewan (North and Caldwell, 1975a).

Haplophragmoides linki Nauss, 1947

Plate 2, figures 12a, b, 14a, b, 16a, b

Haplophragmoides linki Nauss, 1947, Journal of Paleontology, v. 21, no. 4, p. 339, pl. 49, figs. 7a, b.

Haplophragmoides linki Nauss. North and Caldwell, 1975a, Geological Survey of Canada Paper 74-38 pl. 1, figs. 17a, b.

Occurrence. This species occurs in the Bluesky and Spirit River formations, Harmon Member of the Peace River Formation and Shaftesbury Formation at Spirit River, northwestern Alberta; and in the Upper Mannville (undifferentiated) Formation at Fort Augustus.

Remarks. *H. linki* was originally described from the Lloydminster Member of the Cantuar Formation in the Vermilion area of Alberta.

Haplophragmoides multiplum Stelck and Wall, 1956

Haplophragmoides multiplum Stelck and Wall, in Stelck *et al.*, 1956, Research Council of Alberta, Report no. 75, p. 37-38, pl. 4, figs. 14-16.

Haplophragmoides multiplum Stelck and Wall. Eicher, 1960, Peabody Museum of Natural History, Bulletin, no. 15, p. 58-59, pl. 3, fig. 12.

Occurrence. This species is recognized in the Wilrich and Falher members of the Spirit River, Harmon Member of the Peace River, and the Shaftesbury formations at Spirit River, northwestern Alberta.

Remarks. *H. multiplum* was originally described from the Early Albian Gates Formation of northeastern British Columbia.

Haplophragmoides postis Stelck and Wall, 1956

Plate 3, figures 1a, b

Haplophragmoides postis Stelck and Wall, in Stelck *et al.*, 1956, Research Council of Alberta, Report no. 75, p. 38, pl. 4, figs. 23, 24.

Haplophragmoides sp. cf. *H. postis* Stelck and Wall. Koke and Stelck, 1985, Canadian Journal of Earth Sciences v. 22, pl. 2, figs. 15-21, 26-30.

Occurrence. This species occurs in the Falher and Notikewin members of the Spirit River, Harmon and Paddy members of the Peace River, and the Shaftesbury formations at Spirit River, northwestern Alberta; and in the Upper Mannville (undifferentiated) Formation at Fort Augustus, central Alberta.

Remarks. *H. postis* was originally reported from the Early Albian Gates Formation of northeastern British Columbia, but has since been recognized in the Upper Albian Joli Fou Formation.

Haplophragmoides postis goodrichi Sutherland and Stelck, 1972

Plate 3, figures 2a, b

Haplophragmoides postis goodrichi Sutherland and Stelck, 1972, Bulletin of Canadian Petroleum Geology, p. 570, pl. 3, figures 13 - 15.

Occurrence. This species is recognized in the Shaftesbury Formation at Spirit River, northwestern Alberta; and in the Joli Fou, Viking and Westgate formations at Fort Augustus and Youngstown, central Alberta.

Remarks. *H. postis goodrichi* was originally described from the Upper Albian Goodrich Formation in northeastern British Columbia.

Haplophragmoides topagorukensis Tappan, 1957

Haplophragmoides topagorukensis Tappan, 1957, United States National Museum, Bulletin 215, p. 203, pl. 65, figs. 15-25.

Haplophragmoides topagorukensis Tappan. Sutherland and Stelck, 1972, Bulletin of Canadian Petroleum Geology, p. 570 - 571, pl. 3, figures 10 - 12.

Occurrence. This species occurs in the Bluesky, Wilrich and Falher members of the Spirit River and Shaftesbury formations at Spirit River, northwestern Alberta; and in the Upper Mannville (undifferentiated), Joli Fou and Westgate formations at Fort Augustus, central Alberta.

Remarks. *H. topagorukensis* was originally described from the Albian upper Torok, Topagoruk, and Grandstand formations in northern Alaska. Chamney (1978) divided Tappan's 1962 (plate 31) illustrated figures into three species. The Middle and Upper Albian *H. topagorukensis* (*sensu stricto*) encompasses Tappan (1962) pl. 31 figs. 4, 5, 7, 9, 12, 13; the Lower and Middle Albian *H. yukonensis* includes Tappan (1962) pl. 31, figs. 6, 8, 14; and Lower to Upper Albian *H. peelensis* contains Tappan (1962) pl. 31, figs. 1, 2, 3, 10, 11, 15. The identification in this study follows this classification.

Haplophragmoides uniorbis Eicher, 1960

Haplophragmoides uniorbis Eicher, 1960, Peabody Museum of Natural History, Bulletin 15, p. 59, pl. 3, figs. 13-15.

Haplophragmoides uniorbis Eicher. Stelck, 1991, Canadian Journal of Earth Sciences v. 28, pl. 2, figs. 19-24.

Occurrence. This species occurs in the Wilrich and Falher members of the Spirit River Formation at Spirit River, northwestern Alberta.

Remarks. *H. uniorbis* was originally described from the Upper Albian Shell Creek and Mowry formations.

Haplophragmoides yukonensis Chamney, 1978

Plate 3, figures 3a, b, 4a, b

Haplophragmoides yukonensis Chamney, 1978, Geological Survey of Canada, Bulletin no. 253, p. 13, pl. 2, figs. 8, 9.

Haplophragmoides yukonensis Chamney. Stelck, 1991, Canadian Journal of Earth Sciences, v. 28, pl. 2, figs. 36-39.

Occurrence. This species occurs in the Bluesky, Wilrich and Falher members of the Spirit River, Harmon Member of the Peace River, and Shaftesbury formations at Spirit River, northwestern Alberta; in the Upper Mannville (undifferentiated), Joli Fou and Westgate formations at Fort Augustus, central Alberta and in the Joli Fou and Viking formations at Youngstown, central Alberta.

Remarks. *H. yukonensis* was originally described as a break-off species of *H. topagorukensis*.

This species differs from *H. topagorukensis* in the greater number of chambers in the final whorl and tends to be more evolute.

Genus *Ammobaculites* Cushman, 1910

Ammobaculites sp. cf. *A. erectus* Crespin, 1963

Ammobaculites erectus Crespin, 1963, Department of National Development, Bureau of Mineral Resources, Geology and Geophysics, Bulletin no. 66, p. 36-37, pl. 8, figs. 9-12.

Ammobaculites erectus Crespin. Stelck and Koke, 1987, Journal of Earth Sciences, v. 24, pl. 3, figs. 22, 23.

Occurrence. This species occurs in the Harmon Member of the Peace River Formation at Spirit River, northwestern Alberta.

Remarks. *A. erectus* has been recognized in the Upper Albian of northeastern British Columbia.

Ammobaculites fragmentarius Cushman, 1927

Plate 3, figures 5 - 8

Ammobaculites fragmentaria Cushman, 1927a, Royal Society of Canada Transactions, 3rd series, v. 21, sec. 4, p. 130, pl. 1, fig. 8.

Ammobaculites fragmentarius Cushman. Stelck, Wall, Bahan, and Martin, 1956, Alberta Research Council Report no. 75, p. 21-22, pl. 5, figs. 18-19.

Occurrence. This species is recognized in the Bluesky, Wilrich and Falher members of the Spirit River, Harmon Member of the Peace River, and Shaftesbury formations at Spirit River, northwestern Alberta; in the Joli Fou, Viking and Westgate formations at Fort Augustus, central Alberta; and in the Viking Formation at Youngstown, central Alberta.

Remarks. *A. fragmentarius* was originally reported from the Cretaceous of east-central Alberta.

Ammobaculites pacalis pattersoni Sutherland and Stelck, 1972

Plate 3, figures 9, 11a, b, 15a, b

Ammobaculites pacalis pattersoni Sutherland and Stelck, 1972, Bulletin of Canadian Petroleum Geology v. 20, p. 571, pl. 4, figs. 4, 5, 10.

Occurrence. This species occurs in the Shaftesbury Formation at Spirit River, northwestern Alberta; and in the Joli Fou and Westgate formations at Fort Augustus, central Alberta

Remarks. *A. pacalis pattersoni* was originally described from the Goodrich Sandstone in northeastern British Columbia.

Ammobaculites petilus Eicher, 1960

Plate 3, figures 12a, b

Ammobaculites petilus Eicher, 1960, Peabody Museum of Natural History, Bulletin 15, p. 62-63, pl. 4, figs. 2a, b, 6.

Ammobaculites petilus Eicher. North and Caldwell, 1975a, Geological Survey of Canada
Paper 74-38, pl. 2, figs. 6, 7.

Occurrence. This species occurs in the Shaftesbury Formation at Spirit River, northwestern Alberta; in the Joli Fou Formation at Fort Augustus, central Alberta; and in the Westgate Formation at Youngstown, central Alberta.

Remarks. *A. petilus* was originally described from the Upper Albian Thermopolis Shale, Wyoming.

Ammobaculites tyrrelli Nauss, 1947

Plate 3, figures 10, 13, 14; Plate 4, figures 1a, b

Ammobaculites tyrrelli Nauss, 1947, Journal of Paleontology v. 21, no. 4, p. 333, pl. 48, fig. 2.

Ammobaculites tyrrelli jolifouensis Stelck and Wall, in Stelck *et al.*, 1956, Research Council of Alberta Report no. 75, p. 23, pl. 5, fig. 20.

Occurrence. This species occurs in the Spirit River and Shaftesbury formations, northwestern Alberta; in the Upper Mannville, Joli Fou, Viking and Westgate formations at Fort Augustus, central Alberta; and in the Joli Fou, Viking and Westgate formations at Youngstown, central Alberta.

Remarks. I included *Ammobaculites tyrrelli jolifouensis* Stelck and Wall in this category as the specimens quite closely resembled *A. tyrrelli tyrrelli*. Also included in this category is *A. humei* Nauss which has a similar stratigraphic range in this study to *A. tyrrelli*. Nauss described the difference between *A. tyrrelli* and *A. humei* as the latter having

more coarse grains in the test and a pyriform last chamber. These differences may be the result of differing substrates and preservation. *A. tyrrelli* (*sensu stricto*) was originally described from the Llyodminster Shale in the Vermilion area of Alberta.

Ammobaculites wenonahae Tappan, 1960

Plate 4, figures 2, 3, 7

Ammobaculites wenonahae Tappan, 1960, American Association of Petroleum Geologists Bulletin, v. 44, no. 3, p. 291, pl. 1, figs. 3-6.

Ammobaculites wenonahae Tappan. Koke and Stelck, 1984, Canadian Society of Petroleum Geologists Memoir 9, pl. 1, figs. 33-35.

Occurrence. This species is recognized in the Shaftesbury Formation at Spirit River, northwestern Alberta.

Remarks. *A. wenonahae* was initially described from the Middle Albian Topagoruk and Upper Albian Grandstand formations, northern Alaska.

Ammobaculoides whitneyi (Cushman and Alexander), 1932

Spiroplectammina whitneyi Cushman and Alexander, 1932, Contributions to the Cushman Laboratory of Foraminiferal Research, v. 6, no. 1, p. 8, pl. 2, figs. 12a-b.

Ammobaculoides whitneyi (Cushman and Alexander). Loeblich and Tappan, 1949, Journal of Paleontology v. 23, no. 3, p. 252, pl. 47, figs. 2-4.

Ammobaculoides whitneyi (Cushman and Alexander). North and Caldwell, 1975a, Geological Survey of Canada Paper 74-38, pl. 2, fig. 12.

Occurrence. This species occurs in the Shaftesbury Formation at Spirit River, northwestern Alberta.

Remarks. This species is represented by a single specimen.

Genus *Ammomarginulina* Wiesner, 1931

Ammomarginulina asperata Guliov, 1966

Ammomarginulina asperata Guliov, 1966, Contributions of the Cushman Foundation for Foraminiferal Research, p. 142-143, pl. 12, figs. 6-9.

Occurrence. This species is recognized in the Joli Fou and Viking formations at Fort Augustus, central Alberta.

Remarks. *A. asperata* was originally described from the Joli Fou Formation in Saskatchewan.

Ammomarginulina cragini Loeblich and Tappan, 1950

Plate 4, figure 4

Ammomarginulina cragini Loeblich and Tappan, 1950, University of Kansas Paleontological Contributions, Protozoa, art. 3, p. 6, pl. 1, figs. 4-6.

Ammomarginulina cragini Loeblich and Tappan. Koke and Stelck, 1985, Canadian Journal of Earth Sciences v. 22, pl. 3, figs. 18-22.

Occurrence. This species is recognized in the Shaftesbury Formation at Spirit River, northwestern Alberta; and in the Westgate Formation at Fort Augustus, central Alberta.

Remarks. *A. cragini* was originally recorded from the Lower Cretaceous type Kiowa shale of Kansas.

Ammomarginulina paterella Eicher, 1967

Ammomarginulina paterella Eicher, 1967, Journal of Paleontology, v. 41, no. 1, p. 182, pl. 17, figs. 15, 16.

Occurrence. This species occurs in the Shaftesbury Formation at Spirit River, northwestern Alberta.

Remarks. *A. paterella* was originally described from the Belle Fourche Formation, Montana.

Family EGGERELLIDAE Cushman, 1937

Genus *Eggerella* Cushman, 1933

Eggerella sp. A

Plate 4, figures 15a, b

Eggerella sp. A Stelck and Wall, in Stelck *et al.*, 1956, Research Council of Alberta, Report no. 75, p. 31, pl. 2, figs. 17 - 20.

Eggerella sp. A Stelck and Wall. Koke and Stelck, 1985, Canadian Journal of Earth Sciences, v. 22, pl. 4, figs. 24 - 26.

Occurrence. This species occurs in the Wilrich Member of the Spirit River and in the Shaftesbury formations at Spirit River, northwestern Alberta.

Remarks. *Eggerella* sp. A was originally recorded from the Clearwater Formation in northeastern Alberta.

Family TEXTULARIIDAE Ehrenberg, 1838

Genus *Textularia* DeFrance, 1824

Textularia topagorukensis Tappan, 1957

Plate 4, figures 5a, b, 6

Textularia topagorukensis Tappan, 1957, United States National Museum, Bulletin no. 215, p. 205, pl. 66, figs. 8, 9.

Textularia topagorukensis Tappan. Stelck, 1975, Geological Association of Canada Special Paper no. 13, pl. 3, figs. 22, 23.

Occurrence. This species occurs in the Bluesky Formation and in the Wilrich and Falher members of the Spirit River Formation at Spirit River, northwestern Alberta.

Remarks. *T. topagorukensis* was originally described from the Middle Albian Topagoruk and Upper Albian Grandstand formations, northern Alaska.

Genus *Pseudobolivina* Wiesner, 1931

Pseudobolivina variana (Eicher), 1960

Bimonilina variana Eicher, 1960, Peabody Museum of Natural History, Bulletin 15, p. 67, pl. 4, figs. 15-19.

Pseudobolivina variana (Eicher). Eicher, 1965, Journal of Paleontology v. 39, p. 897, pl. 104, fig. 8.

Occurrence. This species occurs in the Bluesky, Wilrich Member of the Spirit River, and Shaftesbury formations at Spirit River, northwestern Alberta; in the Upper Mannville,

Joli Fou, Viking and Westgate formations at Fort Augustus, central Alberta; and in the Westgate Formation at Youngstown, central Alberta.

Remarks. *P. variana* was originally recorded from the Upper Albian Thermopolis shale in Wyoming

Family TEXTULARIOPSIDAE Loeblich and Tappan, 1982

Genus *Textulariopsis* Banner and Pereira, 1981

Textulariopsis minuta (Berthelin), 1880

Plate 4, figures 8a, b, 10a, b, 11a, b

Textulariopsis minuta (Berthelin). Stelck and Hedinger, 1983, Canadian Journal of Earth Sciences v. 20, pl. 2, figs. 9, 10.

Textulariopsis minuta (Berthelin). Stelck and Koke, 1987, Canadian Journal of Earth Sciences v. 24, pl. 4, figs. 26, 27.

Occurrence. This species occurs in the Bluesky and Spirit River formations at Spirit River , northwestern Alberta; in the Viking and Westgate formations at Fort Augustus, central Alberta; and in the Joli Fou, Viking and Westgate formations at Youngstown, central Alberta.

Remarks. The original reference was unavailable for this species. *T. minuta* may have been placed originally in one of a number of genera including *Textularia*, *Bigenerina* or *Vulvulina*.

Family TROCHAMMINIDAE Schwager, 1877

Genus *Trochammina* Parker and Jones, 1859

Trochammina alcanensis Stelck, 1975

Plate 4, figures 9a, b

Trochammina alcanensis Stelck, 1975, Geological Association of Canada Special Paper no. 13, p. 266, pl. 3, figs. 16, 17, 20, 21.

Trochammina alcanensis Stelck. Stelck and Koke, 1987, Canadian Journal of Earth Sciences v. 24, pl. 4, figs. 14-16.

Occurrence. This species is recognized in the Shaftesbury Formation at Spirit River, northwestern Alberta; in the Westgate Formation at Fort Augustus, central Alberta; and in the Joli Fou and Viking formations at Youngstown, central Alberta.

Remarks. *T. alcanensis* was originally described from the Upper Albian Buckinghorse shale in northeastern British Columbia.

Trochammina bredini Stelck, 1991

Trochammina bredini Stelck. 1991, Canadian Journal of Earth Sciences, p. 572, pl. 3, figs. 15-17, 22.

Occurrence. This species is recognized in the Shaftesbury Formation at Spirit River, northwestern Alberta.

Remarks. *T. bredini* was originally described from the Upper Albian Hasler Shale in northeastern British Columbia.

Trochammina sp. cf. *T. depressa* Lozo, 1944

Trochammina depressa Lozo, 1944, American Midland Naturalist v. 31 no. 3, p. 552, pl. 2, figs. 4, 5.

Trochammina depressa Lozo. Koke and Stelck, 1985, Canadian Journal of Earth Sciences v. 22, pl. 4, figs. 6-8.

Occurrence. This species is recognized in the Notikewin Member of the Spirit River Formation at Spirit River, northwestern Alberta.

Trochammina sp. cf. *T. diagonis* (Carsey), 1926

Haplophragmoides diagonis Carsey, 1926, University of Texas Bulletin no. 2612, p. 22, fig. 1.

Occurrence. This species is recognized in the Shaftesbury Formation at Spirit River, northwestern Alberta.

Remarks. *Trochammina* sp. cf. *T. diagonis* is represented by a single specimen.

Trochammina gatensis Stelck and Wall, 1956

Plate 4, figures 12a, b

Trochammina gatensis Stelck and Wall, in Stelck *et al.*, 1956, Research Council of Alberta, Report no. 75, p. 53-54, pl. 4, figs. 9-11.

Trochammina gatensis Stelck and Wall. Koke and Stelck, 1985, Canadian Journal of Earth Sciences v. 22, pl. 4, figs. 11, 12, 17, 18.

Occurrence. This species is recognized in the Falher Member of the Spirit River and the Shaftesbury formations at Spirit River, northwestern Alberta; in the Viking and Westgate formations at Fort Augustus and Youngstown, central Alberta.

Remarks. *T. gatensis* was originally described from the Gates Sandstone in northeastern British Columbia.

Trochammina mcmurrayensis Mellon and Wall, 1956

Trochammina mcmurrayensis Mellon and Wall, 1956, Research Council of Alberta, Report no. 72, p. 28, pl. 1, figs. 2-5.

Occurrence. This species is found near the base of the Wilrich Member of the Spirit River Formation in northwestern Alberta, Imperial Spirit River 12-20-78-6W6.

Remarks. This species was first described from the upper McMurray Formation of northeastern Alberta.

Trochammina rainwateri Cushman and Applin, 1946

Trochammina rainwateri Cushman and Applin, 1946, Cushman Laboratory for Foraminiferal Research, Cont. v. 22, no. 3, p. 75, pl. 13, fig. 9.

Trochammina rainwateri Cushman and Applin. Bloch *et al.*, 1993, Bulletin of Canadian Petroleum Geology v. 41, pl. 1, figs. 7, 8.

Occurrence. This species is recognized in the Shaftesbury Formation at Spirit River, northwestern Alberta; in the Westgate Formation at Fort Augustus, central Alberta; and in the Joli Fou and Viking formations at Youngstown, central Alberta.

Remarks. *T. rainwateri* was originally described from the Woodbine Formation (Upper Cretaceous) of Texas.

Trochammina rutherfordi Stelck and Wall, 1955

Plate 4, figure 13

Trochammina rutherfordi Stelck and Wall, 1955, Research Council of Alberta, Report no. 70, p. 56-57, pl. 1, figs. 11, 12.

Trochammina rutherfordi Stelck and Wall. North and Caldwell, 1975a, Geological Survey of Canada Paper 74-38, pl. 3, fig. 1.

Occurrence. This species was recognized in the Shaftesbury Formation at Spirit River, northwestern Alberta.

Remarks. *T. rutherfordi* was originally described from the Cenomanian Kaskapau Formation in northwestern Alberta.

Trochammina umiatensis Tappan, 1957

Plate 4, figures 14a, b

Trochammina umiatensis Tappan, 1957, United States National Museum, Bulletin no. 215, p. 214, pl. 67, figs. 27-29.

Trochammina umiatensis Tappan. Sutherland and Stelck, 1972, Bulletin of Canadian Petroleum Geology v. 20, p. 575, pl. 5, figs. 1-4.

Occurrence. This species is recognized in the Bluesky and Spirit River formations at Spirit River, northwestern Alberta.

Remarks. *T. umiatensis* was originally described from the Upper Albian Grandstand Formation, northern Alaska.

Trochammina wetteri Stelck and Wall, 1955

Trochammina wetteri Stelck and Wall, 1955, Research Council of Alberta, Report no. 70, p. 59-60, pl. 2, figs. 1-3, 6.

Trochammina wetteri Stelck and Wall. Stelck and Hedinger, 1983. Canadian Journal of Earth Sciences, v. 20, pl. 2, figs. 19, 20, 33, 34.

Occurrence. This species is recognized in the Bluesky Formation and the Wilrich and Falher members of the Spirit River Formation at Spirit River, northwestern Alberta.

Remarks. This species is represented by very few specimens. *T. wetteri* was originally described from the Cenomanian Kaskapau Formation in northwestern Alberta.

Family VERNEUILINIDAE Cushman, 1911

Genus *Uvigerinammina* Majzon, 1943

Uvigerinammina athabascensis (Mellon and Wall), 1956

Plate 5, figure 9

Tritaxia athabascensis Mellon and Wall, 1956, Research Council of Alberta, Report no. 72, p. 27, pl. 1, figs. 16, 17.

Uvigerinammina athabascensis (Mellon and Wall). Tappan, 1962, United States Geological Survey, Professional Paper 236-C, p. 144-145, pl. 33, fig. 12.

Occurrence. Recognized in the Wilrich Member of the Spirit River Formation of northwestern Alberta

Remarks. Tappan (1962) changed the generic assignment of *Tritaxia athabascensis* Mellon and Wall, 1956 and *Tritaxia manitobensis* Wickenden, 1932, to *Uvigerinammina* based on chamber arrangement. There is a tendency to biserial chamber arrangement in both species. *Uvigerinammina athabascensis* (Mellon and Wall) differs from *Uvigerinammina manitobensis* (Wickenden) in being larger, and more flaring from a pointed base. Originally described from the basal Clearwater Formation of northeastern Alberta, it has also been recognized at the same stratigraphic level in the Alaskan Torok Formation by Tappan (1962) who speculated that this species may be ancestral to the younger *Uvigerinammina manitobensis* (Wickenden).

Genus *Verneuilinoides* Loeblich and Tappan, 1949

Verneuilinoides borealis Tappan, 1957

Plate 5, figures 7a, b, 8a, b, 10a, b

Verneuilinoides borealis Tappan, 1957, United States National Museum, Bulletin 215, p. 206, pl. 66, figs. 10-18.

Verneuilinoides borealis Tappan. Sliter, 1981, Geological Survey of Canada Bulletin 300, p. 57, pl. 11, figs. 11, 16.

Occurrence. This species is recognized in the Bluesky, Wilrich Member of the Spirit River and Shaftesbury formations at Spirit River, northwestern Alberta; and in the Upper Mannville and Westgate formations at Fort Augustus, central Alberta.

Remarks. *V. borealis* was originally recognized in the Albian Torok, Topagoruk, and Grandstand formations, northern Alaska.

Genus *Gaudryina* d'Orbigny, 1839

Gaudryina canadensis Cushman, 1943

Plate 4, figures 17a, b; Plate 5, figures 1, 2

Bigennerina angulata Cushman, 1927a, Transactions of the Royal Society of Canada, ser. 3, v. 4, p. 131, pl. 1, fig. 10.

Gaudryina canadensis Cushman, 1943, Contrib. Cushman Laboratory for Foraminiferal Research, v. 19, pt. 2, p. 28, pl. 6, figs. 7, 8.

Gaudryina canadensis Cushman. McNeil and Caldwell, 1981, Geological Association of Canada Special Paper 21, p. 175, pl. 14, fig. 10, 11.

Occurrence. This species is recognized in the Shaftesbury Formation at Spirit River, northwestern Alberta; and in the Joli Fou and Westgate formation at Fort Augustus and Youngstown, central Alberta.

Remarks. *G. canadensis* was originally described from the subsurface of Alberta. The name was changed from *Bigennerina angulata* in 1943 due to name duplication.

Gaudryina nanushukensis Tappan, 1951

Plate 5, figures 3 - 5

Gaudryina nanushukensis Tappan, 1951, Cushman Foundation for Foraminiferal Research, Contributions, v. 2, pt. 1, pl. 1, figs. 8a-11.

Gaudryina sp. B. Wickenden, 1951, Canada Dept. Mines and Tech. Surv., Geol. Survey of Canada, Paper 51-16, p. 44, pl. 1B, fig. 7.

Occurrence. This species occurs in the Wilrich and Falher members of the Spirit River Formation at Spirit River, northwestern Alberta; and in the Upper Mannville Formation At Fort Augustus, central Alberta.

Remarks. *G. nanushukensis* was originally described from the Middle Albian Topagoruk Formation, northern Alaska. The description of *Gaudryina* sp. B of Wickenden matches very closely that of Tappan and is placed here in synonymy. The forms described by Tappan exhibit a wide variability in height, and how flaring the sides of the test are.

Gaudryina tailleuri (Tappan), 1957

Plate 5, figure 6

Verneuilinoides tailleuri Tappan, 1957, United States National Museum, Bulletin 215, p. 208, pl. 66, figs. 19-22.

Gaudryina tailleuri (Tappan). Tappan, 1962, United States Geological Survey Professional Paper 236-C, p. 149, pl. 35, figs. 8-16.

Verneuilinoides tailleuri Tappan. Stelck, 1975, Geological Association of Canada Special Paper no. 13, pl. 3, figs. 29-34.

Occurrence. This species is recognized in the Bluesky Formation and Wilrich Member of the Spirit River Formation at Spirit River, northwestern Alberta; and in the Upper Mannville and Joli Fou formations at Fort Augustus, central Alberta.

Remarks. *G. tailleuri* was originally described from the Lower Albian Fortress Mountain Formation, northern Alaska.

Genus *Verneuilina* d'Orbigny, 1839

Verneuilina canadensis Cushman, 1927

Plate 4, figures 16a, b

Verneuilina canadensis Cushman, 1927a, Transactions of the Royal Society of Canada ser. 3, v. 21, sec. 4, p. 131, pl. 1, fig. 11.

Verneuilina canadensis Cushman. McNeil and Caldwell, 1981, Geological Association of Canada Special Paper 21, p. 175, pl. 14, fig. 3.

Occurrence. This species is recognized in the Shaftesbury Formation at Spirit River, northwestern Alberta; and in the Westgate Formation at Fort Augustus and Youngstown, central Alberta.

Remarks. *V. canadensis* was originally described from the subsurface of Alberta, uncertain formation.

Family ATAXOPHRAGMIIDAE Schwager, 1877

Genus *Arenobulimina* Cushman, 1927

Arenobulimina paynei Tappan, 1957

Arenobulimina paynei Tappan, 1957, United States National Museum, Bulletin 215, p. 208, pl. 67, figs. 1-4.

Arenobulimina paynei Tappan. North and Caldwell, 1975a, Geological Survey of Canada Paper 74-38, pl. 3, figs. 16, 17.

Arenobulimina? paynei Tappan. Koke and Stelck, 1984, Canadian Society of Petroleum Geologists Memoir 9, pl. 1, fig. 64.

Occurrence. This species is recognized in the Bluesky and Spirit River formations at Spirit River, northwestern Alberta; and in the Upper Mannville and Westgate formations at Fort Augustus, central Alberta.

Remarks. *A. paynei* was originally recognized in the Topagoruk and Grandstand formations, northern Alaska.

Family GLOBOTEXTULARIIDAE Cushman, 1927b

Genus *Gravellina* Brönnimann, 1933

Gravellina chamneyi Stelck, 1975

Plate 5, figures 11 - 13

Gravellina chamneyi Stelck, 1975, Geological Association of Canada Special Paper 13, p. 267-268, pl. 3, figs. 27, 28, 37-44.

Gravellina chamneyi Stelck. Koke and Stelck, 1985, Canadian Journal of Earth Sciences v. 22, pl. 4, figs. 30, 31, 34-36.

Occurrence. This species is recognized in the Falher Member of the Spirit River and Shaftesbury formations at Spirit River, northwestern Alberta; and in the Joli Fou, Viking and Westgate formations at Fort Augustus and Youngstown, central Alberta.

Remarks. *G. chamneyi* was originally described from the upper Buckinghorse shale (Upper Albian) in northeastern British Columbia.

Family NODOSARIIDAE Ehrenberg, 1838

Genus *Lenticulina* Lamarck, 1804

Lenticulina bayrocki Mellon and Wall, 1956

Plate 6, figure 1

Lenticulina sp. Wickenden, 1951, Geological Survey of Canada, Paper 51-16, p. 37, pl. 1A, figs. 12, 13.

Lenticulina bayrocki Mellon and Wall, 1956, Research Council of Alberta, Report no. 72, p. 20-21, pl. 2, figs. 1, 2.

Occurrence. This species occurs in the Bluesky Formation and the Wilrich Member of the Spirit River Formation of northwestern Alberta, Imperial Spirit River.

Remarks. This species was first described from the Clearwater Formation of northeastern Alberta (Mellon and Wall, 1956). It has also been recognized in the Falher Member of the Spirit River Formation (Wickenden, 1951) and in the Grandstand, Topagoruk and Torok formations of Alaska (Tappan, 1962)

Genus *Marginulina* d'Orbigny, 1826

Marginulina sp.

Occurrence. This species occurs in the Wilrich Member of the Spirit River Formation of northwestern Alberta, Imperial Spirit River.

Remarks. A similar species was described from the lower Moosebar Formation by Stelck and Wall (1956) but remained unnamed.

Genus *Marginulinopsis* Silvestri, 1904

Marginulinopsis collinsi Mellon and Wall, 1956

Plate 6, figure 2

Marginulina sp. A Wickenden, (*pars*), 1951, Geological Survey of Canada, Paper 51-16, p. 37, pl. 1A, figs. 14, 16 (*non* 15).

Marginulinopsis collinsi Mellon and Wall, 1956, Research Council of Alberta, Report no. 72, p. 20-21, pl. 2, figs. 1, 2.

Occurrence. This species occurs in the Wilrich Member of the Spirit River Formation of northwestern Alberta, Imperial Spirit River 12-20-78-6W6, and in the lower Mannville Formation (undifferentiated) of central Alberta, Fort Augustus.

Remarks. *M. collinsi* was originally described from the Falher Member of the Spirit River Formation of northwestern Alberta (Wickenden, 1951), this species has also been recognized in the Clearwater Formation of northeastern Alberta (Mellon and Wall, 1956) and in the Torok, Topagoruk, and Grandstand formations of Alaska (Tappan, 1962).

Genus *Pseudonodosaria* Boomgaart, 1949

Pseudonodosaria clearwaterensis Mellon and Wall, 1956

Pseudonodosaria clearwaterensis Mellon and Wall, 1956, Research Council of Alberta, Report no. 72, p. 23-24, pl. 2, figs. 15-17.

Pseudonodosaria clearwaterensis Mellon and Wall. Stelck and Wall, in Stelck *et al.*, 1956, Research Council of Alberta, Report no. 75, p. 47-48, pl. 1, figs. 9, 10; pl. 3, figs. 1, 2, 5, 6.

Occurrence. This species occurs in the Wilrich Member of the Spirit River Formation of northwestern Alberta, Imperial Spirit River 12-20-78-6W6, and in the lower Mannville Formation (undifferentiated) of central Alberta, Fort Augustus.

Remarks. *P. clearwaterensis* was originally described from the Clearwater Formation of northeastern Alberta, this species has also been recognized in the Moosebar Formation of northeastern British Columbia (Stelck, 1950). It is one of the few calcareous foraminifera species of the Clearwater Formation which was not recognized by Tappan (1962) in Alaska within the time equivalent Torok Formation.

Genus *Saracenaria* Defrance, 1824

Saracenaria projectura Stelck and Wall, 1956

Plate 6, figures 4a, b

Saracenaria projectura Stelck and Wall, in Stelck *et al.*, 1956, Research Council of Alberta, Report no. 75, p. 50, pl. 3, figs. 22-25.

Occurrence. This species occurs in the Wilrich Member of the Spirit River Formation of northwestern Alberta, Imperial Spirit River.

Remarks. This species differs from *S. trollopei* Mellon and Wall in being smaller, with a more pronounced coil and somewhat more compressed test. It was first described from the Clearwater Formation of northeastern Alberta, and has since been recognized in the Grandstand, Topagoruk, Torok, and Fortress Mountain formations of Alaska (Tappan, 1962).

Saracenaria trollopei Mellon and Wall, 1956

Saracenaria trollopei Mellon and Wall, 1956, Research Council of Alberta, Report no. 72, p. 25, pl. 2, figs. 26, 27.

Saracenaria trollopei Mellon and Wall. Stelck and Wall, *in* Stelck *et al.*, 1956, Research Council of Alberta, Report no. 75, p. 50-51, pl. 1, figs. 4, 5; plate 3, fig. 21.

Occurrence. This species is found in the Wilrich Member of the Spirit River Formation of northwestern Alberta, Imperial Spirit River.

Remarks. This species was originally described from the basal Clearwater Formation in northeastern Alberta. It has also been recognized in the lower part of the Moosebar Formation of northeastern British Columbia (Stelck, 1950) and in the Topagoruk and Torok formations of Alaska (Tappan, 1962).

Saracenaria sp. A

Plate 6, figures 3a, b

Saracenaria sp. Mellon and Wall, (*pars*), 1956, Research Council of Alberta, Report no. 72, p. 26, pl. 2, figs. 20, 21, possibly 24, 25 (*non* 18, 19, 22, 23).

Saracenaria sp. A Mellon and Wall. Stelck and Wall, in Stelck *et al.*, 1956, Research Council of Alberta, Report no. 75, p. 51-52, pl. 3, figs. 26, 27.

Occurrence. This species is found in the Wilrich Member of the Spirit River Formation of northwestern Alberta, Imperial Spirit River 12-20-78-6W6.

Remarks. This species was originally described from the Clearwater Formation of northeastern Alberta.

Saracenaria sp. B

Plate 6, figures 6a, b

Saracenaria sp. Mellon and Wall, 1956, Research Council of Alberta, Report no. 72, p. 26, pl. 2, figs. 18, 19 (*non* 20-25).

Occurrence. This species is found in the Wilrich Member of the Spirit River Formation of northwestern Alberta, Imperial Spirit River.

Remarks. This species was originally described from the Clearwater Formation of northeastern Alberta.

Family POLYMORPHINIDAE d'Orbigny, 1839

Genus *Globulina* d'Orbigny, 1839

Globulina lacrima Reuss ssp. *canadensis* Mellon and Wall

Plate 6, figures 5a, b

Globulina sp. Wickenden, 1951, Geological Survey of Canada, Paper 51-16, p. 40, pl. 1A, fig. 27.

Globulina lacrima Reuss ssp. *canadensis* Mellon and Wall, 1956, Research Council of Alberta, Report no. 72, p. 16, pl. 2, fig. 6 .

Occurrence. This variety is found in the Wilrich Member of the Spirit River Formation of northwestern Alberta, Imperial Spirit River.

Remarks. This form was considered to be a subspecies of Reuss' species because of its consistently smaller size. The geographical range of this variety is one of the largest of the lower Albian calcareous species. This variety was first recorded from the lower Falher Member of the Spirit River Formation of northwestern Alberta (Wickenden, 1951). It has also been recognized in the lower part of the Moosebar Formation of northeastern British Columbia (Stelck, 1950), the basal Clearwater Formation of northeastern Alberta (Mellon and Wall, 1956) and the Grandstand, Topagoruk, Torok, and Fortress Mountain formations of Alaska (Tappan, 1962).

Family DISCORBIDAE Ehrenberg, 1838

Genus *Discorbis* Lamarck, 1804

Discorbis norrisi Mellon and Wall, 1956

Plate 6, figures 7a, b, 8a, b

Discorbis norrisi Mellon and Wall, 1956, Research Council of Alberta, Report no. 72, p. 15, pl. 2, figs. 9-11.

Discorbis norrisi Mellon and Wall. Stelck and Wall, in Stelck *et al.*, 1956, Research Council of Alberta, Report no.75, p. 30, pl. 2, figs. 4-6.

Occurrence. This variety is found in the Wilrich Member of the Spirit River Formation of northwestern Alberta, Imperial Spirit River.

Remarks. *D. norrisi* was originally described from the Clearwater Formation of northeastern Alberta, this species has also been recognized from the Wilrich Member of the Spirit River Formation of northwestern Alberta (Stelck *et al.*, 1956).

Family QUADRIMORPHINIDAE Saidova, 1981

Genus *Quadrिमorphina* Finlay, 1939

Quadrिमorphina albertensis Mellon and Wall, 1956

Plate 6, figures 9a, b, 10a, b

Quadrिमorphina sp. Wickenden, 1951, Geological Survey of Canada, Paper 51-16, p. 42, pl. 1A, fig. 36.

Quadrिमorphina albertensis Mellon and Wall, 1956, Research Council of Alberta, Report no. 72, p. 24-25, pl. 2, figs. 12-14.

Occurrence. This species is found in the Wilrich Member of the Spirit River Formation of northwestern Alberta, Imperial Spirit River.

Remarks. This species was first recorded from the lower Falher Member of the Spirit River Formation of northwestern Alberta (Wickenden, 1951). It has also been recognized in the lower part of the Moosebar Formation of northeastern British Columbia (Stelck, 1950) and the basal Clearwater Formation of northeastern Alberta (Mellon and Wall, 1956).

Family ALABAMINIDAE Hofker, 1951

Genus *Gyroidina* d'Orbigny, 1826

Gyroidina sp. cf. *G. nitida* (Reuss), 1844

Plate 6, figures 11a, b, 12

Rotalina nitida Reuss, 1844, Geognostische, Skizzen Böhmen, v. 2, pt. 1, p. 214; Verstein. böhmische. Kreideformation, 1845, pt. 1, p. 35, pl. 8, figs. 52a, b; pl. 12, figs. 8a-c, 20a, b.

Gyroidina sp. cf. *G. nitida* (Reuss). Stelck and Wall, in Stelck *et al.*, 1956, Research Council of Alberta, Report no. 75, p. 33-34, pl. 1, figs. 11-13; pl. 2, figs. 7-9.

Occurrence. This species is found in the Wilrich Member of the Spirit River Formation of northwestern Alberta, Imperial Spirit River.

Remarks. This species was originally described from the Cretaceous of Bohemia. In western Canada it has been recognized in the Falher Member of the Spirit River Formation (Wickenden, 1951) and the upper part of the Loon River (?Spirit River) Formation (Trollope, 1951) of northwestern Alberta, the Moosebar Formation of northeastern British Columbia and the Clearwater Formation of northeastern Alberta (Stelck *et al.* 1956).

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PLATE 1

PLATE 1

Agglutinated taxa:

Figures 1, 2. *Bathysiphon brosegi* Tappan. Side views, are from Spirit River, figure 1, fine grained test, from 1158.5 - 1159.7 m (3801 - 3805 ft) X91; figure 2, coarse grained test, from 997.9 - 998.6 m (3274 - 3276.5 ft) X91.

Figure 3. *Hyperammina emacerata* (Chamney), Side view, from Fort. Augustus 688.2 - 690.9 m (2258 - 2267 ft) X95.

Figure 4. *Psammosphaera* sp. A. Side view, from Fort. Augustus 688.2 - 690.9 m (2258 - 2267 ft) X127.

Figures 5, 10, 11. *Saccamina lathrami* Tappan. Figures 5 side view, from Spirit River 623.3 - 626.3 m (2045 - 2055 ft) X115; figure 10 side view, from Spirit River 649.8 - 652.8 m (2132 - 2142 ft) X131; figure 11, side view, from Fort Augustus 723.9 - 726.6 m (2375 - 2384 ft) X105.

Figures 6, 7. *Saccamina globosa* Cressin. Side views, from Spirit River , figure 6 from 1060.3 - 1063.4 m (3479 - 3489 ft) X86; figure 7 from 997.9 - 998.6 m (3274 - 3276.5 ft) X92.

Figures 8, 9. *Ammodiscus rotalarius* Loeblich and Tappan. Side views, from Spirit River 1060.3 - 1063.4 m (3479 - 3489 ft), figure 8 X95; figure 9 X77.

Figures 12, 15. *Hippocrepina barksdalei* (Tappan). Side views, from Spirit River, figure 12 from 1092.0 - 1093.9 m (3583 - 3589 ft) X131; figure 15 from 931.4 - 934.5 m (3056 - 3066 ft) X91.

Figures 13a, 13b. *Glomospira reata* Eicher. Side and apertural view of specimen from Spirit River 1158.5 - 1159.7 m (3801 - 3805 ft), 13a X128, 13b X127.

Figures 14a, 14b. *Glomospira tortuosa* Eicher. Side and edge view, from Spirit River 1158.5 - 1159.7 m (3801 - 3805 ft), 14a X142, 14b X136.

Figures 16, 17a, 17b. *Reophax deckeri* Tappan. Figure 16, side view, from Fort Augustus 688.2 - 690.9 m (2258 - 2267 ft) X113; two different side views of figure 17 from Spirit River 667.8 - 671.1 m (2191 - 2202 ft), 17a X72, 17b X68.

Figure 18. *Reophax sikanniensis* Stelck. Side view, from Spirit River 667.8 - 671.1 m (2191 - 2202 ft) X103.

Figure 19. *Reophax Troyeri* Tappan. Side view, from Spirit River 667.8 - 671.1 m (2191 - 2202 ft) X78.

PLATE 2

PLATE 2

Figures 1a, 1b. *Reophax troyeri* Tappan. Opposite sides, from Spirit River 658.6 - 661.7 m (2161 - 2171 ft), 1a X103, 1b X105.

Figure 2. *Reophax tundraensis* Chamney. Side view, from Fort Augustus 663.5 - 666.3 m (2177 - 2186 ft) X120.

Figure 3. *Miliammina awunensis* Tappan. Side view, from Spirit River 931.4 - 934.5 m (3056 - 3066 ft) X113.

Figures 4, 6a, 6b. *Miliammina manitobensis* Wickenden. From Spirit River: figure 4, side view, from 605.9 - 608.4 m (1988 - 1996 ft) X132; figure 6 opposite side views from 667.8 - 671.1 m (2191 - 2202 ft), 6a X112, 6b X111.

Figures 5a, 5b. *Miliammina ischnia* Tappan. Opposite side views, from Spirit River 649.8 - 652.8 m (2132 - 2142 ft), 5a X130, 5b X137.

Figures 7, 8. *Psamminopelta bowsheri* Tappan. Figure 7, side view, from Youngstown 801 m (2630 ft) X162; figure 8, side view, from Spirit River 923.8 - 925.3 m (3031 - 3036 ft) X98. These two specimens represent the range of sizes recorded by Tappan.

Figures 9a, 9b, 11a, 11b, 15a, 15b. *Haplophragmoides gilberti* Eicher. Figure 9 opposite side views, from Spirit River 676.9 - 680.0 m (2221 - 2231 ft), 9a X146, 9b X152; figure 11, side and apertural views, from Fort Augustus 730.9 - 733.6 m (2398 - 2407 ft), 11a X139, 11b X137; figure 15 opposite side views, from Spirit River 614.4 - 617.5 m (2016 - 2026 ft), 15a X129, 15b X135.

Figures 10a, 10b, 13. *Haplophragmoides gigas minor* Nauss. Figure 10, side and apertural views, from Spirit River 986 - 986.7 m (3235 - 3237.5 ft), 10a X85, 10b X84; figure 13, side view, from Fort Augustus 871.7 - 874.4 m (2860 - 2869 ft) X153.

Figures 12a, 12b, 14a, 14b, 16a, 16b. *Haplophragmoides linki* Nauss. Figure 12, opposite side (oblique) views, from Spirit River 1158.5 - 1159.7 m (3801 - 3805 ft), 12a X101, 12b X107; figure 14, opposite side (oblique) views, from Spirit River 931.4 - 934.5 m (3056 - 3066 ft), 14a X93, 14b X89; figure 16, opposite side views, from Fort Augustus 871.7 - 874.4 m (2860 - 2869 ft), 16a X156, 16b X142.

PLATE 3

PLATE 3

Figures 1a, 1b. *Haplophragmoides postis* Stelck and Wall. Side and apertural views, from Spirit River 676.9 - 680.0 m (2221 - 2231 ft), 1a 78, 1b 74.

Figures 2a, 2b. *Haplophragmoides postis goodrichi* Sutherland and Stelck. Opposite side views, from Fort Augustus 730.9 - 733.6 m (2398 - 2407 ft), 2a 129, 2b 119.

Figures 3a, 3b, 4a, 4b. *Haplophragmoides yukonensis* Chamney. Figure 3, side and apertural views, from Spirit River 923.8 - 925.3 m (3031 - 3036 ft), 3a 77, 3b 78; figure 4, opposite side views, from Spirit River 1158.5 - 1159.7 m (3801 - 3805 ft), 4a 93, 4b 93.

Figures 5 - 8. *Ammobaculites fragmentarius* Cushman. All side views from Spirit River: figure 5 from 716.2 - 719.3 m (2350 - 2360 ft) X74; figure 6 from 676.9 - 680.0 m (2221 - 2231 ft) X79; figure 7 from 649.8 - 652.8 m (2132 - 2142 ft) X79; figure 8 from 716.2 - 719.3 m (2350 - 2360 ft) X82.

Figures 9, 11a, 11b, 15a, 15b. *Ammobaculites pacalis pattersoni* Sutherland and Stelck. Figure 9, side view, from Fort Augustus 733.6 - 736.4 m (2407 - 2416 ft) X82; figure 11, side views, from Spirit River 649.8 - 652.8 m (2132 - 2142 ft), 11a X120, 11b X127; figure 15, opposite side views, from Spirit River 676.9 - 680.0 m (2221 - 2231 ft), 15a X135, 15b X130.

Figures 10, 13, 14. *Ammobaculites tyrrelli* Nauss. Figure 10 side view, from Spirit River 667.8 - 671.1 m (2191 - 2202 ft) X72; figs. 13, 14 side view, both from Spirit River 658.6 - 661.7 m (2161 - 2171 ft), figure 13 X117, figure 14 X107.

Figures 12a, 12b. *Ammobaculites petilus* Eicher. Opposite side views, from Spirit River 676.9 - 680.0 m (2221 - 2231 ft), 12a X120, 12b X114.

PLATE 4

PLATE 4

Figures 1a, 1b. *Ammobaculites tyrrelli* Nauss. Opposite side views, from Spirit River 649.8 - 652.8 m (2132 - 2142 ft), 1a X95, 1b X92.

Figures 2, 3, 7. *Ammobaculites wenonahae* Tappan. Figure 2, side view, from Fort Augsutus 688.2 - 690.9 m (2258 - 2267 ft) X93; figs. 3 and 7, side views, from Spirit River 716.2 - 719.3 m (2350 - 2360 ft), figure 3 X89, figure 7 X83.

Figure 4. *Ammomarginulina cragini* Loeblich and Tappan. Side view, from Spirit River 685.5 - 688.5 m (2249 - 2259 ft) X89.

Figures 5a, 5b, 6. *Textularia topagorukensis* Tappan. Figure 5, side and edge view, from Spirit River 1139.9 - 1142.9 m (3740 - 3750 ft), 5a X100, 5b X100; figure 6, side view, from Spirit River 1158.5 - 1159.7 m (3801 - 3805 ft) X98.

Figures 8a, 8b, 10a, 10b, 11a, 11b. *Textulariopsis minuta* (Brthelin). Figure 8, opposite side views, from Spirit River 1158.5 - 1159.7 m (3801 - 3805 ft), 8a X135, 8b X131; figure 10, opposite side views, from Spirit River 1139.9 - 1142.9 m (3740 - 3750 ft), 10a X100, 10b X100; figure 11, opposite side views, from Spirit River 1158.5 - 1159.7 m (3801 - 3805 ft), 11a X127, 11b X121.

Figures 9a, 9b. *Trochammina alcanensis* Stelck. Spiral and umbilical views, from Fort Augsutus 663.5 - 666.3 m (2177 - 2186 ft), 9a X100, 9b X100.

Figures 12a, 12b. *Trochammina gatensis* Stelck and Wall. Spiral and umbilical views, from Spirit River 923.8 - 925.3 m (3031 - 3036 ft), 12a X135, 12b X130.

Figure 13. *Trochammina rutherfordi* Stelck and Wall. Spiral view, from Spirit River 658.6 - 661.7 m (2161 - 2171 ft) X106.

Figures 14a, 14b. *Trochammina umiatensis* Tappan. Spiral and umbilical views, from Spirit River 1069.5 - 1070.1 m (3509 - 3511 ft), 14a X147, 14b X159.

Figures 15a, 15b. *Eggerella* sp. A. Opposite side views, from Spirit River 676.9 - 680.0 m (2221 - 2231 ft), 15a X131, 15b X128.

Figures 16a, 16b. *Verneuulina canadensis* Cushman. Opposite side views, from Spirit River 667.8 - 671.1 m (2191 - 2202 ft), 16a X89, 16b X85.

Figures 17a, 17b. *Gaudryina canadensis* Cushman. Opposite side views, from Spirit River 667.8 - 671.1 m (2191 - 2202 ft), 17a X99, 17b X98.

PLATE 5

PLATE 5

Figures 1, 2. *Gaudryina canadensis* Cushman. Figure 1 side view, from Fort Augustus 688.2 - 690.9 m (2258 - 2267 ft) X95; figure 2 side view, from Fort Augsutus 730.9 - 733.6 m (2398 - 2407 ft) X140.

Figures 3 - 5. *Gaudryina nanushukensis* Tappan. Figure 3 opposite side views, from Spirit River 1158.5 - 1159.7 m (3801 - 3805 ft), 3a X114, 3b X109; figure 4 side view, from Spirit River 1069.5 - 1070.1 m (3509 - 3511 ft) X116; figure 5 side view, from Spirit River 997.9 - 998.6 m (3274 - 3276.5 ft) X142.

Figure 6. *Gaudryina tailleuri* (Tappan). Side view, from Fort Augustus 738.8 - 741.5 m (2424 - 2433 ft) X85.

Figures 7a, b, 8a, b, 10a, b. *Verneuilioides borealis* Tappan. Figure 7 opposite side views, from Spirit River 658.6 - 661.7 m (2161 - 2171 ft), 7a X90, 7b X92; figure 8 opposite side views, from Fort Augsutus 663.5 - 666.3 m (2177 - 2186 ft), 8a X117, 8b X121; figure 10 opposite side views, from Fort. Augustus 688.2 - 690.9 m (2258 - 2267 ft), 10a X106, 10b X105.

Figure 9. *Uvigerinamina athabascensis* Mellon and Wall. Side view, from Spirit River 1092.0 - 1093.9 m (3583 - 3589 ft) X125.

Figures 11 - 14. *Gravellina chamneyi* Stelck. Figure 11 opposite side views, from Fort. Augustus 688.2 - 690.9 m (2258 - 2267 ft), 11a X136, 11b X143; figure 12 side view, from Spirit River 667.8 - 671.1 m (2191 - 2202 ft), X152; figure 13 side view, from Spirit River 676.9 - 680.0 m (2221 - 2231 ft), X151; figure 14 oblique side views, from Fort. Augustus 688.2 - 690.9 m (2258 - 2267 ft), 14a X230, 14b X220.

PLATE 6

PLATE 6

Calcareous taxa:

Figure 1. *Lenticulina bayrocki* Mellon and Wall. Side view, from Spirit River 1139.9 - 1142.9 m (3740 - 3750 ft) X133.

Figure 2. *Marginulinopsis collinsi* Mellon and Wall. Side view, from Spirit River 997.9 - 998.6 m (3274 - 3276.5 ft) X113.

Figures 3a, b. *Saracenaria* sp. A. Side and apertural views, from Spirit River 997.9 - 998.6 m (3274 - 3276.5 ft), 3a X122, 3b X119.

Figures 4a, b. *Saracenaria projectura* Stelck and Wall. Opposite side views, from Spirit River 1050.6 - 1051.8 m (3447 - 3451 ft), 4a X126, 4b X128.

Figures 5a, b. *Globulina lacrima canadensis* Mellon and Wall. Opposite side views, from Spirit River 1092.0 - 1093.9 m (3583 - 3589 ft), 5a X140, 5b X137.

Figures 6a, b. *Saracenaria* sp. B. Opposite side views, from Spirit River 1060.3 - 1063.4 m (3479 - 3489 ft), 6a X135, 6b X132.

Figures 7a, b, 8a, b. *Discorbis norrisi* Mellon and Wall. Figure 7 umbilical and dorsal views, from Spirit River 986 - 986.7 m (3235 - 3237.5 ft), 7a X145, 7b X141; figure 8 umbilical and dorsal views, from Spirit River 1139.9 - 1142.9 m (3740 - 3750 ft), 8a X216, 8b X236.

Figures 9a, b, 10a, b. *Quadrिमorphina albertensis* Mellon and Wall. Figure 9 dorsal and umbilical views, from Spirit River 997.9 - 998.6 m (3274 - 3276.5 ft), 9a X193, 9b X194; figure 10 dorsal and umbilical views, from Spirit River 1128.6 - 1129.4 m (3703 - 3705.5 ft), 10a X195, 10b X216.

Figures 11a, b, 12. *Gyroidina* sp. cf. *G. nitida* (Reuss). Figure 11 oblique side views, from Spirit River 997.9 - 998.6 m (3274 - 3276.5 ft), 11a X144, 11b X147; figure 12 dorsal view, from Spirit River 1128.6 - 1129.4 m (3703 - 3705.5 ft) X181.

Figure 13. Unidentified species. Side view, from Spirit River 1158.5 - 1159.7 m (3801 - 3805 ft) X161.

Figures 14a, b. Unidentified species. Side views, from Fort Augustus 863.5 - 866.2 m (2833 - 2842 ft), 14a X170, 14b X182.

Depth (m)	Depth (ft)	Freq.	Hippocrepina barkdalei	Reophax spp.	Haplophragmoides spp.	Saracenaria spp.	Ammobaculites cf. A. fragmentarius	Ammobaculites kiowensis	Bathylphoron brosgel	Gaudryina talleyi	Glomospira recta	Glomospira tortuosa	Haplophragmoides collyra	Haplophragmoides linki	Haplophragmoides topogonukensis	Hippocrepina spp.	Williamina spp.	Williamina aproulei	Peanosphaera spp.	Pseudobolivina variana	Reophax troyeri	Saccamina laframti	Trochammina umialensis	Verneuilinoides borealis	Ammobaculites spp.	Ammobaculoides spp.	Trochammina spp.	Hyperammina strombotubulara
541.8-584.0	1809-1919																											
591.0-594.0	1939-1949																											
596.8-600.0	1958-1968																											
605.9-608.4	1988-1996	>		3	29				1								1		1		3	1			1		15	
614.4-617.5	2016-2026	-		8													1		3						4		3	
621.3-626.3	2045-2055	>		6	4												1		2						1		3	
641.0-644.0	2103-2113	D		10	3														7		1						2	
644.0-647.1	2113-2123	#		18	2				1										1						1		1	
648.8-652.8	2132-2142	#		17	1												1		2		1				6		1	
654.6-661.7	2161-2171	-		15								1									3				5		3	
667.8-671.1	2191-2202	-		12	2													3		2					6		10	
676.9-680.0	2221-2231	#		20	32				1						3				2		1			2	3		2	
685.5-688.5	2249-2259	#		38	38				4						4				6		12			2				
696.1-699.2	2284-2294	#		33	56				18						4						9	1			14		8	
706.3-708.3	2314-2324			44	38				32						10					2	4	2			20		2	
710.1-713.2	2330-2340			35	80				27				1		11		2		1		7				12		5	
716.2-719.3	2350-2360			6	57				13						2				6						18		4	
725.4-728.4	2380-2390			5	208									1	41		1				3				2		4	
737.6-740.6	2420-2430	poly			1														1									
748.7-749.8	2450-2460																											
772.6-773.5	2535-2538																											
783.3-784.8	2570-2575	poly																										
789.4-792.4	2590-2600	C			29																							
792.4-795.5	2600-2610	E			76																							
800.0-803.1	2625-2635	E		5	124		1		7					1	7				1		1	2			3			
807.7-810.7	2650-2660	-			1	19													6			3						
813.8-816.8	2670-2680	H																										
841.5-842.3	2761-2763.5	C			2																							
844.6-845.0	2771-2772.5	-			11																						5	
854.6-859.2	2817-2819	B			4																				1			
864.2-866.8	2842-2844	#			1									1														
869.2-870.0	2852-2854.5	#																										
872.3-872.9	2862-2864	-	2	2	13																						10	
874.1-876.9	2868-2877	-		8	6																1				4		1	
877.2-880.2	2878-2888	O		2	10														1						4		1	
880.2-881.7	2888-2893	Z																					1				4	
900.0-900.6	2953-2956				1																			2			1	
905.2-905.8	2970-2972				1																							
911.3-912.1	2990-2992.5	-		1	17										1												1	
914.4-915.4	3000-3003.5	#		4	21									1														
920.5-922.6	3020-3027	E			1	9								1														
922.6-923.3	3027-3029.5	-			10										1												2	
923.9-925.3	3031-3036	#	10	8	65				4				2	2			2						2				1	
925.3-928.1	3036-3045	L	10	14	70				3				4	1			2	1	3				2		2		2	
928.4-931.4	3046-3056			2	19	68		1					3	3			1	2			2	1	2		1		9	
931.4-934.5	3056-3066			29	50				1					2	3						1				8			

			Hippocrepina barkdalei	Rhopax spp.	Haplophragmoides spp.	Sarcenaria spp.	Ammobaculites cf. A. fragmentarius	Ammobaculites kioensis	Bathysiphon broegel	Gaudryina talliei	Glomospira reata	Glomospira tortuosa	Haplophragmoides collyra	Haplophragmoides linki	Haplophragmoides topogorukensis	Hippocrepina spp.	Miliammina spp.	Miliammina sproulei	Pearmoosphaera spp.	Pseudobolivina varians	Rhopax troyeri	Saccamina lahami	Trochammina umilensis	Verruculinoides borealis	Ammobaculites spp.	Ammobaculoides spp.	Trochammina spp.	Hyperammina strombolubula
Depth (m)	Depth (m)																											
937.5-938.0	3076-3077.5			29									1														2	
939.0-940.9	3081-3087			1	37																							
951.8-954.1	3123-3130.5																											
954.9-957.9	3133-3143			1	3										4													
957.9-961.0	3143-3153	r																										
978.4-979.9	3210-3215	e			1																							
979.9-981.7	3215-3221	n		1	8									2														
982.9-983.2	3225-3226	i			3																							
986.0-986.7	3235-3237.5	e	2		3				2					4									1					
989.0-989.5	3245-3246.5	k		4	6									1														
994.8-997.6	3264-3273.5			6	35				1					10	1						1				4			
997.9-998.6	3274-3276.5		1	33	79			2	3					13	2						13				7			
1000.9-1004.0	3284-3284			3	50		1	2	1					1	8										7		1	
1011.9-1012.2	3320-3321	l	1	1	17				1						9								2					
1013.4-1014.9	3325-3330				1																							
1044.5-1045.6	3427-3430.5		2	20				2						2					1									
1047.5-1048.2	3437-3439			10				1											2									
1050.9-1051.8	3447-3451		5	27		3								5											3			
1051.8-1054.3	3451-3459		7	28				5	5					4	1			3	3						1	2		
1054.3-1056.7	3459-3467		5	33	1	1	8	4					1	7				8				1			4	2		
1060.3-1063.4	3479-3489		1	56			17	8	1					4				2							1	1		
1063.4-1064.6	3489-3493		3	10			2	2						2											1			
1068.4-1068.5	3499-3509			14	60		1	14	3					12		1		2		1	1				4	4		
1068.5-1070.1	3509-3511	a	1	3	31			2					1	4								1		6	5	5		
1072.5-1075.3	3519-3528	o		7	11	2	2	1	1									1				1		2		1		
1090.2-1092.0	3577-3583	-	3	7	45	2	5	8	9					2	8					4	2	8				1		
1092.0-1093.9	3583-3589	-	1	8	29	1	1	5	11					4						3	2				2		10	
1095.1-1096.2	3593-3596.5	-		3	23				8	1				2				1						2	2	1		
1107.3-1108.2	3633-3636	-	1		4				2																			
1111.6-1113.7	3647-3654	3	3	5	12																						2	
1113.7-1116.7	3654-3664		2		3																							
1116.7-1119.8	3664-3674		2		1									1														
1119.8-1122.1	3674-3681.5		2	7	8				1					1							1				1			
1122.5-1125.6	3683-3693			1	6													1										
1125.6-1128.6	3693-3703		4		11									1	3												1	
1128.6-1129.4	3703-3705.5		9		2									2							1						1	
1131.4-1134.1	3712-3721			1	15			5	6					5	12	2	2		1						1	4	9	
1137.2-1139.4	3731-3734.5			4	14		1		5					2	1			2	1	1				1	2	7	30	
1139.9-1142.9	3740-3750			11	31				15					1	4						1						9	20
1142.9-1145.1	3750-3757			4	10		1		1					2	1	2									4		28	
1156.7-1158.5	3795-3801	h		3	75			12	7		8			9				3	1						2	1	3	
1158.5-1159.7	3801-3805	u		4	35			8	16	1	16	1		9	3	1		2		4					4	1	4	
1158.5-1160.0	3801-3806	g		3	48		1	5	4	2	9			1	3	1	5		11	1		1		3	2		11	
1160.0-1161.5	3806-3811	2	2	1	52		2	17	7	7	26	5	1	5	6	2	2	1	9	5	2	2	4	2	2	3	2	1
1171.9-1173.7	3845-3851	B	20	1	5	3																						
1223.7-1226.8	4016-4025	d																										

S single; R Rare (2-8); C Common (9-19); A Abundant (20-199); F Flood (>200)

Depth (m)	Fm	Hyperammina spp.	Gaudryina spp.	Lenticulina spp.	Trochammina cf. T. wetteri	Schererchorella minuta	Textularia topogorukensis	Bathysiphon spp.	Glomospira spp.	Reophax cf. R. incompta	Textulariopsis minuta	Arenobulimina paynei	Haplophragmoides cf. H. krki	Reophax alkanitensis	Textularia spp.	Ammodiscus spp.	Haplophragmoides uniorbis	Hyperammina enaceraia	Reophax deckeri	Quadrinorthis albertensis	Saccammina spp.	Gyrodina spp.	Trochammina cf. T. memurrayensis	Gaudryina nanuhukensis	Trochammina sp. A	Thuramminoides septagonalis	Margulinopsis collinae	Verneuilina spp.	Dicorbis norrisi
581.8-584.9																													
591.0-594.0																													
596.8-600.0																													
605.9-608.4	Y		1																2										
614.4-617.5	Y		1											4					2		1								
623.3-626.3	U												5		2				2		4								1
641.0-644.0	B		1										4		1			2	1		4								
644.0-647.1	B		6										3								7								
648.8-652.8	B		3										6						1		11								1
658.6-661.7	I		3										10								3								3
667.8-671.1	I		5										14						2		7								
676.9-680.0	B		3										10						2		6								
685.5-688.5	L		6										10						6		16								
696.1-699.2	S												11					3	5		20								
705.3-708.3													12						4		6								
710.1-713.2													1	7				1	6		4								
716.2-719.3																					4								
725.4-728.4														2					1		2								1
737.6-740.6	P																				1								
746.7-749.8	P																												
772.6-773.5	L																												
783.3-784.8	V																												
789.4-792.4	C																												
792.4-795.5	E																												
800.0-803.1	E					1																							
807.7-810.7	I																				2								
812.8-815.8	H																												
841.5-842.3	C																												
844.6-845.0	I											1																	
858.6-859.2	B																												
868.2-868.8	B																												
869.2-870.0	A																												
872.3-872.9	I																												3
874.1-876.9	I																												
877.2-880.2	O																												
880.2-881.7	N																												
900.0-900.6																													
905.2-905.8																													
911.3-912.1	I																												1
914.4-915.4	B										1										1								
920.5-922.6	A																												
922.6-923.3	I										1			1															
923.8-925.3	B																				2								
925.3-928.1	L										1	1		2															
928.4-931.4											3	3	2	4							2								1
931.4-934.5											8	4		4							4								6

		Hyperammina spp.	Gaudryina spp.	Lenticulina spp.	Trochammina cf. T. walteri	Scherochorella minuta	Textularia topogorukensis	Bathysiphon spp.	Glomospira spp.	Reophax cf. R. Incompta	Textulariopala minuta	Arenobulimina paynei	Haplophragmoides cf. H. kirki	Reophax sikanniensis	Textularia spp.	Ammodiscus spp.	Haplophragmoides uniorbia	Hyperammina emacerata	Reophax deckeri	Quadrinorthis albertensis	Saccammina spp.	Gyrodina spp.	Trochammina cf. T. mcmurrayensis	Gaudryina nanushukensis	Trochammina sp. A	Thuramminoides septagonalis	Margulinipala collinsii	Verneulina spp.	Discorbis norrisi
Depth (m)																													
937.5-938.0					1																								
939.0-940.9																													
951.8-954.1																													
954.9-957.9																	1												
957.9-961.0																													
978.4-978.9																													
979.9-981.7																						1							
982.9-983.2																													
986.0-986.7													1				2												1
989.0-989.5					1																								
994.6-997.6																					5	2					1	3	7
997.9-998.6												1	3	12					3		3	1		1				6	18
1000.9-1004.0							1				1										1								12
1011.9-1012.2					1		1														4								
1013.4-1014.9																													
1044.5-1045.6																	2				3								
1047.5-1048.2																													
1050.6-1051.8													1				4				2								
1051.8-1054.3							1				1										7							1	
1054.3-1056.7											2	2		1			3			1	3	8					1		12
1060.3-1063.4											1		3				6				1			1				1	
1063.4-1064.6											2																		
1066.4-1069.5							1				1		4				3				3			6					4
1069.5-1070.1											1						2	4			2			12					
1072.5-1075.3					2												1			4	6	27					3		14
1090.2-1092.0					3						2						12	1			5	47		1			1	6	7
1092.0-1093.9							2				2						5			1	3	9		3					5
1095.1-1096.2							1	1			2						6				1	1		2		2	1	1	6
1107.3-1108.2																											1		
1111.6-1113.7		1			3																				1				
1113.7-1116.7																													
1116.7-1119.8																													
1119.8-1122.1						1																				1			
1122.5-1125.6																													
1125.6-1128.6																													
1128.6-1129.4																					1								
1131.4-1134.1						1		6			2	1									2				2				
1137.2-1139.4						4	3					1						2	1	1	1	1	1	8					
1139.9-1142.9				1											2	1	1												
1142.9-1145.1				1		1							2	1	1														
1156.7-1158.5			4			12					2	1																	
1158.5-1159.7			4			3	10	1	1	1	2																		
1158.5-1160.0		1	2	1	3	1																							
1160.0-1161.5		1																											
1171.9-1173.7																													
1223.7-1226.8																													

Depth (m)		Saracenaria sp. A	Saracenaria trolopei	Globulina lacrima sp. canadensis	Saccammina alexanderi	Pseudonodosaria clearwaterensis	Lenticulina bayrocki	Uvigerinammina athabascensis	Pseudonodosaria spp.	Diacorbis spp.	Haplophragmoides sp. A	Saccammina globosa	Verneulinoides spp.	Marginulina spp.	Haplophragmoides multiplex	Haplophragmoides gigas sp. minor	Millammina subcylindrica	Hyperammina strombotubularis	Saracenaria projectura	Haplophragmoides sp. B	Haplophragmoides gilberti	Eggerella spp.	Gravellina chamneyi	Ammobaculites lyrelli	Reophax cf. R. densa	Haplophragmoides postila	Millammina awunensis	Millammina mantobensis	Psammimopelta bowsheri	Reophax vaaliformis
837.5-838.0																4														
838.0-840.9					1											11							1			2	1			
851.8-854.1																														
854.9-857.9										1																				
857.9-861.0	F																													
878.4-878.9	S																													
878.9-881.7	A																													
882.9-883.2	I																													
886.0-886.7	A											1																		
888.0-888.5	L																													
894.8-897.6					3					3															2					
897.9-898.6		1			7			1				23												13	1					
1000.9-1004.0										1												2								
1011.9-1012.2					2					1		1					1				1									
1013.4-1014.9																	1													
1044.5-1045.6																1	1				3									
1047.5-1048.2													1				2													
1050.8-1051.8																	4	2	1											
1051.8-1054.3												1					4													
1054.3-1056.7										3	1	2					1													
1060.3-1063.4								1		1			2			1														
1063.4-1064.6				2						1																				
1066.4-1069.5												4	1																	
1069.5-1070.1	A				2		1	2				8	1	1	1															
1072.5-1075.3	C	2	1	4		2	1		2	5	3	3																		
1090.2-1092.0	I	5				1	1	4	2																					
1092.0-1093.9	I	1		6	2	1		1																						
1095.1-1096.2	I	1	1																											
1107.3-1108.2	I																													
1111.6-1112.7	W																													
1113.7-1116.7																														
1116.7-1119.8																														
1119.8-1122.1																														
1122.5-1125.6																														
1125.6-1128.6																														
1128.6-1129.4																														
1131.4-1134.1																														
1137.2-1138.4																														
1138.9-1142.9																														
1142.9-1145.1																														
1156.7-1158.5	>																													
1158.5-1159.7	X																													
1158.5-1160.0	SS																													
1160.0-1161.5	SS																													
1171.9-1173.7	B																													
1223.7-1226.8	d																													

S single; R Rare (2-8); C Common (9-19); A Abundant (20-199); F Flood (>200)

		Millammina lechnia	Trochammina gatensis	Trochammina cf T. depressa	Ammobaculites cf A. erectus	Ammobaculites fragmentarius	Ammomarginulina cragini	Ammomarginulina cf A. paterella	Haplophragmoides posita asp. goodrichi	Psammimopelta spp.	Trochammina cf T. diagonis	Ammobaculites pelius	Ammobaculites tyrelli jolifouensis	Trochammina sp. cf T. bredini	Ammobaculites wenonahae	Haplophragmium sp. cf H. swarzi	Trochammina aicanensis	Trochammina sp. cf T. ruherfordi	Reophax tundraensis	Trochammina rainwateri	Millammina infata	Gaudryina canadensis	Pseudobolivina spp.	Ammobaculoides whitneyi	Unidentified foraminifera	Agglutinated foram fragments	Calcareous foram fragments	Fish remains	Algal cysts	SUM OF FORAMS
Depth (m)																														
937.5-938.0																								R	R					40
938.0-940.9																								R	C					59
951.8-954.1																														0
954.9-957.9																										R	R			10
957.9-961.0	r																													0
978.4-979.9	e																								S					1
979.9-981.7	h																								C					10
982.9-983.2	i																							S	R					3
986.0-986.7	u																								C	C				17
989.0-989.5	f																							R	C	R				12
994.8-997.6																								R	A	C				84
997.9-998.6																								R	A	R				247
1000.9-1004.0																								C	A					93
1011.9-1012.2																									C					43
1013.4-1014.9																														2
1044.5-1045.6																								R	C					37
1047.5-1048.2																								R	R					16
1050.6-1051.8																								R	R					57
1051.8-1054.3																								C	A					74
1054.3-1056.7																								A	A	R				115
1060.3-1063.4																								C	A					109
1063.4-1064.6																								R	R					26
1066.4-1069.5																								A	A	S				146
1069.5-1070.1	h																							R	A					96
1072.5-1075.3	o																							C	A	C				109
1090.2-1092.0	i																							C	A	C				202
1092.0-1093.9	r																							R	A	R				118
1095.1-1096.2	i																							R	C	S				69
1107.3-1108.2	i																							R	C					8
1111.6-1113.7	W																							R	C	R				27
1113.7-1116.7																								R	R					5
1116.7-1119.8																								R	R					4
1119.8-1122.1																								R	A					23
1122.5-1125.6																									R					8
1125.6-1128.6																								R	R					20
1128.6-1129.4																								S	C					16
1131.4-1134.1																								C	A	S				77
1137.2-1139.4																								C	A					93
1139.9-1142.9																								R	A	R				124
1142.9-1145.1																								R	A					59
1156.7-1158.5	y																							C	A					141
1158.5-1159.7	x																							C	A					131
1158.5-1160.0	ss																								A					119
1160.0-1161.5	sl																								A					169
1171.9-1173.7	B																								R					29
1223.7-1226.8	C																								S					0

			<i>Haplophragmoides gigas ssp. minor</i>	<i>Haplophragmoides linki</i>	<i>Haplophragmoides spp.</i>	<i>Millammina awunensis</i>	<i>Millammina spp.</i>	<i>Psammospaera spp.</i>	<i>Pseudobolivina variata</i>	<i>Saccammina spp.</i>	<i>Pseudonodosaria cf P. clearwaterensis</i>	<i>Saracenaria sp.</i>	<i>Haplophragmoides kirki</i>	<i>Haplophragmoides topagorukensis</i>	<i>Millammina inflata</i>	<i>Millammina manitobensis</i>	<i>Reophax spp.</i>	<i>Gaudryina nanushukensis</i>	<i>Margulinopsis collinsi</i>	<i>Haplophragmoides postis</i>	<i>Millammina tchnia</i>
Depth (m)	Depth (ft)	Fm.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
652.5-655.3	2141-2150				1											1	3				
655.3-658.0	2150-2159				26		1	4		3						1					
658.0-660.8	2159-2168				24		1	7	1							5	10				
660.8-663.5	2168-2177				19		2			1						4	4				1
663.5-666.3	2177-2186	e			26		1	2		1					1	11	15				4
666.3-669.0	2186-2195	g			10		1	7		2						3	2				2
669.0-671.7	2195-2204	a			13	1	6	3		5					1	10	11				5
671.7-674.5	2204-2213	t			7		2	4							1	7					8
674.5-677.2	2213-2222	g														2					1
677.2-680.0	2222-2231	e			3											1	3				1
680.0-682.7	2231-2240	s			1		1	1		2					2	6					5
682.7-685.5	2240-2249	t			4		4	3							2	10					
685.5-688.2	2249-2258	g			24		5	4							1	15	14				2
688.2-690.9	2258-2267				46		4	9		6				5	5	11	5				1
690.9-693.7	2267-2276				24		3	1	1	2				1	1	4	5				3
696.4-699.2	2285-2294				15			3		2						1	1				
699.2-701.9	2294-2303																				
701.9-704.7	2303-2312																				
704.7-707.4	2312-2321	g			15			1									2				
707.4-710.1	2321-2330	i			53			3		2							4				
710.1-712.9	2330-2339	n			3																
712.9-715.6	2339-2348	k			77		2	5		3						4	8				
715.6-721.1	2348-2357	i			68			2		4						2	10				1
718.4-721.1	2357-2366	V			44		6	8	1	2						1	8				4
721.1-723.9	2366-2375				7		1														
723.9-726.6	2375-2384																				
726.6-729.4	2384-2393	u			73								3	26			1				
729.4-730.9	2393-2398	o			87			2					3	45							
730.9-733.6	2398-2407	F			48									6							
733.6-736.4	2407-2416	o			80			2	1				1	4			3				
736.4-738.8	2416-2424	l			34			2						3			1				
738.8-741.5	2424-2433	J			28					1				2							
819.6-822.6	2689-2699	e			2	3	14			1					1	3	1				5
822.6-825.4	2699-2708	i			2																
825.4-828.1	2708-2717	l	5	3	12								4								
828.1-830.5	2717-2725	l		2	38		9		1	1				5	1			8			5
830.5-833.3	2725-2734	v																			
833.3-836.0	2734-2743	n	11	10	52								1	8							
858.0-859.5	2815-2820	n				2	20			1					12		5	1			12
860.7-863.5	2824-2833	a			2	1	4										6				3
863.5-866.2	2833-2842	M	1	3	4	2	4						1			2		1			6
866.2-868.9	2842-2851	J	23	8	19	2	4							10	2	1	1			2	13

			<i>Haplophragmoides gigas ssp. minor</i>	<i>Haplophragmoides linki</i>	<i>Haplophragmoides spp.</i>	<i>Millammina awunensis</i>	<i>Millammina spp.</i>	<i>Psammospaera spp.</i>	<i>Pseudobolivina variana</i>	<i>Saccamina spp.</i>	<i>Pseudonodosaria cf P. clearwaterensis</i>	<i>Saracenaria sp.</i>	<i>Haplophragmoides kirki</i>	<i>Haplophragmoides topagorukensis</i>	<i>Millammina inflata</i>	<i>Millammina manitobensis</i>	<i>Reophax spp.</i>	<i>Gaudryina nanushukensis</i>	<i>Marginulinopsis collinsi</i>	<i>Haplophragmoides postis</i>	<i>Millammina ischnia</i>
868.9-871.7	2851-2860		3		8	1	3			1	1		1	5		1				1	6
871.7-874.4	2860-2869	M.	14	7	17	3	4			1	1		3	4	2	5	5	3	1		
874.4-877.2	2869-2878	U.	8	5	21	4	1	3	1	2	11	1									
880.0-882.7	2887-2896																				
895.5-898.2	2938-2947	a c.																			
900.9-903.7	2956-2965	a c.																			
903.7-906.4	2965-2974	r																			
906.4-909.2	2974-2983	t																			
911.9-914.7	2992-3001	s																			
917.4-920.1	3010-3019	O																			
945.4-948.2	3102-3111	e																			
948.2-950.9	3111-3120	ill																			
961.9-964.6	3156-3165	s																			
968.9-971.7	3179-3188	r																			
979.3-982.0	3213-3222	e																			
982.0-984.8	3222-3231	r																			
998.2-1000	3275-3281	E																			

		<i>Millammina sproulei</i>	<i>Millammina subelliptica</i>	<i>Saccammina lathrami</i>	<i>Trochammina spp.</i>	<i>Hyperammina strombotubulare</i>	<i>Haplophragmoides collyra</i>	<i>Saccammina globosa</i>	<i>Ammobaculites spp.</i>	<i>Gaudryina spp.</i>	<i>Ammobaculites tyrrelli</i>	<i>Ammodiscus rotularius</i>	<i>Arenobulimina paynei</i>	<i>Psammimnopelta subcircularis</i>	<i>Gaudryina canadensis</i>	<i>Gaudryina tailfeuri</i>	<i>Psammimnopelta bowseri</i>	<i>Psammimnopelta spp.</i>	<i>Textularia topagorukensis</i>	<i>Vermeulinoides borealis</i>	<i>Ammobaculites pellus</i>	<i>Bathysiphon brosgel</i>	<i>Gravellina chamneyi</i>
868.9-871.7		2	1	1	1																		
871.7-874.4	M.																						
874.4-877.2	U.																						
880.0-882.7																							
895.5-898.2	C.																						
900.9-903.7	A.																						
903.7-906.4																							
906.4-909.2	T																						
911.9-914.7	S																						
917.4-920.1	O																						
945.4-948.2	E																						
948.2-950.9	I																						
961.9-964.6	S																						
968.9-971.7	R																						
979.3-982.0	E																						
982.0-984.8																							
998.2-1000	E																						

			<i>Haplophragmoides gigas</i>	<i>Haplophragmoides gilberti</i>	<i>Ammodiscus planus</i>	<i>Ammomarginulina asperata</i>	<i>Haplophragmoides postis ssp. goodrichi</i>	<i>Reophax vasiformis</i>	<i>Saccammina alexanderi</i>	<i>Trochamminoides apiciculus</i>	<i>Haplophragmoides gigas phaseolus</i>	<i>Ammobaculites fragmentarius</i>	<i>Ammodiscus klowensis</i>	<i>Reophax troyeri</i>	<i>Hyperammina spp.</i>	<i>Reophax sikanniensis</i>	<i>Trochammina gatensis</i>	<i>Hippocrepina spp.</i>	<i>Textulariopsis minuta</i>	<i>Reophax tundraensis</i>	<i>Ammobaculites pacalis ssp. pattersoni</i>
Depth (m)	Fm.	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	
652.5-655.3																					
655.3-658.0						2											1				
658.0-660.8							2								1			2			
660.8-663.5																		3			
663.5-666.3	W e s t g a t e					1	7						3		1		1				
666.3-669.0							6								3	3	2				
669.0-671.7						4											1	1			
671.7-674.5																					
674.5-677.2																					
677.2-680.0							1								3	2					
680.0-682.7							1										5	1			
682.7-685.5	W e s t g a t e														1		3				
685.5-688.2						3	1				1				2	4	4	2			
688.2-690.9							1	3		1	2			1		3	5	1			
690.9-693.7						1	1	3							2	3	1	1		1	
696.4-699.2						4											1	1			
699.2-701.9																					
701.9-704.7																					
704.7-707.4	g i n g																	1			
707.4-710.1																		6	2		
710.1-712.9										1								3			
712.9-715.6	k i k				1	4	1			2			1		1		1				
715.6-721.1					1						1				1						
718.4-721.1	V i l l e							1		4		1		1	1	1					
721.1-723.9					1		1					1	1								
723.9-726.6																					
726.6-729.4	u		28							33	1										
729.4-730.9	F o		39							49											
730.9-733.6	8								1	16											
733.6-736.4	o l l F o	2	10	2	1	1	2	1	4											1	
736.4-738.8	1	12																			
738.8-741.5	J o																				
819.6-822.6	e																				
822.6-825.4	i l l e																				
825.4-828.1																					
828.1-830.5																					
830.5-833.3	v i l l e																				
833.3-836.0																					
858.0-859.5	n n																				
860.7-863.5																					
863.5-866.2	M a n n																				
866.2-868.9	U. M a n n																				

		<i>Haplophragmoides gigas</i>	<i>Haplophragmoides gilberti</i>	<i>Ammodiscus planus</i>	<i>Ammomarginulina asperata</i>	<i>Haplophragmoides postis</i> ssp. <i>goodrichi</i>	<i>Reophax vasiformis</i>	<i>Saccammina alexanderi</i>	<i>Trochamminoides apicarius</i>	<i>Haplophragmoides gigas phaseolus</i>	<i>Ammobaculites fragmentarius</i>	<i>Ammodiscus kiowensis</i>	<i>Reophax troyeri</i>	<i>Hyperammina</i> spp.	<i>Reophax sikanniensis</i>	<i>Trochammina gatensis</i>	<i>Hippocrepina</i> spp.	<i>Textulariopsis minuta</i>	<i>Reophax tundraensis</i>	<i>Ammobaculites pacalis</i> ssp. <i>pattersoni</i>
868.9-871.7																				
871.7-874.4	U. M.																			
874.4-877.2	U.																			
880.0-882.7																				
895.5-898.2	C.																			
900.9-903.7	a																			
903.7-906.4	r																			
906.4-909.2	t																			
911.9-914.7	s																			
917.4-920.1	O																			
945.4-948.2	e																			
948.2-950.9	l																			
961.9-964.6	s																			
968.9-971.7	r																			
979.3-982.0	e																			
982.0-984.8	l																			
998.2-1000	E																			

		<i>Hippocrepina barkedalei</i>	<i>Trochammina alcanensis</i>	<i>Verneulina canadensis</i>	<i>Bathysiphon</i> spp.	<i>Trochammina rainwateri</i>	<i>Ammodiscus</i> spp.	<i>Reophax deckeri</i>	<i>Ammomarginulina cragini</i>	Ostracoda	Unidentified foraminifera	Agglutinated foram fragments	Fish remains	Algal cysts	Sum OF FORAMINIFERA
Depth (m)	Fm.	61	62	63	64	65	66	67	68						
652.5-655.3											R	R	A		7
655.3-658.0											A		A		40
658.0-660.8								1			A		R		80
660.8-663.5				1					1		R	A	R		54
663.5-666.3	e			3				1			S	A	S		101
666.3-669.0	a		3	1		1					S	A			65
669.0-671.7	t			3			1				R	C			74
671.7-674.5	g										C			S	32
674.5-677.2	s										S	R			5
677.2-680.0	t					1									17
680.0-682.7	e						1				R	R	C		29
682.7-685.5	W										S	C			28
685.5-688.2		3	2	2							R	A			141
688.2-690.9		2	1	4	3	3					R	A			191
690.9-693.7		1	4	2							S	A			108
696.4-699.2											R	A	R		29
699.2-701.9												A	A		0
701.9-704.7											R		R		0
704.7-707.4	g										A				22
707.4-710.1	i										R	A	S		94
710.1-712.9	n										S	C		S	10
712.9-715.6	k										A			S	136
715.6-721.1	i										R	A		C	112
718.4-721.1	V										S	A		R	110
721.1-723.9											C				16
723.9-726.6	.												R		0
726.6-729.4	u										R	A			193
729.4-730.9	F										R	A			278
730.9-733.6	o										S	A	R	S	122
733.6-736.4	l										R	A			187
736.4-738.8	J										C	A			95
738.8-741.5	o										C	A	S		57
819.6-822.6	t														119
822.6-825.4	e										R				2
825.4-828.1	i														25
828.1-830.5	l										S	A			86
830.5-833.3	v														0
833.3-836.0	n														90
858.0-859.5	n										R				60
860.7-863.5	a										R				28
863.5-866.2	M														26
866.2-868.9	U.														94

		<i>Hippocrepina barkdalei</i>	<i>Trochammina alcanensis</i>	<i>Verneulina canadensis</i>	<i>Bathysiphon</i> spp.	<i>Trochammina rainwateri</i>	<i>Ammodiscus</i> spp.	<i>Reophax deckeri</i>	<i>Ammomarginulina cragini</i>	Ostracoda	Unidentified foraminifera	Agglutinated foram fragments	Fish remains	Algal cysts	Sum OF FORAMINIFERA
868.9-871.7										S	A				36
871.7-874.4	M.									S	R				70
874.4-877.2	U.										A				57
880.0-882.7															0
895.5-898.2	c.									S		A			0
900.9-903.7	a									R					0
903.7-906.4	r									A					0
906.4-909.2	t									A					0
911.9-914.7	s									R		S			0
917.4-920.1	O														0
945.4-948.2	e														0
948.2-950.9	ll														0
961.9-964.6	s												S		0
968.9-971.7	r											S			0
979.3-982.0	e											A	R		0
982.0-984.8	ll												R		0
998.2-1000	E												S		0

[illegible]

[illegible]

		<i>Verneullina canadensis</i>	<i>Psamminopelta subcircularis</i>	<i>Psamminopelta bowsheri</i>	<i>Verneullina spp.</i>	<i>Ammobaculites pettitus</i>	<i>Trochammina bredini</i>	Unidentified foraminifera	Agglutinated foram fragments	Fish remains	Algal cysts	SUM OF FORAMS
Depth (m)	Fm	39	40	41	42	43	44					
743.7-746.7								S				0
749 m								R	S			2
752 m								S	C			45
755 m					1			R	A			68
758 m					2				A	R		60
765 m										R		0
768 m									R	R		13
771 m	e			1			2		R	R		51
774 m				2	7			S	A	R		164
777 m	t			1		1			A		S	68
780 m		2			1				A			52
783 m	a		1					R	A			19
786 m		1		1	1				A			29
789 m	g	6	1		3				A			25
792 m		1							R			10
795 m	t								R			7
798 m				1	1				A			46
801 m	s		1						R			6
804 m		2						S	C	R		20
807 m	e											5
810 m									C			4
813 m	W								R			1
816 m									C			28
819 m									A			46
822 m									R			16
825 m									C	R		40
829 m									R			8
832 m	g								C			17
835 m	n								R			17
838 m	i								S			5
841 m	k								R			16
843 m	V								R			4
847 m	u								R			18
850 m	o								R			3
853 m	F								R			17
856 m	i								C			28
858 m	l								C			32
862 m	J								C			19
865 m	O						S		R			15