MICROFAUNA OF THE JOLI FOU FORMATION IN NORTH CENTRAL ALBERTA

BY

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MICROFAUNA OF THE JOLI FOU FORMATION IN NORTH CENTRAL ALBERTA

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BY

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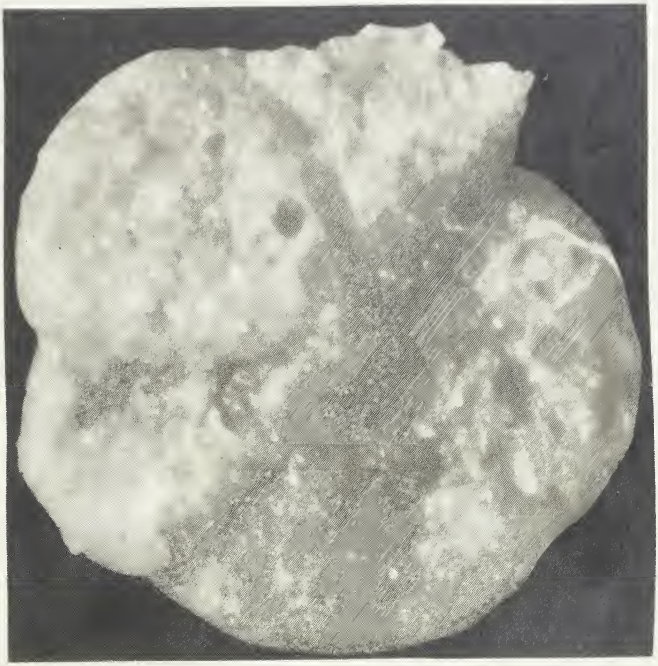
FRONTISPIECE

X 115
HAPLOPHRAGMOIDES cf. CUSHMANI
(LOEBLICH AND TAPPAN)



ABSTRACT

Nineteen diagnostic species of microfauna constituted the most significant foraminifera found in the uppermost Lower Cretaceous strata in North Central Alberta. Previous literature carries descriptions of four of these foraminifera; this study deals with fifteen additional new forms. Of the nineteen selected forms, fourteen are found in the Joli Fou formation, one in the Grand Rapids, and four in the Labiche; the fauna of the Pelican sand is considered a sandy facies of the Joli Fou fauna. The range and distribution of the described species is graphically illustrated. The basal Labiche formation is correlated with a 90' section 200 to 290 feet below the fish-scale beds in the Shaftesbury formation of the Peace River Plains area; the basal Labiche formation corresponds to the upper portion of the Buckinghorse formation of the Sikanni Chief River area in Northeastern British Columbia; the basal Labiche and Joli Fou formation are equivalent to the Lower Lloydminster shale of the Vermilion area, Alberta; the basal Labiche formation correlates with the lower portion of the Lloydminster shale above the Viking sandstone in the Redwater area, Alberta, and the Joli Fou shale correlates with the remainder of the Lloydminster shale below the Viking sand in this same area; the Pelican sand and the Viking sand are the coextensive with each other and homotaxial with the Cadotte sandstone.

Chapter I

Introduction

Introductory Statement

Recent oil development in Western Canada brings a need for accurate methods of correlating the various formations contemporaneously deposited. Various methods and aids are used to make these correlations, with paleontology taking a leading role. Considerable data has been compiled on macropaleontology in Western Canada, but scarcely any is available, as yet, on micropaleontology. The author offers this contribution to the knowledge of the micropaleontology of Western Canada.

This dissertation includes descriptions and figures of the more diagnostic microfossils of the Joli Fou formation and includes correlations of this formation with the formations of the Peace River valley, Vermilion and Redwater areas of Alberta and with northeastern British Columbia. It also includes brief outlines of the paleo-ecological conditions which existed during the deposition of the Joli Fou formation.

The Joli Fou is a shale series comprised of 110 feet of strata exposed in nearly continous outcrops along a portion of the Athabaska River from N.W. $\frac{1}{4}$ Sec. 19, T. 80, R. 17, W. 4 Mer. to S. E. $\frac{1}{4}$, Sec. 19, T. 86, R. 17, W. 4 Mer. in north central Alberta. Overlying the Joli Fou shale section is 40 feet of sand containing minor lenses of shale, known as the Pelican formation. The Pelican formation might well be considered a sandy phase of the Joli Fou formation as variations in the thickness of the Pelican sand are compensated by thickening and thinning of the Joli Fou shale. For this latter reason, faunal studies of the Joli Fou include also the studies of the Pelican sand faunas. Faunas of the shale lenticles occuring in the uppermost Grand Rapids formation

are included to permit evaluation of the stratigraphic hiatus involved in the Grand Rapids - Joli Fou contact. Shale samples immediately above the top of the Pelican sand yielded additional data on the range of the Joli Fou fauna. All faunas studied in this report proved to be from the Albian Stage (uppermost Lower Cretaceous).

Material Used and Method of Collecting Samples

Samples of shale were collected during the summer of 1949, along every outcrop of Joli Fou shale exposed along the Athabaska River and shales of the overlying and the underlying strata were also sampled. During the following winter, studies of these shale samples were undertaken by the writer in the micropaleontological laboratories of the University of Alberta, Edmonton.

Sampling was carried out at 5 foot intervals except in the Pelican sand where sporadic intercalated shale beds were sampled as they appeared. Sim ilarly the upper portion of the Grand Rapids formation, where shales, were sampled down for a thickness of 40 feet from the top. Shales overlying the Pelican sand were sampled also for a thickness of 40 feet above the contact.

Each sample was collected in a cloth sample bag on which was written its number, elevation and location; this information was also recorded in field note books.

Treatment of Sample

Each individual sample studied was put into a pint sized preservative sealer and soaked in water until the shale broke down. The fossils were separated from the disintegrated material by "washing" the coarse grains and fossil tests out of the clay using a set of sieves with 28, 48, 80, 100 and 150 mesh to the inch. The residue in each sieve was collected in separate pans and allowed to dry. This method

of washing was adopted because it provided for a maximum recovery of whole fossils since no rough handling of the material was involved. The residue containing the fossils was picked under a binocular microscope under magnifications ranging from 10 to 60 power, depending on the size of grains examined. A pointed, long-haired, wetted, sable-hair brush (number 00) was used for picking. The fossils were transferred to 10 cell oil-field type slides which were treated with gum tragacanth.

Specific Count

For correlative purposes a specific count of the fauna was made as the writer endeavoured to establish the relative assemblage of species present. All recognizable specific morphological entities were recorded, totalled, and their ranges determined.

Hypotypes representing well-defined specific populations are selected from various suites, described and photographed, and appear in chapter three of this paper. All hypotypes are in the micropaleontological collections of the University of Alberta, Edmonton.

Photographing and Drawing Hypotypes

Representative specimens from well-defined specific assemblages were selected and mounted in special slides having one compartment; into each compartment was mounted four identical specimens. The best preserved specimen in each slide was then selected for photographing.

For photographing, a Leitz Wetzlar M4B camera having a magnification of 1.8X was used in conjunction with a Leitz Wetzlar No. 394712 monocular microscope capable of magnification of 25X and 50X making a total magnification of 45X and 95X possible.

Each selected specimen was then photographed, developed, and finally printed on contact matte paper. Only side views of the

fossils are photographed; end views and apertures are sketches. The fossils' pictures are cut out and pasted on a black cardboard background to make a plate. Retouching of photographs is necessary in some cases to bring out important features. The entire plate is rephotographed. One such plate appears in chapter 3, along with descriptions of each fossil.

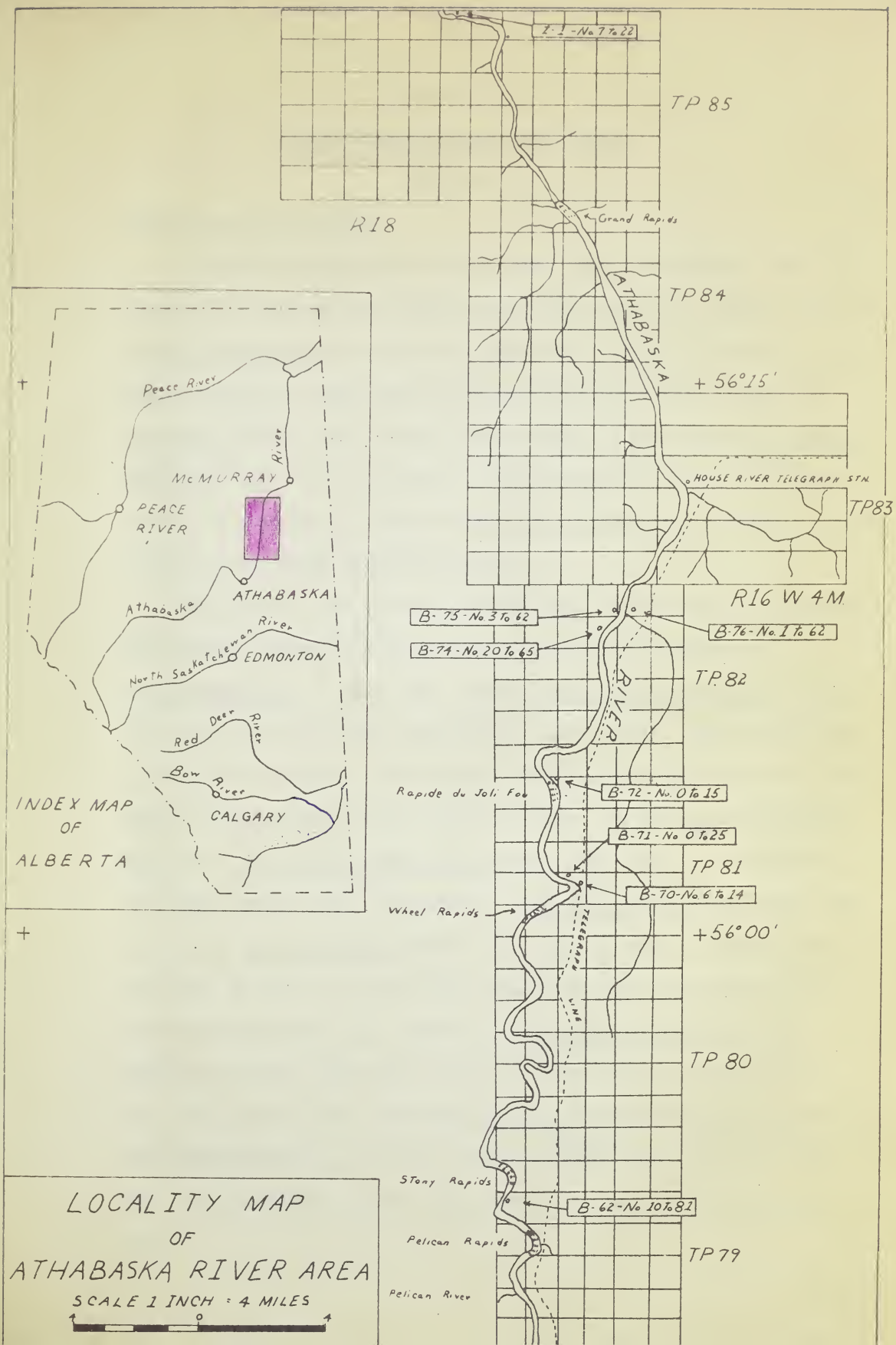
Previous Work

R. T. D. Wickenden (1949) published a paper "Some Cretaceous Sections along Athabaska River from the mouth of Calling River to below Grand Rapids, Alberta" from a reconnaissance trip into the area; but although he treats of the microfauna, no detailed descriptions or photographs of fossils he discussed were included. Wickenden had previously (1944) reported that a micro-faunal zone was found in the Pelican shale, (now known as Joli Fou shale), at depths of 1,310-15 feet in the Deca No. 1 well and from 1,570-90 feet in the Deca No. 2 well. Wickenden also reported that the same micro-faunal zone appeared in the Pelican Rapids well, although still earlier reported (Wickenden, 1930) as coming from the Clearwater shale, now known to be within the Joli Fou shale. F. H. McLearn (1916) ~~went through~~ traversed the area while studying the Cretaceous sections from the town of Athabaska to Fort McMurray.

Acknowledgments

Dr. C. R. Stelck of the University of Alberta has acted as an adviser throughout the writing of this paper. Dr. A. W. Nauss, Bear Oil Company, has contributed many pertinent and helpful suggestions. The writer has had access to unpublished theses of C. R. Stelck, A. Neilsen and B. Bullock on closely allied microfaunal studies. Dr. R. E. Folinsbee advised in the photographing of specimens.

The writer was assisted financially by the Bear Oil Company, which also provided the shale samples and field notes used in this report.


L-1-No 7 To 22
TP 85
R18
Grand Rapids
ATHABASKA
TP 84
+56°15'
HOUSE RIVER TELEGRAPH STN.
TP83
R16 W 4M.
B-75-No 3 To 62
B-74-No 20 To 65
B-76-No 1 To 62
RIVER
TP 82
Rapide du Joli Fou
B-72-No 0 To 15
B-71-No 0 To 25
TP 81
B-70-No 6 To 14
Wheel Rapids
+56°00'
TP 80
Stony Rapids
B-62-No 10 To 81
Pelican Rapids
TP 79
Pelican River
Peace River
McMURRAY
River
PEACE
RIVER
ATHABASKA
Athabaska
North Saskatchewan River
EDMONTON
Red Deer River
Bow River
CALGARY
INDEX MAP
OF
ALBERTA
LOCALITY MAP
OF
ATHABASKA RIVER AREA
SCALE 1 INCH = 4 MILES

Chapter II

Micropaleontology and Correlation

(Part A)

Discussion of Microfauna

Microfossils are scarce in the Grand Rapids formation. Only the uppermost 40 feet of the formation have been examined. Several species of Haplophragmoides are found but none are of diagnostic significance. Twenty-three feet below the top of the formation several species of Miliammina ~~become~~ are very abundant; among these is the species Miliammina QB-76-23 (figs. 1, 2, 3, plate 1). The presence of these two genera suggests a brackish or shallow marine environment for at least the upper portion of the Grand Rapids formation.

The basal 50 feet of the Joli Fou shale immediately overlying the Grand Rapids formation has at least 15 different varieties of Haplophragmoides; of these the species Haplophragmoides gigas Cushman (fig. 18, pl. 1) has been selected as a zone fossil. This fossil has a vertical distribution of 55 feet, extending from the top of the Grand Rapids formation up into the Joli Fou shale. In the Haplophragmoides gigas zone, Haplophragmoides cf. cushmani (fig. 21, pl. 1) Loeblich and Tappan occurs quite frequently. Haplophragmoides linki Nauss (fig. 25, pl. 1), H. cf. collyra Nauss, (fig. 23, 24, pl. 1) characterize the basal 25 feet of the Joli Fou shale. At about the middle of the formation the numbers and varieties of Haplophragmoides diminish, ~~becoming~~ are abundant again near the top of the formation, the variety being less pronounced. Two forms, H. cf. excavata Cushman and Waters, and Haplophragmoides sp. have a vertical ~~extent~~ distribution throughout the whole Joli Fou formation; they are also present in the overlying Pelican sand.

Ammobaculites is ~~rather limited~~ sparsely represented in the Joli Fou shale; Ammobaculites KB-72-6 (fig. 27, pl. 1) is found in the basal 50 feet of the formation. Ammobaculites fragmentaria Cushman has approximately the same vertical distribution, but is rarer. Ammobaculites tyrrelli var. At (fig. 6, pl. 1) and A. humei Nauss occur in the basal 20 feet of the formation. The presence of Ammobaculites GB-72-0 n. sp. (fig. 12, pl. 1) dominates the central portion of the formation. Except for several ~~doubtful~~ crushed Ammobaculites GB-72-0 specimens near the top, the upper 40 feet of the Joli Fou shale is almost barren of Ammobaculites.

Ammobaculoides ABZ-1-7 (fig. 20, pl. 1) occurs at the base of the Joli Fou formation and has a vertical extent of about 10 feet.

Miliammina first appears in the Joli Fou shale 20 feet above the top of the Grand Rapids formation; specimens of this form are never very abundant ~~but~~ and, when present, are usually well developed. The specimen Miliammina manitobensis var. C (fig. 15, 16, 17, pl. 1) has a vertical range of 90 feet, extending down from the top of the Joli Fou shale, to 20 feet above the top of the Grand Rapids formation. M. manitobensis var. C has been chosen as a zone fossil. Several other unfigured specimens are abundant in this zone.

The presence of Gaudryina canadensis var. A. Cushman (fig. 4, pl. 1) is restricted to the basal 25 feet of the Joli Fou shale. In this lower portion several other species make their appearance. The central portion of the formation shows few Gaudryina. Near the top several badly crushed specimens of new varieties of Gaudryina occur.

Besides the principal genera discussed above Hyperammina EB-74-45 (fig. 19, pl. 1) is present in the central portion of the Joli Fou section. Two species of Glomospira were recognized 12 feet above the base of the formation. A few very coarse grained Proteonina sp.

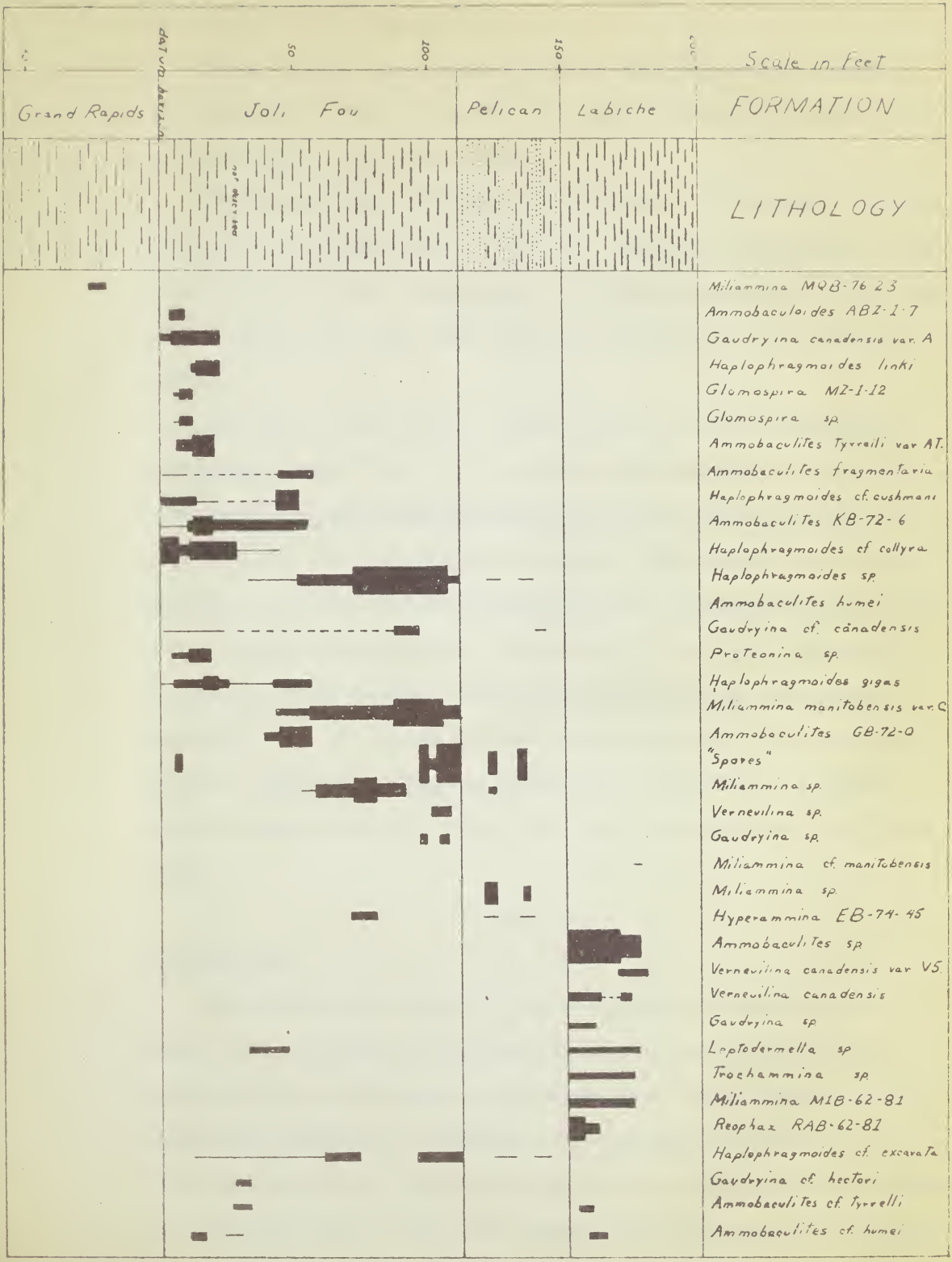


FIG. II Range chart showing the distribution of the more common microfossils from the uppermost Lower Cretaceous of the Athabasca River area, Alberta.

were found in the basal 20 feet.

Plant "spores" were among the most common microfossils found in the uppermost 15 feet of the Joli Fou shale, but no attempt has been made to identify the various forms.

The microfossils occurring in the overlying Pelican sand formation consisted for the most part of "spores". Hyperammina EB-74-45, several well developed forms of Miliammina, a few Haplophragmoides and Gaudryina occur, but no forms were found which were peculiar to the Pelican formation.

The basal 40 feet of the Labiche formation carries Verneuilina canadensis Cushman (fig. 10, 11, pl. 1), which has been selected as a zone fossil. Verneuilina canadensis var. V5 and Verneuilina sp. are also present. The Verneuilina are not very abundant but are well preserved. A few tiny forms of Gaudryina appear. Trochammina sp. is rare but is useful for correlation. The basal 30 feet of the formation is marked by a flood of badly flattened Ammobaculites sp., and Reophax RAB-62-81 (fig. 14, pl. 1) is quite common and useful for correlative purposes. Haplophragmoides, so common below the Pelican, is almost entirely absent from the suites of the basal Labiche above the Pelican sand.

(Part B)

Correlations

Correlations are subject to two complementary possibilites for error. The occurrence of identical fossils in various areas often indicated that merely similar conditions prevailed in these localities during the deposition of sediments. Local changes of facies on the other hand results in dissimilar faunas and a consequent misinterpretation of historical facts. Such facies changes have been taken into consider-

ation throughout the investigation of this project. The correlations established in this report are supported by paleontological evidence, but in addition stratigraphic position and lithologic character of the sediments, are incorporated. The writer has found it possible to correlate the Joli Fou formation, the Pelican sandstone and the basal portion of the Labiche formation with similar strata occurring throughout the central and east-central portion of Alberta and northeastern British Columbia.

Correlation with Redwater Area, Alberta

Imperial Eldorena No. 1 Well

No evidence was obtained which would warrent correlation of the Grand Rapids formation of the Athabaska River area, with any formation found in the Redwater area. The Mannville formation is sometimes correlated with the Grand Rapids, but the facies of the Grand Rapids is conglomeratic and quite distinct from the facies of the Mannville which is known to conclude with residual soils. This would suggest that the Grand Rapids represents deposition during the period represented by the stratigraphic highness between the Mannville and the basal Lloydminster.

Examination by the writer of microfossils picked from the basal Lloydminster by Bullock (1950) from the Imperial Eldorena No. 1 well reveals a nearly identical suite of fossils to those obtained from the Joli Fou formation on the Athabaska River. In the Eldorena area a total thickness of 72 feet of basal Lloydminster shale was present, and from this shale the following fossils have been identified; two lists of fossils are given, one from the Joli Fou shale, and the other from the basal Lloydminster:

Basal Lloydminster Formation (Eldorena Well)	Joli Fou Formation
Ammobaculoides ABZ-1-7	Ammobaculoides ABZ-1-7
Gaudryina canadensis var. A	Gaudryina canadensis var. A
Haplophragmoides linki	Haplophragmoides linki
Proteonina sp.	Proteonina sp.
Glomospira MZ-1-12	Glomospira MZ-1-12
Glomospira sp.	Glomospira sp.
Ammobaculites tyrrelli var. AT	Ammobaculites tyrrelli var. AT
Ammobaculites fragmentaria	Ammobaculites fragmentaria
Haplophragmoides cf. cushmani	Haplophragmoides cf. cushmani
Ammobaculites cf. KB-72-6	Ammobaculites cf. KB-72-6
- - - - - - - -	Ammobaculites KB-72-6
Haplophragmoides cf. collyra	Haplophragmoides cf. collyra
Haplophragmoides sp.	Haplophragmoides sp.
Ammobaculites humei	Ammobaculites humei
Gaudryina cf. canadensis	Gaudryina cf. canadensis
Haplophragmoides gigas	Haplophragmoides gigas
Haplophragmoides sp.	Haplophragmoides sp.
Miliammina manitobensis var. C	Miliammina manitobensis var. C
Miliammina sp.	Miliammina sp.
Ammobaculites GB-72-0 n. sp.	Ammobaculites GB-72-0 n. sp.

Overlying the basal Lloydminster in the Redwater area is the Viking sand; the sand is not very fossiliferous, but sufficient evidence is available to warrant correlation with the Pelican sand of the Athabaska River area. The following fossils have been identified:

Viking Sand	Pelican Sand
Haplophragmoides cf. cushmani	Haplophragmoides cf. cushmani
Spores ?	Spores?
Miliammina sp.	Miliammina sp.
Verneuilina sp.	Verneuilina sp.
Gaudryina sp.	Gaudryina sp.
Miliammina cf. manitobensis	Miliammina cf. manitobensis
Ammobaculites sp.	Ammobaculites sp. (found in Labiche
Miliammina sp.	Miliammina sp. fmt)
Hyperammina EB-74-45	Hyperammina EB-74-45
Verneuilina canadensis var. V-5	Verneuilina canadensis var. V-5 (found in Labiche fmt.)

Fossils from forty feet of the Lloydminster shale, immediately above the Viking sand, were examined and, proved to be identical to fossils from the basal 40 feet of the Labiche formation. There is continuous deposition in the first few hundred feet of the Labiche shale up to the fish-scale beds, and correlation of the Labiche and

Lloydminster shale seems feasible up as far as the fish-scale beds*, which occur in both areas, about 250 feet above both the Viking and Pelican sands.

The following fossils have been identified as occurring in both the Labiche shale and the Lloydminster shale above the Pelican and Viking sand respectively:

Lloydminster Shale	Basal Labiche Shale
Gaudryina sp.	Gaudryina sp.
Ammobaculites sp.	Ammobaculites sp.
Leptodermella sp.	Leptodermella sp.
Trochammina 2 sp.	Trochammina 2 sp.
Miliammina sp.	Miliammina sp.
Reophax RAB-62-81	Reophax RAB-62-81
Verneuilina canadensis var. V-5	Verneuilina canadensis var. V-5

Conclusions

The basal Lloydminster shale, Viking sand and the lower portion of the Lloydminster shale above the Viking of the Redwater area, correlate exactly with corresponding sections of Joli Fou shale, Pelican sand and basal Labiche shale respectively of the Athabaska River area. Paleontological evidence is sufficient to justify correlation of the Joli Fou and basal Lloydminster formations.

Both the fossils found in the Viking and its stratigraphic position between the basal Lloydminster shale and the remainder of the Lloydminster formation indicate that it should correlate with the Pelican.

Fossil evidence allows correlation of the basal 40 feet of the Labiche formation and 40 feet of the Lloydminster shale immediately

* Fish-scale beds are considered to be the break between the upper and lower Cretaceous strata in Alberta (Stelck 1950).

overlying the Viking sand; the presence of fish-scale sands at similar distances above both the Viking and Pelican sands indicates complete equivalence of these two shale sections below the fish-scale beds.

Correlation with Vermilion [12] Area

The basal portion of the Lloydminster shale in this area which correlates with the Joli Fou, Pelican and basal Labiche consists of a series of grey shales with minor sandy lenses, and occupies a position from the top of the Mannville formation to the fish-scale beds.

The Pelican sand, present in the Athabaska River section, is not present as such in the Lloydminster area. Instead, it is represented by a shaly facies. The Lloydminster shale section up to the fish-scale beds is a continuous shaly series and is not broken into discrete formations or members as is the Athabaska River section, nevertheless identical fossils have been found in these sections to provide correlation. The following fossils have been found:

Lloydminster Shale	Joli Fou Shale
Ammobaculites humei	Ammobaculites humei
Ammobaculites fragmentaria	Ammobaculites fragmentaria
Ammobaculites tyrrelli	---
---	Ammobaculites tyrrelli var. AT
Haplophragmoides linki	Haplophragmoides linki
Haplophragmoides gigas	Haplophragmoides gigas
Haplophragmoides sp.	Haplophragmoides sp.
Verneuilina canadensis	---
---	Haplophragmoides cf. excavata
---	Miliammina manitobensis var. C
Miliammina cf. manitobensis	Miliammina cf. manitobensis
Gaudryina hectori	Gaudryina cf. hectori
Ammobaculites cf. KB-72-6	Ammobaculites cf. KB-72-6
---	Ammobaculites KB-72-6
---	Haplophragmoides cf. collyra

[12] (12) Nauss (1945)

Lloydminster Shale	Basal Labiche Shale
Ammobaculites fragmentaria	----------
Haplophragmoides excavata	Haplophragmoides excavata
----------	Verneuilina canadensis
Haplophragmoides sp.	Haplophragmoides sp.
Leptodermella sp.	Leptodermella sp.
Ammobaculites sp.	Ammobaculites sp.
Haplophragmoides linki	----------
Ammobaculites tyrrelli	Ammobaculites cf. tyrrelli
Ammobaculites humei	Ammobaculites cf. humei

Conclusions

Sufficient paleontological evidence is present to justify corre- of the Joli Fou shale, Pelican sand and basal Labiche shale up to the fish-scale beds, with the Lloydminster shale of the Vermilion area from the top of the Mannville to the fish-scale beds; a range of about 300 feet. The upper 50 feet of the Lloydminster shale section under consideration was correlated on the basis of its stratigraphic position as paleontological evidence is rare. The basal 250 feet of the Lloydminster shale possessed identical fossils to the Joli Fou shale and Pelican sand.

Correlation with the Fort St. John Group of the Peace River Plains

The sampled portion of the Shaftesbury formation from 290' below the fish-scale beds to 200' below the fish-scale beds correlates with the basal 50 feet of the Labiche formation of the Athabaska River area. The following species are identical in both areas:

Shaftesbury (200 to 290' below fish-scales)	Labiche (basal 40')
Miliammina M1 (B-62-81)	Miliammina M1 (B-62-81)
Haplophragmoides excavata	Haplophragmoides cf. excavata
Hyperammina sp.	Hyperammina sp. (found in Pelican)
Trochammina sp.	Trochammina sp.
Ammobaculites sp.	Ammobaculites sp.
Gaudryina 2 sp.	Gaudryina 2 sp.
Reophax RAB-62-81	Reophax RAB-62-81
Verneuilina canadensis	Verneuilina canadensis
Leptodermella sp.	Leptodermella sp.
Verneuilina canadensis var. V-5	Verneuilina canadensis var. V-5

Conclusions

The lower portion of the Shaftesbury has been definitely correlated with the basal Labiche formation. The remainders of both the Shaftesbury formation up to the fish-scale beds and the Labiche formation up to the fish-scale beds are continuous series of shales without any stratigraphic break. On this basis it is reasonable to assume correlation of the remaining portions of these formations up as far as the fish-scale beds.

No direct fossil evidence has been obtained correlating any section in the Peace River Plains area with the Pelican sand. However, since the Cadotte sandstone underlies the Shaftesbury formation and the Pelican sand underlies the Labiche formation, it is reasonable to assume at least homotaxial correlation of the Pelican sandstone with a portion of the Cadotte sandstone on the basis of their stratigraphic positions.

The Harmon shale underlies the Cadotte sandstone in the Peace River area and carries Haplophragmoides gigas Cushman the principal zone fossil of the Joli Fou shale. The Harmon shale ~~then~~ therefore, is equivalent to at least part of the Joli Fou shale.

An additional microfauna occurs at the top of the Joli Fou shale which does not occur in the top of the Harmon shale. Another fauna occurs in the base of the Shaftesbury formation but does not occur in the base of the Labiche. The writer feels that although the Cadotte sandstone is homotaxial with the Pelican sandstone the former is probably slightly older, at least in part.

Correlation with the Buckinghorse Formation of the Sikanni Chief River Area, British Columbia

Several fossils were found in the upper portion of the Buckinghorse formation which are identical to species occurring in the basal 40 feet

of the Labiche formation of the Athabaska River area. From this evidence the writer has seen fit to correlate the portions of the formations mentioned. The following fossils are identical or reasonably so:

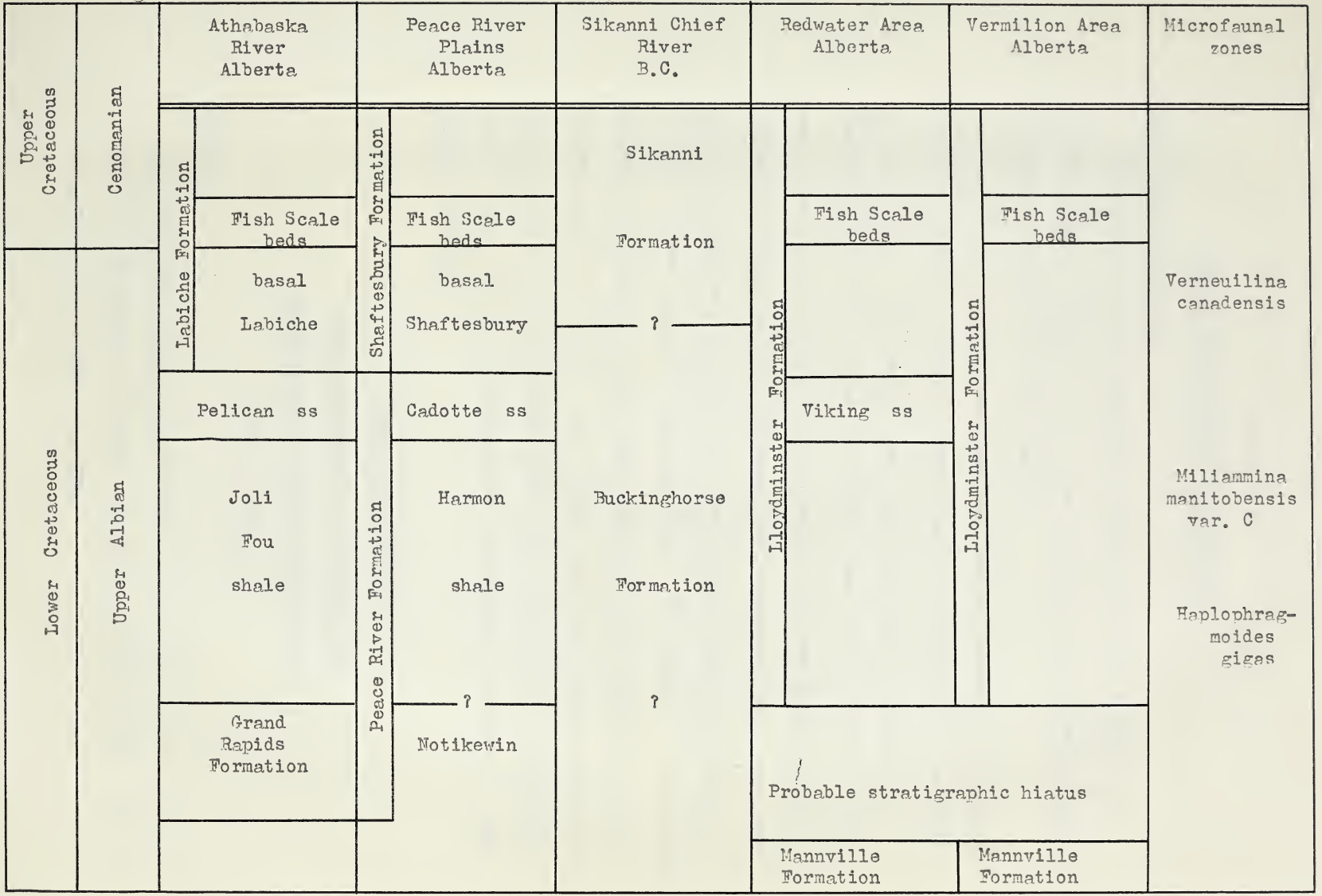
Upper Buckinghorse	Basal Labiche
Verneuilina canadensis	Verneuilina canadensis
Verneuilina sp.	Verneuilina sp.
Trochammina sp. ?	Trochammina sp.
Miliammina sp.	Miliammina sp. (in Pelican)
Bathysiphon sp.	Bathysiphon sp. (in Pelican)

Conclusions

From fossil evidence it is possible to correlate the upper portion of the Buckinghorse formation with the basal Labiche shale. No fossils were recognized from the Buckinghorse formation which would permit correlation of any portion of that formation with the Joli Fou shale. Since the uppermost portion of the Buckinghorse only was examined and several fossils were found in the Buckinghorse that also occur in the Pelican sand it is reasonable to assume that the uncollected portion of the Buckinghorse formation includes equivalents of the Pelican and the Joli Fou on the basis of its stratigraphic position.

From the conclusions given above, the writer has drawn up a correlation chart (see Fig. 111). The zone fossils ~~were~~ are mentioned selected in a previous chapter.

Figure III. Correlation chart of the Joli Fou, Pelican and basal Labiche formation and their Correlatives



Chapter III

Formal Description of Microfauna

Introductory Statement

Microfossils in the Cretaceous strata of Western Canada, are relatively rare, compared to the great numbers of microfossils found in Tertiary deposits of North America.

Comparatively little work has been done on Cretaceous microfauna in Western Canada, and only a small amount of literature is available on the subject. This chapter deals with the formal description of some Cretaceous forms, found in outcrop areas of the Athabaska River. Some of the forms described in this report have been previously described by various authors, (Cushman 1927, Wickenden 1932, Nauss 1947) none of the species, however, have been figured from the Cretaceous deposits exposed along the Athabaska River. The species of foraminifera figured and described in this paper represent only a portion of the species present in the Joli Fou, Pelican and basal Labiche formations, being confined to those species which have the greatest stratigraphic significance. All descriptions are in alphabetical sequence for convenient reference.

Order Foraminifera

Genus Ammobaculites Cushman 1910

Ammobaculites fragmentarius Cushman

Plate 1, Figure 13

Synonymy:

Ammobaculites fragmentaria Cushman, J. A., 1927, Some Foraminifera from the Cretaceous of Canada: Royal Soc. Canada, Trans., Ser. 3, vol. 21, pt. 2, sect. 4, p. 130.

Test large, inflated, tapering, early portion planispiral, involute with 4 chambers, later portion rectilinear, uniserial, consisting of 6 chambers; chambers distinct, rapidly increasing in size as added, greatest width of test made by last formed chamber; sutures distinct depressed; wall of very coarse sand up to 0.156mm. in diameter, grains angular, imbedded in a more finely arenaceous matrix; aperture simple, irregular, terminal, at the end of a slightly pyriform terminal chamber.

Length of hypotype - 1.53 mm., greatest width - 0.56 mm., diameter of coiled portion 0.27 mm.

Hypotype - University of Alberta Paleontological Type Collection.

Hypotype locality: Athabaska River, Alberta, N.E. $\frac{1}{4}$, Sec. 32, T. 81, R. 17, W. 4 Mer., locality B-72-0, in the Joli Fou shale, 53' above the top of the Grand Rapids formation. It is not very abundant in this locality.

Remarks: This species is extremely coarse grained, the paratypes usually show much less matrix on the terminal chambers; it differs from the holotype in that the surface is composed of rounded or angular sand grains that give a very irregular knobby exterior to the test.

Ammobaculites tyrrelli var. At new var.

Plate 1, Figure 6

Test small, inflated, early portion planispiral, involute, with 4 chambers, later portion rectilinear, uniserial, consisting of 4 chambers, test circular in cross-section; chambers poorly defined in coiled portion, distinct in straight portion; sutures distinct depressed; wall arenaceous with grains up to 0.04 mm. in diameter, with grains forming a close mosaic on the inside and having a smooth surface developed on the outside

from the considerable cement filling the external irregularities presented by the sand grains; aperture round, terminal at the end of a pronounced neck.

Length of hypotype 0.56 mm., width of hypotype 0.17 mm., diameter of coiled portion 0.19 mm.

Hypotype - University of Alberta Paleontological Type Collection. Hypotype locality; Athabaska River, Alberta, N.E. $\frac{1}{4}$, Sec. 32, T. 81, R. 17, W. 4 Mer., locality B-72-0, in the Joli Fou shale, 53' above the top of the Grand Rapids formation. It is not very abundant in this locality.

Remarks: This variety is differentiated from Ammobaculites tyrrelli tyrrelli Nauss in having the chambers of the rectilinear portion more elongate.

Ammobaculites GB-72-0 n. sp.

Plate 1, Figure 2

Test large, inflated, early portion planispiral, involute, with 4 chambers, later portion rectilinear, uniserial, with the sides gradually tapering consisting of 6 chambers, greatest width of test made by last formed chamber; chambers poorly defined in coiled portion, well defined in straight portion, increasing slightly in size as added; sutures poorly defined, slightly depressed; wall of very coarse angular sand up to 0.211 mm. in diameter, neatly cemented, surface very irregular; aperture small, simple, round, terminal, at the end of the last formed chamber.

Length of hypotype - 1.33 mm., greatest width 0.33 mm., diameter of coiled portion 0.23 mm.

Hypotype - University of Alberta Paleontological Type Collection.

Hypotype locality: Athabaska River, Alberta, N.E. $\frac{1}{4}$, Sec. 32,

T. 81, R. 17, W. 4 Mer., locality B-72-0 in the Joli Fou shale, 53' above the top of the Grand Rapids formation; relatively scarce in this locality.

Remarks: This species has extremely coarse angular grains; it is distinguished from the holotype of Ammobaculites fragmentaria Cushman by the strong tapering test of the latter. The "form - species" A. fragmentarius Cushman would undoubtedly cover the hypotype, but the author feels that the extension of the species to forms which are not tapering but merely have a coarsely arenaceous make-up, supresses the diagnostic worth of a great number of distinctive Ammobaculites species that have a valuable stratigraphic connotation. Ammobaculites GB-72-0 is probably the form R. T. D. Wickenden (1949, p. 19) designated Ammobaculites B.

Ammobaculites KB-72-6

Plate 1, Figure 27

Test large, inflated, tapering, early portion planispiral, involute with 4 chambers revealed, later portion rectilinear, uniserial consisting of 3 chambers, greatest width of test formed by planispiral portion; chambers distinct in uniserial portion, poorly defined in planispiral portion; sutures distinct, depressed; wall of very coarse angular sand grains up to 0.13 mm., with considerable finely arenaceous cement; aperture terminal, at the end of a pyriform terminal chamber, broken off in the hypotype.

Length of hypotype with last formed chamber missing 1.02 mm., length of hypotype with last formed chamber added 1.17 mm., diameter of coiled portion 0.44 mm.

Hypotype - University of Alberta Paleontological Type Collection.

Hypotype locality: Athabaska River, Alberta N.E. $\frac{1}{4}$, Sec. 32, T. 81, R. 17, W. 4 Mer., locality B-72-6 in the Joli Fou shale 43 feet above the top of the Grand Rapids formation.

Remarks: Ammobaculites KB-72-6 has greatest width of test formed by the planispiral portion; in preservation the test is slightly compressed, giving an elliptical shape in cross section; the hypotype is something like A. torosus Loeblich and Tappan, but the latter is much finer grained and has greater indentation of the sutures; Ammobaculites KB-72-6 is probably the form Wickenden (1949, p. 19) designated Ammobaculites C.

Genus Ammobaculoides Plummer 1932

Ammobaculoides ABZ-1-7

Plate 1, Figure 20

Test elongate, slightly compressed; early chambers planispiral, later chambers in rectilinear alternating biserial pattern, 4 chambers visible in coiled portion, 6 to 7 chambers in biserial portion, suggestion of uniseriality in the unltimate chamber only, chambers increase in size in the coiled portion as added, the biserial chambers almost the same size throughout, with slightly larger terminal chamber, chambers slightly inflated; sutures distinct, depressed, oblique, with zigzag median suture between the two series; wall coarsely arenaceous, composed of large angular quartz grains, firmly cemented, but not covered by the cement, leaving the surface rough; aperture terminal, small, very irregularily elliptical.

Length of hypotype 0.78 mm., width of hypotype 0.30 mm.

Hypotype - University of Alberta Paleontological Type Collection.

Hypotype locality: Athabaska River, Alberta, Sec. 31, T. 85,

R. 17, W. 4 Mer., locality Z-1-7, at the base of Joli Fou shale, 7' above the top of Grand Rapids formation.

Remarks: The hypotype species differs from Ammobaculoides plummerae Loeblich in being much more coarsely arenaceour and in being much more involute in the coiled portion and having fewer chambers in the coiled portion. This is probably the form Wickenden (1949, p. 20) is designating Ammobaculoides sp.

Genus Gaudryina d'Orbigny 1839

Gaudryina canadensis var. A

Plate 1, Figure 4

Test elongate, early portion triserial, later becoming biserial; chambers distinct, inflated, 7 to 9 in biserial portion, 9 to 12 in triserial portion, gradually increasing in size as added; sutures distinct, slightly curved, depressed; wall arenaceous, with grains up to 0.025 mm., with considerable cement; aperture large, high crescent shaped arch or semicircular opening at the base of the interface of the last formed chamber; honey colored.

Length of hypotype 0.48 mm., greatest width of hypotype 0.17 mm.

Hypotype - University of Alberta Paleontological Type Collection.

Hypotype locality: Athabaska River, Alberta, Sec. 31, T. 85, R. 17, W. 4 Mer., locality Z-1-22, near the base of the Joli Fou shale, twenty-two feet above the top of the Grand Rapids formation.

Remarks: The hypotype of G. canadensis var. A is slightly distorted as are the paratypes; G. canadensis var. A differs from G. canadensis Cushman; G. canadensis var. A has a relatively longer triserial portion; this small species is about the same size as G. bearpawensis Wickenden, but has fewer chambers in the triserial

portion than the latter.

Genus Glomospira Rzehak 1888

Glomospira MZ-1-12

Plate 1, Figure 22

Test flattened, disc like, very small, composed of proloculum and long tubular undivided second chamber, the whole test irregularly planispiral consisting of 6 to 8 turns, the diameter of the tube increases with the diameter of specimen; wall finely arenaceous, smooth with considerable clear cement; aperture, the open end of the tubular second chamber.

Greatest diameter 0136 mm.

Hypotype - University of Alberta Paleontological Type Collection.

Hypotype locality: Athabaska River, Alberta, Sec. 31, T. 85, R. 17, W. 4 Mer., locality Z-1-12, at the base of the Joli Fou shale twelve feet above the top of the Grand Rapids formation.

Remarks: The coils in the later stage never change greatly from a planispiral type of growth; where the specimens are badly compressed in preservation they may be mistaken for specimens of Spirillina.

Genus Haplophragmoides Cushman 1910

Haplophragmoides cf. cushmani Loeblich and Tappan

Plate 1, Figure 21

Test large, usually flattened in preservation, planispiral, involute becoming evolute, periphery broadly rounded, somewhat lobate; chambers $6\frac{1}{2}$, in last whorl; sutures straight, well defined, at base of the apertural face of the last formed chamber.

Greatest diameter of hypotype 0.89 mm. least diameter of hypotype 0.78 mm.

Hypotype - University of Alberta Paleontological Type Collection.

Hypotype locality: Athabaska River, Alberta, N.E. $\frac{1}{4}$, Sec. 27, T. 82, R. 17, W. 4 Mer., locality B-75-13; basal part of Joli Fou shale thirteen feet above the top of the Grand Rapids formation.

Remarks: This species differs from the H. cushmani Loeblich and Tappan in being almost $2\frac{1}{2}$ times the diameter of the later and in lacking excessively in the inflated ultimate chamber.

Haplophragmoides cf. collyra Nauss

Plate 1, Figure 23, 24

Test planispiral, involute becomes evolute, periphery broadly rounded; chambers, inflated, globular, $7\frac{1}{2}$ in last whorl; sutures, straight, distinct, radial, slightly depressed; wall arenaceous with a fairly even surface, considerable cement; aperture in doubt.

Greatest diameter of hypotype 0.35 mm., least diameter of hypotype 0.26 mm.

Hypotype - University of Alberta Paleontological Type Collection.

Hypotype locality: Athabaska River, Alberta, Sec. 31, T. 85, R. 17, W. 4 Mer., locality Z-1-22, in the basal portion of the Joli Fou shale, 22' above the top of the Grand Rapids formation.

Remarks: H. cf. collyra differs from H. collyra Nauss in that it is smaller, the sutures are slightly thicker in the former.

Haplophragmoides cf. excavata Cushman

Plate 1, Figure 5

Test closely coiled, involute, planispiral; chambers defined, 8 in last formed coil, the partitions between the chambers distinctly thickened, with chambers showing as depressions in normal preservation; sutures straight, radial, obscure with their position indicated by the uncrushed surface supported by the thickened chamber walls; wall finely arenaceous with considerable cement, pebbled finish to the surface; aperture poorly defined in preservation, a low arched slit at base of the apertural face of the last formed chamber.

Greatest diameter of hypotype 0.33 mm., least diameter of hypotype 0.25 mm., thickness of hypotype 0.07 mm.

Hypotype - University of Alberta Paleontological Type Collection.

Hypotype locality: Athabaska River, Alberta, S.E. $\frac{1}{4}$, Sec. 27, T. 82, R. 17, W. 4 Mer., locality B-74-30, near the top of the Joli Fou shale, 80' above the top of the Grand Rapids formation.

Remarks: The hypotype of H. cf. excavata is similar to a hypotype of H. excavata figured by Cushman from the Navarro group (pl. 2, fig. 15). It differs from the holotype of H. excavata by having fewer chambers and it lacks the grey color. The term H. excavata has been used to cover a wide variety of forms that have stout intercameral walls, and relatively weak side walls to the chambers. The high content of cement in the wall make-up allows of a flexibility in deformation, this results in a state of preservation in which the chambers are outlined in limbate fashion surrounding a depression that marks the position of the chamber, this results in an anomolous "preservation form-species", and it is doubtful whether the "species" has any longer diagnostic significance. This is probably the form R. T. D. Wickenden (1949, p. 19) designated Haplophragmoides sp. A.

Haplophragmoides gigas Cushman

Plate 1, Figure 18

Synonymy:

Haplophragmoides gigas, Cushman, 1927. Royal Soc. Canada Trans., 3d. ser., vol. 21, sec. 4, p. 129, pl. 1, fig. 5.

Haplophragmoides gigas, Cushman 1946. U.S.G.S. Prof. Paper 206, p. 21, pl. 3, fig. 2.

Haplophragmoides gigas, Nauss 1947. Jour of Paleontology, vol. 21, no. 4, p. 338, pl. 49, fig. 8a,b.

Test large, planispiral, with terminal face slightly oblique to the planispiral pattern, involute becoming evolute in later stages,

peripheral margin slightly lobate; chambers about 10 in the last whorl, star shaped umbilicus; sutures well defined depressed, slightly thickened, sigmoid when specimen is crushed, only slightly sigmoid when uncrushed, reflecting a concavity of the wall that is present above the aperture on the terminal face; wall finely arenaceous with a great deal of cement; aperture peripheral at the base of the apertural face, fairly large, well-defined, with a lip well-defined on crushed specimen, but on uncrushed specimens the lip seems to represent the inner portion of the concave depression on the terminal face.

Greatest diameter of hypotype 0.98 mm., least diameter of hypotype 0.78, mm., thickness of hypotype about 0.32 mm.

Hypotype - University of Alberta Paleontological Type Collection.

Hypotype locality: Athabaska River, Alberta, Sec. 31, T. 85, R. 17, W. 4 Mer., locality Z-1-22, at the base of the Joli Fou shale 22' above the top of the Grand Rapids formation.

Remarks: This specimen is described as it represents an uncrushed member of the species; it differs from the holotype of H. gigas Cushman in having occasional slightly larger grains embedded in the cement, especially towards the umbilical margin; the specimen from the outcrops lacks the yellow colour of the species when found in well samples.

Haplophragmoides linki Nauss

Plate 1, Figure 25

Synonymy:

Haplophragmoides rugosa Cushman, 1927. Royal Soc. Canada Proc. and Trans., vol. 21, sec. 4, p. 128, pl. 1, fig. 2.

Haplophragmoides linki Nauss, 1947. Jour. of Paleontology, vol. 21, no. 4, p. 339, pl. 49, fig. 7a, 7b.

Test small, planispiral, completely involute, periphery broadly rounded; chambers distinct, 8 to 9 in last formed whorl; sutures distinct, slightly depressed, straight, radial; wall arenaceous, very fined grained with occasional slightly larger grains, considerable cement forming a smooth outer layer to the test; aperture a low arched slit at base of apertural face.

Greatest diameter of hypotype 0.27 mm., least diameter of hypotype 0.21 mm.

Hypotype - University of Alberta Paleontological Type Collection.

Hypotype locality: Athabaska River, Alberta, Sec. 31, T. 85, R. 17, W. 4 Mer., locality Z-1-22, basal part of the Joli Fou shale, 22' above the top of the Grand Rapids formation.

Genus Hyperammina H. B. Brady 1878

Hyperammina EB-74-45

Plate 1, Figure 19

Test elongate, tubular, primary chamber broken off in hypotype, but a paratype from another locality shows a compressed proloculum shown at an angle to the second chamber, test slightly constricted at irregular intervals throughout its length; aperture terminal, the open end of tube; wall, thick, composed of fine arenaceous material, predominently white cement, with a fairly smooth surface.

Length of hypotype 0.71 mm., greatest width of hypotype 0.18 mm., diameter of aperture 0.07 mm., dimensions of paratypes do not vary greatly from these.

Hypotype - University of Alberta Paleontological Type Collection.

Hypotype locality: Athabaska River, Alberta, S.E. $\frac{1}{4}$, Sec. 27, T. 82, R. 17, W. 4 Mer., locality B-74-45, from the Joli Fou shale, 65'

above the top of the Grand Rapids formation. The species is not abundant at this locality.

Remarks: The proloculum is broken off from the hypotype of Hyperammina EB-74-45, but there is strong suggestion that the initial portion of the second chamber is represented by the hypotype. Probably the form R. T. D. Wickenden (1949, p. 19) referred to in his preliminary paper.

Genus Miliammina Heron-Allen and Earland, 1930

Miliammina manitobensis var. C

Plate 1, Figure 15, 16, 17

Test elliptical; chambers distinct, elongate, tubular, each half a turn in length, in quinqueloculine arrangement, three visible on one side, four on the other; sutures distinct, depressed; wall finely arenaceous with considerable black mica flakes concentrated along the suture, considerable cement; aperture, terminal, simple, slightly restricted, on a distinct pronounced neck which is formed by the projection of the last formed chamber beyond the previous chambers.

Length of hypotype 0.70 mm., width of hypotype 0.31 mm.

Hypotype - University of Alberta Paleontological Type Collection.

Hypotype locality: Athabaska River, Alberta, S.E. $\frac{1}{4}$, Sec. 27, T. 82, R. 17, W. 4 Mer., locality B-74-35, near the top of Joli Fou shale, 75' above the top of the Grand Rapids formation.

Remarks: The hypotype of Miliammina manitobensis var. C differs from the paratype of M. manitobensis figured by Cushman (1946, p. 48, pl. 14) in that it is almost twice as large and half as wide again as the latter; color of hypotype of M. manitobensis var. C is white with abundant black mica flakes concentrated in the sutural depressions.

This may be the form Wickenden (1949, p. 19) signifies as M. cf. manitobensis.

Miliammina M1B-62-81

Plate 1, Figure 7, 8, 9

Test elliptical, compressed; chambers poorly defined, elongate, tubular, each half a turn in length in irregular quinqueloculine arrangement, three visible on one side, four on the other; sutures poorly defined, and well defined on last two chambers only, depressed; wall arenaceous, very fine grained, smoothly finished with cement not dominant; aperture terminal, slightly restricted, a simple opening at the last formed chamber, some specimens have a slightly bevelled, incipient neck.

Length of hypotype 0.58 mm., width of hypotype 0.31 mm.

Hypotype - University of Alberta Paleontological Type Collection.

Hypotype locality: Athabaska River, Alberta, S.E. $\frac{1}{4}$, Sec. 30, T. 79, R. 17, W. 4 Mer., locality B-62-81, at the base of Labiche formation, 157' above top of Grand Rapids formation.

Remarks: The hypotype of Miliammina M1B-62-81 resembles slightly M. manitobensis Wickenden; M. M1B-62-81 has no pronounced neck and has less cement in the make-up of the wall.

Miliammina M0B-76-23

Plate 1, Figure 1, 2, 3

Test elliptical; chambers distinct, elongate, tubular, each half a turn in length, in quinqueloculine arrangement, three visible on one side, four on the other; sutures distinct, somewhat depressed; wall finely arenaceous, smooth, with white transluscent cement; aperture, simple, terminal at end of the last formed chamber, immediately

posterior to the aperture the ultimate chamber has its maximum diameter, a slight neck occasionally develops at the end of the last chamber protruding beyond the other chambers.

Length of hypotype 0.62 mm., width of hypotype 0.24 mm.

Hypotype - University of Alberta Paleontological Type Collection.

Hypotype locality: Athabaska River, Alberta, S.W. $\frac{1}{4}$, Sec. 35, T. 82, R. 17, W. 4 Mer., locality B-76-23, in the Grand Rapids formation, 23' below the top.

Remarks: This Miliammina from the Grand Rapids formation is distinguished from the Miliammina sproulei Nauss from the Mannville formation by having a restricted aperture and being white in colour, whereas M. sproulei has a flared aperture and is grey in colour. It is distinguished from M. manitobensis var. C by lacking the oblique aperture and the elliptical shape outline of the latter.

Genus Reophax Montfort 1808

Reophax RAB-62-81

Plate 1, Figure 14

Test rectilinear, sharply tapering, increasing in width rapidly toward the apertural end; chambers 3 to 4, subglobular, undivided, often slightly flattened in preservation, markedly increasing in size as added; sutures depressed, distinct; wall arenaceous, grains moderately uniform in size, up to 0.08 mm. in diameter, roughly finished; aperture small, round, terminal, at the end of a poorly developed neck.

Length of hypotype 0.82 mm., greatest width of hypotype 0.58 mm.

Hypotype locality: Athabaska River, Alberta, S.E. $\frac{1}{4}$, Sec. 30, T. 79, R. 17, W. 4 Mer., locality B-62-81, lower part of the Labiche formation, 157' above the top of the Grand Rapids formation. This species is very abundant in the basal portion of the Labiche formation.

Remarks: This species shows some similarity to the modern deep water form Reophax exentricus Cushman, but the latter form is much larger and more gradually tapered and is made-up of coarser grains.

Genus Verneuilina d'Orbigny 1840

Verneuilina canadensis Cushman

Plate 1, Figure 10, 11

Synonymy:

Verneuilina canadensis Cushman, 1927. Royal Soc. Canada Tran. 3d. ser., vol. 21, sec. 4, p. 131, pl. 1, fig. 11.

Verneuilina canadensis Cushman 1937. Lab. Foram. Research Special Pub. 7, p. 13, pl. 1, figs. 16, 17.

Verneuilina canadensis Cushman 1946. U.S.G.S. Prof. Paper 206 p. 31, pl. 7, figs. 2, 3.

Test fairly large, elongate, gradually tapering throughout, rapidly tapering at base, slightly twisted, triserial throughout; trilobate in cross-section; chambers distinct, inflated, globular, nearly all of same size except for the introductory chambers which are smaller, 6 to 7 in each vertical series; sutures distinct, much depressed; wall coarsely arenaceous, with grains up to 0.06 mm. in size, with a great deal of yellowish cement; aperture a small arcuate openning at the inner margin of the last formed chamber.

Length of hypotype 0.78 mm., width of hypotype 0.27 mm.

Hypotype - University of Alberta Paleontological Type Collection.

Hypotype locality: Athabaska River, Alberta, S.E. $\frac{1}{4}$, Sec. 30, T. 79, R. 17, W. 4 Mer., locality B-62-60 in the basal portion of the Labiche shale 180' above the top of the Grand Rapids formation. This species is not too common in the basal 30' of the Labiche formation.

Remarks: This hypotype agrees in every respect with the holotype description and with topotypes of the species.

Verneuilina canadensis var. V5

Plate 1, Figure 26

Test elongate, medium-sized, tapering, triserial throughout; chambers distinct, inflated, about 6 to 7 in each vertical series, each chamber getting larger as added; sutures distinct, depressed; wall finely arenaceous, with maximum grain size 0.03 mm., with an outer coating of brownish cement obscuring the outline of the grains; aperture a small arcuate openning at the inner margin of the last formed chamber.

Length of hypotype 0.59 mm., greatest width of hypotype 0.33 mm.

Hypotype - University of Alberta Paleontological Type Collection.

Hypotype locality: Athabaska River, Alberta, S.E. $\frac{1}{4}$, Sec. 30, T. 79, R. 17, W. 4 Mer., locality B-62-81 in the basal portion of the Labiche formation, 157' above the top of the Grand Rapids formation. This new variety is restricted to the basal portion of the Labiche formation directly above the Pelican sand.

Remarks: This specimen used as a hypotype is slightly flattened; this variety differs from V. canadensis canadensis Cushman in that the former tapers more continuously and the chambers increase in size as added, the grain size is uniformly finer.

Explanation of Plate I

Page

Figure 1, 2, 3: Miliammina MQB-76-23, X45, hypotype, from upper part of the Grand Rapids formation, locality B-76-23, S.W. $\frac{1}{4}$, Sec. 35, T. 82, R. 17, W. 4 Mer., along Athabaska River, Alberta; 1, sketch of apertural view 2, retouched photograph of side view 3, retouched photograph of other side. 29

Figure 4: Gaudryina canadensis var. A, X95, hypotype from basal part of Joli Fou formation, locality Z-1-22, Sec. 31, T. 85, R. 17, W. 4 Mer. along Athabaska River, Alberta; 4, retouched photograph of side view. .. 22

Figure 5: Haplophragmoides cf. excavata, X95, hypotype, from upper part of Joli Fou formation, locality B-74-30, S.E. $\frac{1}{4}$, Sec. 27, T. 82, R. 17, W. 4 Mer. along Athabaska River, Alberta; 5, retouched photograph of side view. 24

Figure 6: Ammobaculites tyrrelli var. AT, X45, hypotype, from basal part of Joli Fou formation, locality Z-1-22, Sec. 31, T. 85, R. 17, W. 4 Mer. along Athabaska River, Alberta; retouched photograph of side view. 18

Figure 7, 8, 9: Miliammina MLB-62-81, X45, hypotype, from basal part of Labiche formation, locality B-62-81, S.E. $\frac{1}{4}$, Sec. 30, T. 79, R. 17, W. 4 Mer. along Athabaska River, Alberta; 7, sketch of apertural view 8, retouched photograph of side view 9, retouched photograph of other side. 29

Figure 10, 11: Verneuilina canadensis, X45, hypotype, from basal part of Labiche formation, locality B-62-60, S.E. $\frac{1}{4}$, Sec. 30, T. 79, R. 17, W. 4 Mer. along Athabaska River, Alberta; 10, sketch of end view 11, retouched photograph of side view. 31

Figure 12: Ammobaculites GB-72-0, X45, hypotype, from centre of Joli Fou formation, locality B-72-0, N.E. $\frac{1}{4}$, Sec. 32, T. 81, R. 17, W. 4 Mer. along Athabaska River, Alberta; retouched photograph of side view. 19

Figure 13: Ammobaculites fragmentarius, X45, hypotype, from centre of Joli Fou formation, locality B-72-0, N.E. $\frac{1}{4}$, Sec. 32, T. 81, R. 17, W. 4 Mer. along Athabaska River, Alberta; retouched photograph of side view. 17

Figure 14: Reophax RAB-62-81, X45, hypotype, from basal part of Labiche formation, locality B-62-81, S.E. $\frac{1}{4}$, Sec. 30, T. 79, R. 17, W. 4 Mer. along Athabaska River, Alberta; retouched photograph of side view. 30

PLATE I

UPPER ALBIAN FORAMINIFERA
FROM THE
GRAND RAPIDS, JOLI FOU, PELICAN & LABICHE FORMATIONS

Chapter 4

Statistical Analysis

Generic and Specific Count

The generic analysis of the microfauna discussed in this thesis reveals in part the paleo-ecological conditions prevailing during the deposition of the Grand Rapids, Joli Fou, Pelican and early Labiche formations and shows the relative composition of the various faunas discussed.

A specific count of the fauna reveals close correlation with other areas in which similar assemblages prevail.

Generic and specific analysis graphs are included in this thesis.

Paleo-Ecology As Determined From Generic Analysis

Four dominant genera represented are Haplophragmoides, Ammobaculites, Gaudryina and Miliammina. Environmental conditions continued favorable to these, with other genera tolerated to a lesser degree. Brackish conditions with shallow waters (under 100') must have existed throughout the period from Upper Grand Rapids to Lower Labiche time.

The uppermost portion of the Grand Rapids formation is dominantly sandstone with several thin shaly interbeds. These shaly beds carry a scarce micro-fauna of Miliammina, Trochammina, Haplophragmoides, Leptodermella and (Collophane spheres). Miliammina is the more abundant, both in numbers and variety. Studies of recent faunas reveal that Miliammina are bottom living forms thriving best in near-shore, shallow, weakly brackish to moderately brackish waters which are well oxygenated. The remaining genera present are bottom living, brackish water inhabitants preferring bottom conditions where black muds are deposited with abundant carbonized plant remains, causing reducing conditions of

deposition. However, these genera tolerate a wide range of conditions and tolerate well-oxygenated clean waters although not optimum to their development. These studies indicate that the concluding Grand Rapids formation represents the deposites of an advancing sea, shallow tidal like flats developing over an area of low relief.

The change from Grand Rapids time to Joli Fou time brought in a consequent change in fauna both in numbers and in variety. The dominating fauna of the Grand Rapids period gave way to fauna more suited to the silty greyish-black, shaly environment. Early Joli Fou time heralded the appearance of new fauna including: Proteonina, Ammobaculites, Ammobaculoides, Gaudryina, Glomospira and "spores" as well as a marked increase in numbers and variety of Haplophragmoides. Most foraminifera display a delicate adjustment to a preferred environment and consequently any rapid changes unless directly in their favor usually is marked by a sharp decrease in numbers. The greyish-black silty shale of the early Joli Fou indicated conditions of turbid waters with accompaning decrease in light and possibly even a change in salinity. Miliammina the dominant genus in Grand Rapids time is very scarce in early Joli Fou time. Haplophragmoides appears to dominate the entire Joli Fou formation appearing in "floods" during the early portion of Joli Fou time and decreasing in numbers towards the end of Joli Fou time. Anaerobic conditions might exist near the bottom during dominance of the Haplophragmoides as the grey-black, silty shale indicates. These silty conditions on the other hand were probably the ideal source beds to provide Haplophragmoides with the desired sand grains from which their arenaceous tests are constructed. Ammobaculites and Gaudryina will not survive under severe anaerobic conditions, preferring a slight to moderately brackish well oxygenated environment usually found very near to

shore on flooded beaches, bays or inlets. Ammobaculites and Gaudryina, however, are never too abundant in the Joli Fou. Gaudryina appears in a small "flood" in early Joli Fou time and Ammobaculites is present in a small "flood" during middle Joli Fou time, the variety of these genera is limited, even during their maxima around the beginning and the middle of this depositional period. The influx of Hyperammina, Bathysiphon and Verneuilina is also a marked feature during the Ammobaculites "flood". Bathysiphon is dominantly a bottom living form found in shallow marine water, in areas in which mineral and plant components suggest low oxygen content; this Bathysiphon influx is from another outcrop from the faunas mentioned above. The presence of Bathysiphon suggests a still shallower marine facies interfingering into the Joli Fou during middle Joli Fou time. The Verneuilina and Hyperammina fauna live under much the same conditions as Ammobaculites and Gaudryina, consequently their presence indicates similar ecology.

The uppermost Joli Fou becomes very sandy and a consequent change in the numbers and varieties of fauna is the result. Sandy conditions are often the result of land movements, possibly a minor rejuvenation which may in part, be responsible for a decrease in depth of water, a cleaning of water and a decrease in salinity, resulting in a change of fauna or a reduction of fauna. Haplophragmoides, Verneuilina, Miliammina, Gaudryina, Leptodermella, "Collophane spheres" and "spores" are present in limited numbers and varieties in the sandy upper portion of the Joli Fou.

The Pelican sandstone marks a complete sandy facies of the Joli Fou formation; "spores" and Miliammina are the dominant fossils with Ammobaculites and Verneuilina appearing in numbers in the uppermost

Pelican sand; Haplophragmoides is absent in the uppermost Joli Fou, Pelican and basal Labiche. The presence of Miliammina, Verneuilina, Ammobaculites and "spores" marks another change from brackish to moderately brackish conditions; the turbid water of the Joli Fou has given way to clean well oxygenated waters of the Pelican sea, undoubtedly the indirect result of rejuvenation.

A close examination of the Miliammina and the "spore" graphs indicates that a "flood" of "spores" is usually followed by a "flood" of Miliammina. Many species of foraminifera live on algae and other vegetable matter. Because of the relationship shown by these two graphs it is reasonable to assume that, whenever there was a "flood" of "spores" there was abundant food upon which Miliammina thrived. The plants surrounding the margins of the ocean are probably responsible for the "spores", so a greater concentration of "spores" near shore is expected.

The change from a sandy facies represented by the basal Labiche formation did not have severe reflection on the general abundance of the dominating genera; on the contrary, most genera began increasing in numbers as well as varieties, except for Haplophragmoides. Sandy lenses occur in the lowermost Labiche indicating that complete anaerobic conditions did not exist. The dominant genera found in the Labiche is Ammobaculites. The tests of these Ammobaculites are peculiar in that the individual grains from which the test is composed are exceedingly large. The sandy lenses within the basal Labiche provide the proper sand texture from which Ammobaculites obtained their sand grains. Miliammina the dominant genera of the Pelican again is well represented in the Labiche, Verneuilina, Gaudryina and Trochammina are also well represented. The genus Reophax also makes an appearance. The presence of Ammobaculites, Verneuilina, Miliammina, Gaudryina and Reophax indicate

that slight to moderate brackish conditions prevailed; although the Labiche is dominantly a dark grey to black shale, many sandy lenses are present; the overall picture indicates a slow subsidence, accompanying the subsidence was a turbid sea; the subsidence is spasmodic with short quiescent periods. During the subsidence the sea floor and possibly the surrounding land mass began to sink resulting in the shore line retreating. Near the shore the water was always shallow and since fresh water streams poured in from the surrounding land mass, brackish conditions prevailed near shore; during the quiescent periods the sandy lenses were deposited in clean brackish waters and it was in these waters that the Ammobaculites, Verneuilina, Miliammina and Reophax fauna lived. Trochammina a versatile fauna tolerated to some extent the sandy conditions, but this fauna probably represents the muddy phase of this period; it is never too abundant in the basal Labiche.

From the preceeding discussion it can readily be concluded that the period from late Grand Rapids time to early Labiche time was an era of slow subsidence with shallow inundation by brackish waters. During late Grand Rapids time the environment was probably fresh with coal seams developing locally. Miliammina is the dominant foraminiferal fauna representing weak to brackish interfingering advances of the sea; this evidence indicates that Grand Rapids deposits are not entirely continental as once thought, but partly brackish.

The remaining formations namely: Joli Fou, Pelican and basal Labiche indicate varying degrees of brackish environment. The Joli Fou shows that moderate anaerobic conditions prevailed in early Joli Fou time changing to a slightly more oxygenated environment in middle and late Joli Fou time. Haplopragmoides is the dominating genus of the Joli Fou period.

Pelican time was an era of extremely well oxygenated conditions in which Miliammina and "spores" are the dominating microfossils. Ammobaculites becomes very prominent in late Pelican time.

Basal Labiche time was marked by faint indications of subsidence and quiescent periods, in which the waters were turbid and moderately clear respectively. The dominant fauna recorded for this period indicates that well oxygenated moderately brackish conditions prevailed with short periods of anaerobic conditions. Ammobaculites is the dominant fauna of this period with Gaudryina and Miliammina fairly abundant.

Explanation of the Specific Graphs Following

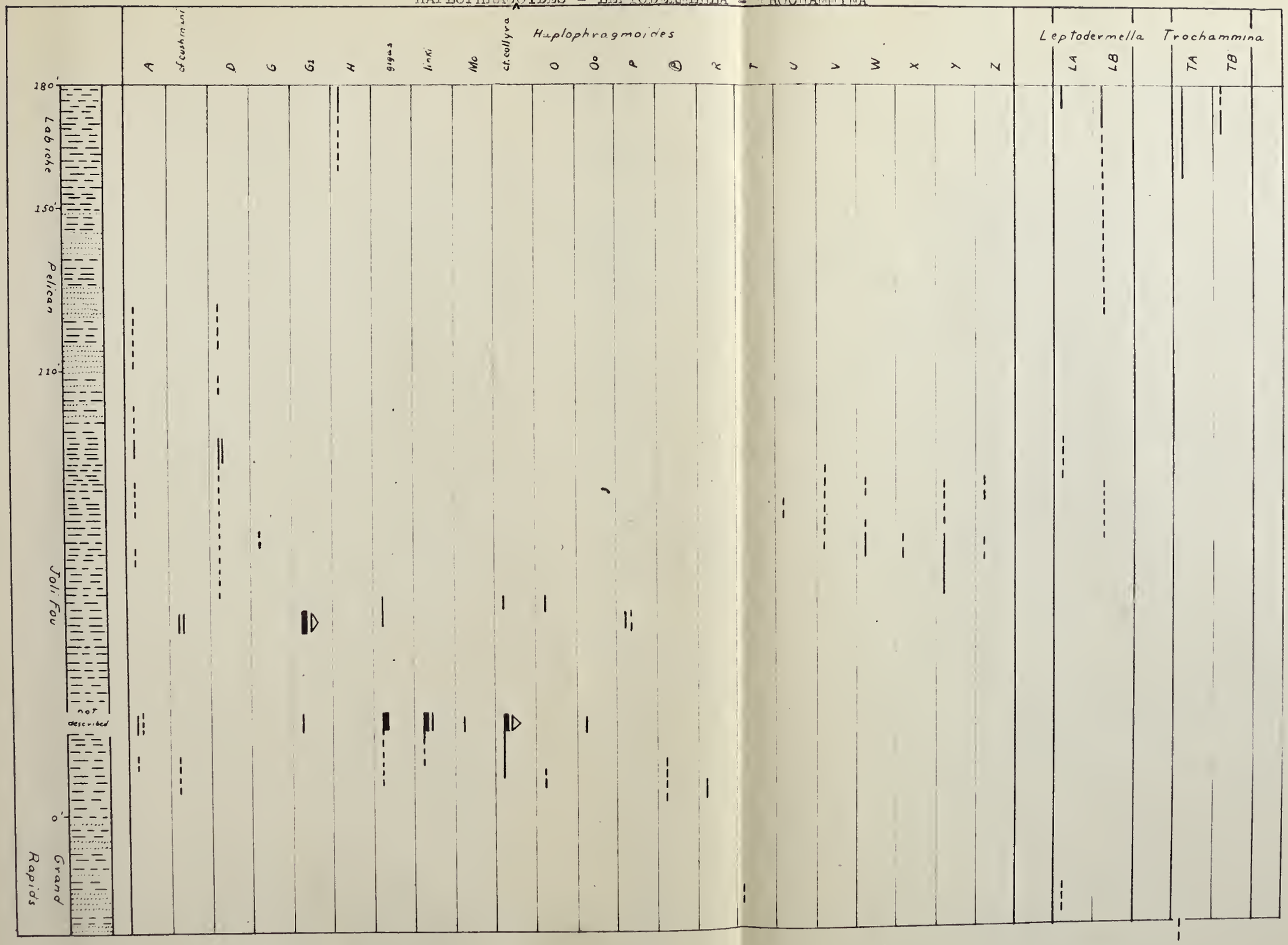
A statistical analysis has been made of all species of foraminifera found in the samples examined, appearing in the appendix portion of this thesis. This specific analysis has been illustrated by means of graphs. The vertical axes of these graphs represent the range and distribution of the various species. The datum is taken as the top of the Grand Rapids formation and is designated as 0'. Strata above this datum line include the Joli Fou, Pelican and Labiche formations. Strata below this line belongs to the Grand Rapids formation.

Each species or morphological entity (i.e. unnamed varieties, etc) occupies one column, within which, various "line symbols" indicate population numbers thus, a broken line indicates a population of from 0 - 10; a solid line from 11 - 100, a solid and a broken line 101 - 200, two solid lines 201 - 300, a bar 301 - 400, a bar and a solid line 401 - 500, a bar and a triangle 501 - 1000.

SPECIFIC GRAPHS

of

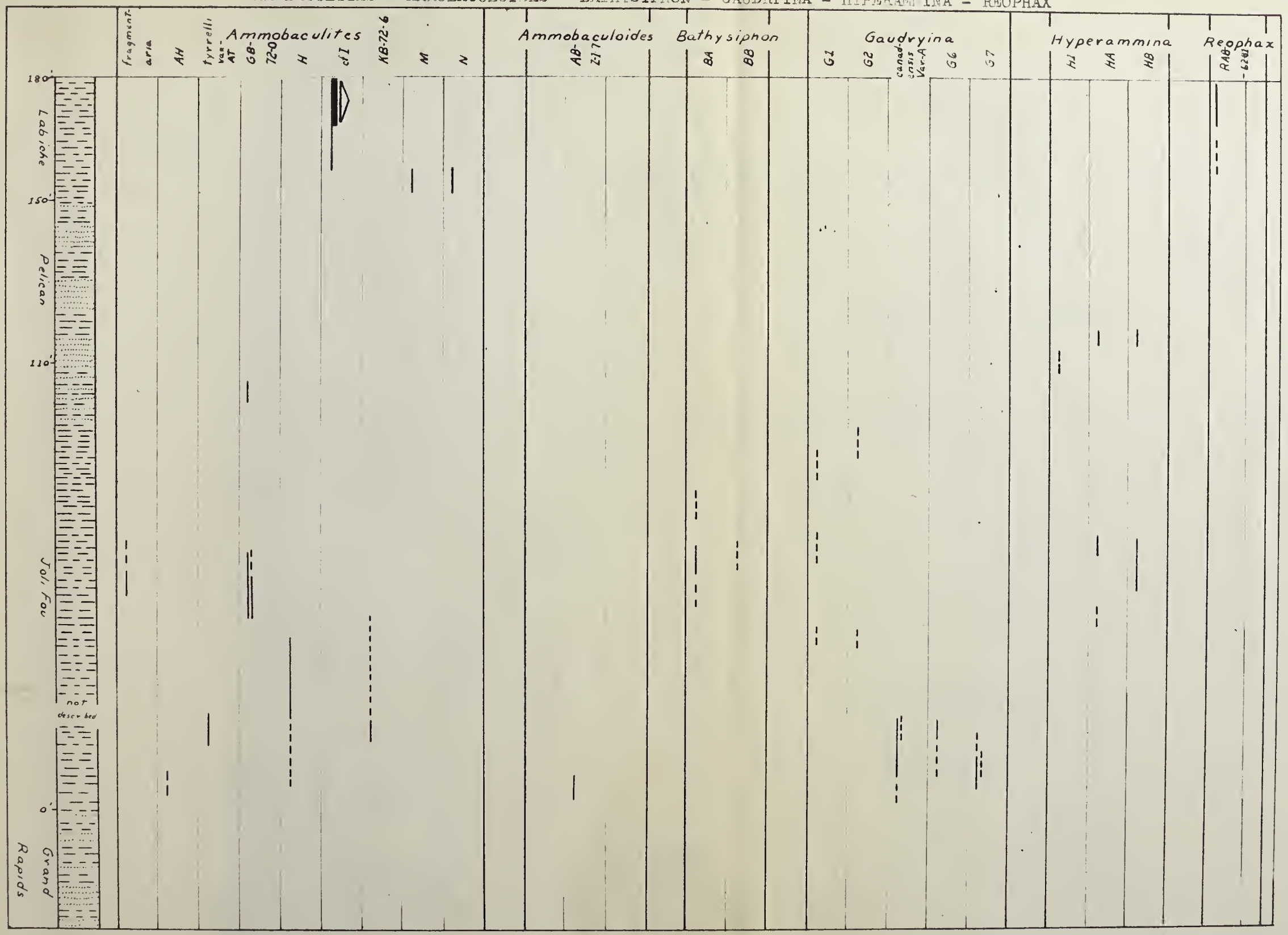
HAPLOPHRAGMOIDES - LEPTODERMELLA - TROCHAMMINA



SPECIFIC GRAPHS

of

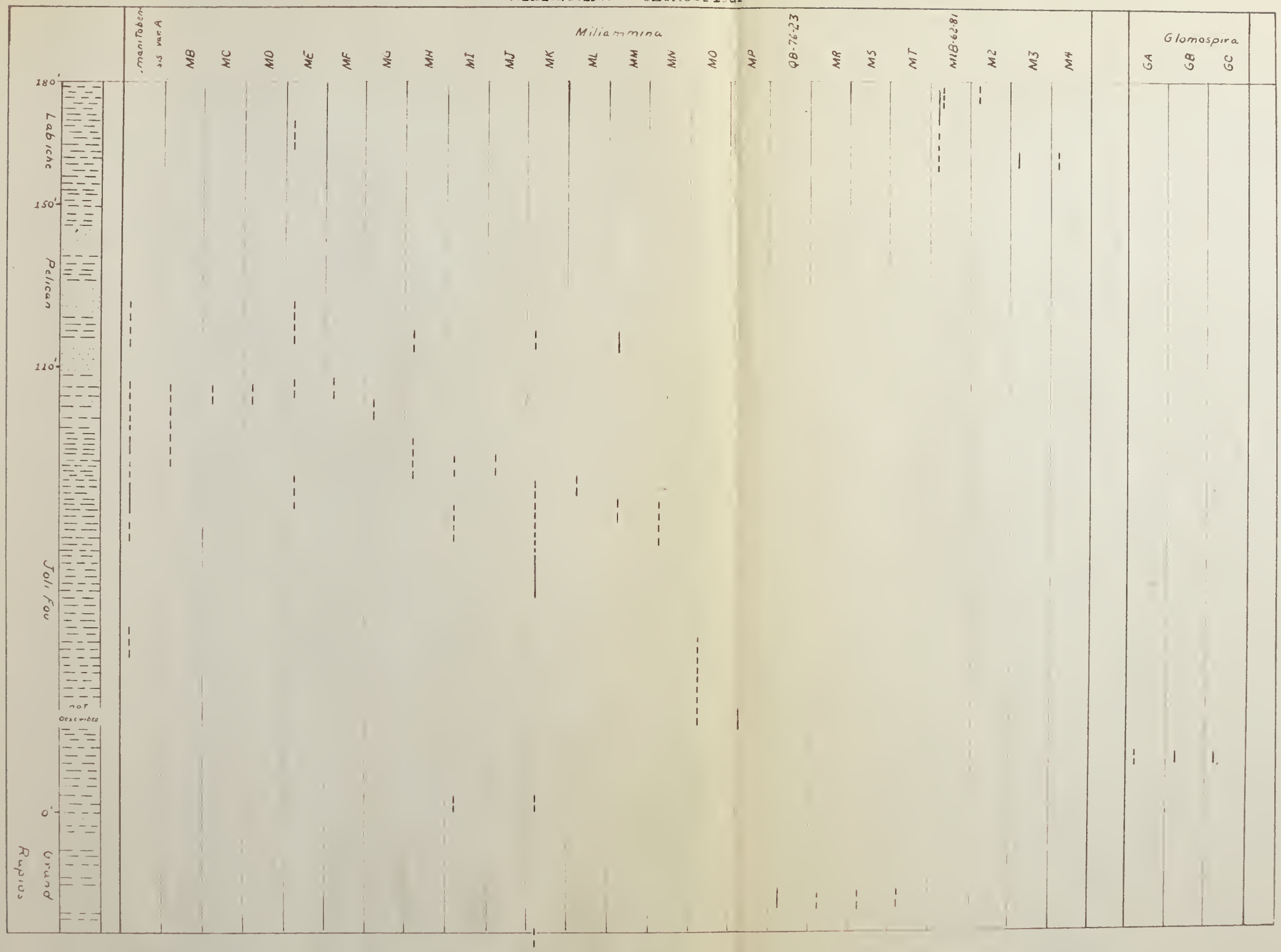
AMMOBACULITES - AMMOBACULOIDES - BATHYSIPHON - GAUDRYINA - HYPERAMMINA - REOPHAX



SPECIFIC GRAPHS

of

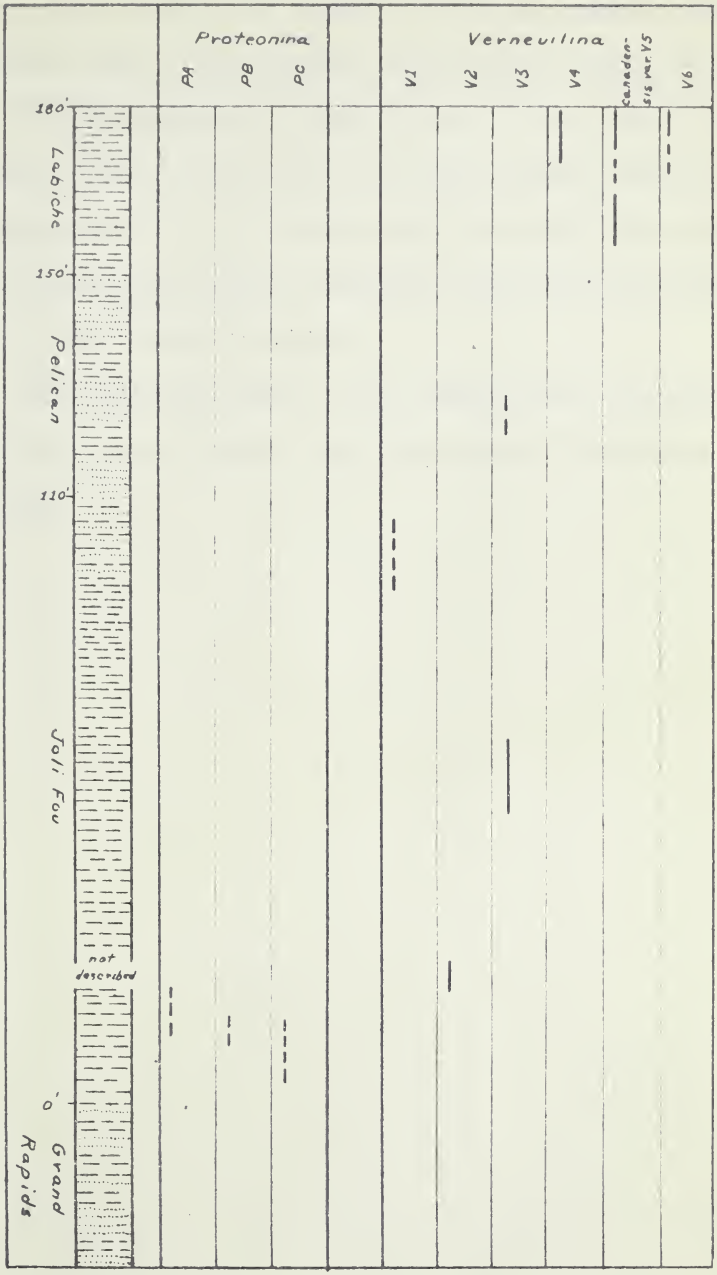
MILIAMMINA - GLOMOSPIRA



SPECIFIC GRAPHS

of

PROTEONINA - VERNEUILINA



Explanation of Generic Graphs Following

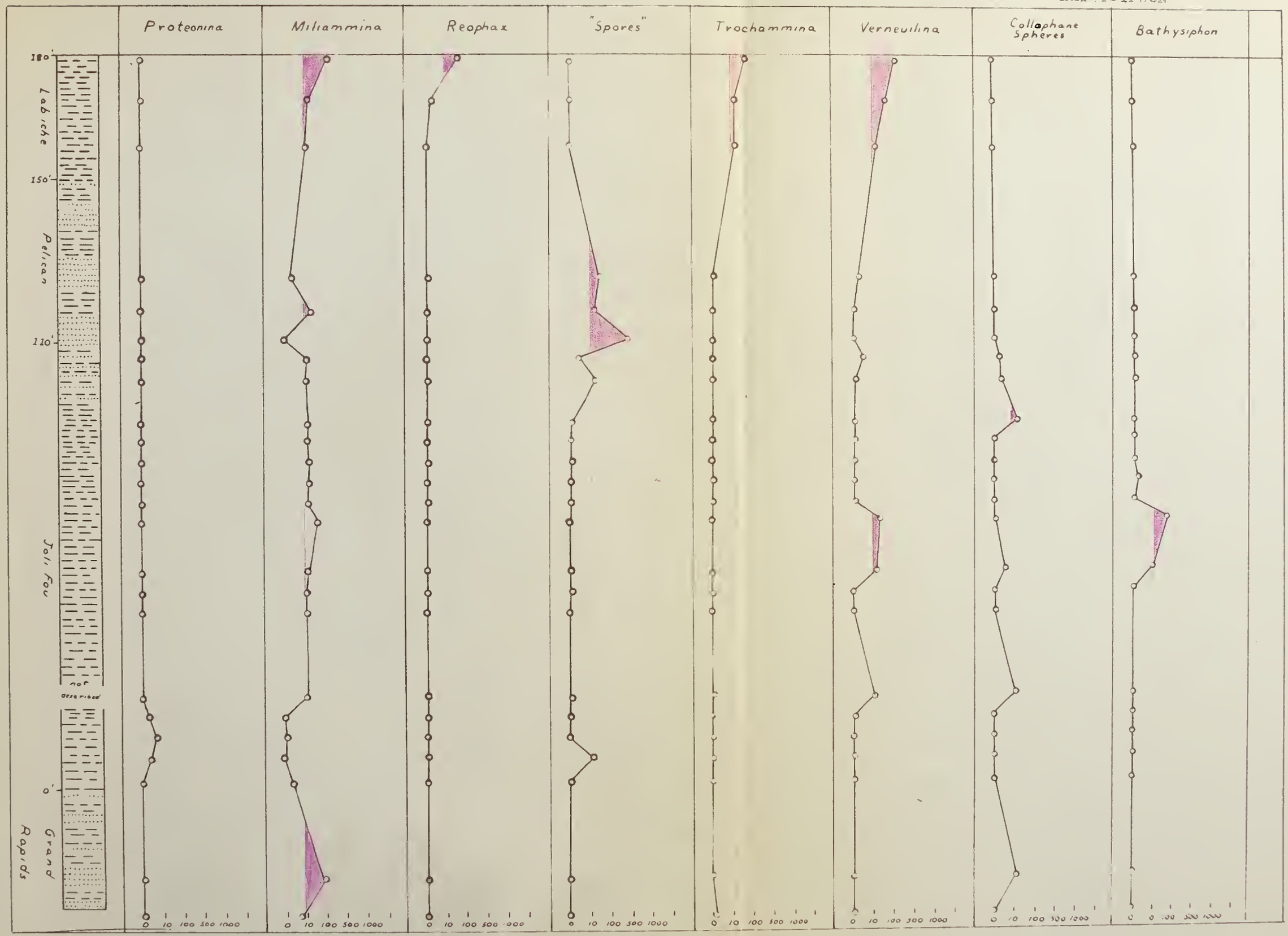
The generic graphs which follow have been constructed from a statistical analysis of genera found in all samples examined. The vertical axes of these graphs represent the range and distribution of the various genera; as was the case in the specific graphs, the datum is taken as the top of the Grand Rapids formation and is designated as O'. All strata above the datum line includes the Joli Fou, Pelican and Labiche formation, all strata below the line belongs to the Grand Rapids formation.

The horizontal axis is self explanitory; the numbers along the horizontal axis indicate the total number of specimens of each genus present.

GENERIC GRAPHS

of

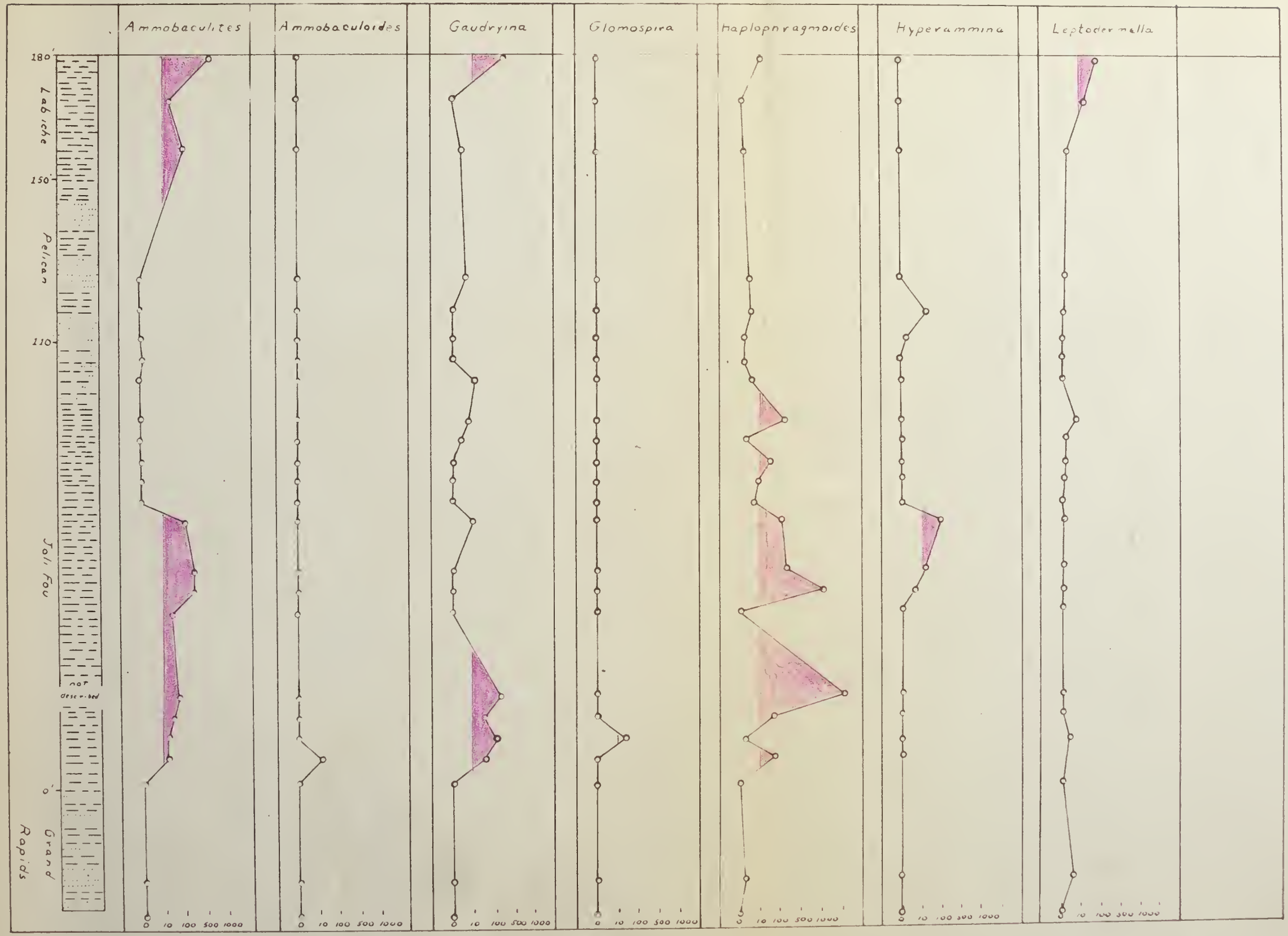
PROTEONINA - MILIAMMINA - REOPHAX - "SPORES" - TROCHAMMINA - VERNEUILINA - COLLOPHANE SPHERES - BATHYSIPHON



GENERIC GRAPHS

of

AMMOBACULITES - AMMOBACULOIDES - GAUDRYINA - GLOMOSPIRA - HAPLOPHRAGMOIDES - HYPERAMMINA - LEPTODERMELLA



APPENDIX

Table of Formations

Age	Name	Lithology	Thickness in Feet
Lower Cretaceous	Labiche	Dark grey to black shale with traces of sandy lenses.	Basal 60 feet studied in detail.
	Pelican	Sand with a few interbeds of dark grey shale.	40 feet
	Joli Fou	Shale - monotonous dark grey shale, somewhat sandy towards the top.	110 feet
	Grand Rapids	Mostly sand and silt with a few interbeds of dark grey shale.	Upper 40 feet studied.

Fig. IV

A detailed description of all formations encountered has been included as a means of explaining why some samples are barren of microfossils.

The discussion of the formations, which follows, is arranged in descending order from the youngest to the oldest to correspond with sections encountered in drilling.

The basal 60 feet only of the Labiche formation was examined for microfossils. This portion of the formation consists of dark grey, crumbly to blocky, marine shale with occasional bands of rusty ironstone. At the Pelican formation contact, the Labiche shale was described from an outcrop in S.E. $\frac{1}{4}$-Sec. 30, T.79, R.17, W. 4 Mer.

No unconformity was found between the Labiche formation and underlying Pelican sand. The Pelican formation consists for the most part of yellowish to whitish-grey, medium to coarse-grained sand of marine origin, with irregular interbeds of grey sandy shale. These

sandy shale beds were sampled for microfossils. The section described occurs at N.W. $\frac{1}{4}$-Sec. 31, T.79, R.17, W. 4 Mer.

Below the Pelican sand lies the Joli Fou formation, a series of dark grey to black marine shales. Near the top, the shale is very sandy and silty, and finally gives way to the overlying Pelican sand. Very poor recovery of fossils was obtained from this sandy shale portion. Lower in the section less sand is encountered, but towards the base, minor lenticles of silt appear as breaks in the shale.

The detailed description of the Joli Fou shale appearing below was pieced together from a number of small sections outcroping along the Athabaska River from S.E. $\frac{1}{4}$-Sec. 16, T.81, R.17, W. 4 Mer. to N.W. $\frac{1}{4}$-Sec. 31, T.85, R.17, W. 4 Mer. Regional dip of strata along with various marker horizons were used to compile this 110 foot composite section of Joli Fou shale.

Underlying the Joli Fou is the Grand Rapids formation. The top 40 feet of the Grand Rapids formation was described from an outcrop appearing in N.E. $\frac{1}{4}$-Sec. 27, T.82, R.17, W. 4 Mer. No unconformity at at the top was recognized here. Below Grand Rapids on the Athabaska River in S.W. $\frac{1}{4}$-Sec. 34, T.84, R.17, W. 4 Mer. a 4 foot thick coal bed appears at the Joli Fou-Grand Rapids contact and below the coal is a 2" to 4" bed of greyish black chert pebble conglomerate, cemented in a dark brown to greyish black sandy matrix.

The described section of the Grand Rapids formation is probably of marine or brackish origin. A few marine (brackish) microfossils were obtained from the upper 30 feet of the formation. For the most part the strata encountered consisted of irregular interbeds of sand, silt and shale. Occasional black chert pebbles occur in the sandy beds.

A detailed description of all formations discussed appears below:

Labiche or Basal Colorado Formation

25.0' Shale-dark grey to black, crumbly, rubbly shale; rare thin brown rusty ironstone concretions.

10.0' Shale-shale as above with the local silty to fine sandy lenses.

0.5' Ironstone-dark grey, somewhat rusty weathering, concretionary ironstone band.

16.0' Shale-as above.

7.5' Shale-dark grey to black, chunky, blocky, conchoidally fractured shale, lower part poorly exposed or covered; lower part becomes crumbly and rubbly.

0.5' Shale-dark grey sandy shale (clayey), shale with irregular coarse sand lenses.

Pelican Formation

0.2' Sand-yellowish grey sand with powdered bright yellow clayey band at top.

0.2' Shale-dark grey sandy shale or shaly sand lens.

1.0' Sand-light brownish grey, very slightly consolidated sand and dark grey shaly sand, irregular lenses, with numerous brownish weathered dark grey ironstone nodules (irregularly shaped).

1.0' Sand-whitish grey to light brownish grey, medium-grained sand; grains are almost all quartz, well rounded to subangular, rare chert grains, with irregular concretions as above. Sand altogether unconsolidated.

0.7' Sandstone-hard, well cemented, brownish grey, coarse, quartzitic, rusted sandstone bands in sand as above.

1.4' Sand and shale-alternating whitish grey, medium-grained sand and dark grey sandy shale, with rare ironstone concretions.

1.8' Sand-whitish grey to light greenish grey, medium to coarse-grained sand (grains well rounded to subangular quartz, rare chert) rusty weathering with reddish brown weathered dark grey ironstone nodules up to 0.5' thick.

1.0' Shale-dark grey, clayey fragile, fractured shale, with sandy partings and lenses.

1.6' Sand-brownish-grey, somewhat consolidated, medium to coarse-

grained sand with nodules and bands of well indurated, grey sandstone and ironstone; streaks of unconsolidated, loose sand.

8.5' Sand-whitish-grey, medium-grained to coarse-grained loose sand (quartz grains, rare chert grains). Thin black, clayey shale bands $\frac{1}{2}$" thick at 1.4' and 1.7' below the top.

1.4' Sand and shale-alternating sand and shale as above, in bands up to 1".

6.2' Sand-whitish-grey sand as above with brownish stained bands and local shale lenses.

1.0' Shale-dark grey shale band.

10.0' Sand-whitish-grey sand as above with occasional thin, dark grey to brownish grey shale bands and brownish silt bands.

2.0' Sandstone-brownish-weathering, hard, grey sandstone with yellowish-grey, medium to fine-grained sand alternations.

3.0' Sand-whitish-grey, fine sand with up to 2" black shale alternations.

Joli Fou Formation

8.0' Shale-dark grey, crumbly shale with abundant lenses of fine, grey sand (up to 1" thick). Sand and shale are equally dominant in the upper part; sand more dominant in top foot.

0.8' Concretions-brownish, weathers rusty, sandy concretions.

3.0' Shale-somewhat sandy dark grey shale.

7.0' Shale-dark grey to black, fairly tough shale.

3.0' Shale-dark grey, crumbly shale with very few thin silty lenses.

8.0' Shale-dark grey, quite chunky, blocky, reddish brown weathering, fractured shale.

0.3' Concretion-rusty, somewhat sandy ironstone concretionary band.

25.0' Shale-as above, in lower part the shale becomes quite rubbly, flaky on weathered surface, badly rusted; some badly rusted concretions locally.

5.0' Shale-dark grey, rubbly shale with thin buff-grey fine sandy lenses.

0.2' Sand-coarse sand or gritty bed; composed of brownish-grey quartz and chert grains.

5.0' Shale-dark grey shale with very minor silty lenses.

8.0' Shale-dark grey, crumbly shale with grey silt and sand lenses.

17.0' Shale?-(not described).

19.0' Shale-dark grey, crumbly, rubbly shale with rare grey to brownish-grey silty and fine sandy lenses; reddish-brown weathering.

1.0' Shale-dark grey, sandy shale or shaly sand, abundant grey to brownish-grey sandy lenses.

0.4' Concretion-medium, grey, sandy ironstone concretion.

Grand Rapids Formation

2.3' Silt-medium grey silt, laminated with dark grey shaly streaks, weathering yellowish, paper-thin streaks of carbonaceous black shale; well laminated, massive appearing.

4.0' Silt-dark grey, rubbly, fractured, crumbly silt (almost silty shale), lighter grey on weathered dry surface, more shaly towards base; local sandy lenses.

2.2' Shale-dark grey, rubbly, crumbly, thin-bedded shale with minor whitish-grey silt and fine sandy partings.

2.3' Sand-whitish-grey to yellowish-grey, medium-grained, massive sand bed; somewhat pepper and salt.

0.6' Sand-as above, with several dark grey shale partings (up to 1"); occasional small black chert pebbles.

0.4' Sand-medium grey, silty to shaly sand, some carbonaceous particles.

1.0' Sand-as above.

5.5' Shale, silt and sand- rapidly alternating dark grey shale, medium grey silt and light grey glauconitic sand; occasional black carbonaceous particles.

1.0' Sand-light greenish-grey, medium-grained, massive sand bed.

2.0' Shale-dark grey, crumbly shale with whitish-grey silt partings and interbeds.

2.0' Sand and Shale-alternating light grey, fine sand and grey silt; sand beds up to 0.8' thick.

1.0' Shale-dark grey, crumbly shale with silty to fine sandy lenses.

0.4' Sand-brownish-grey to grey, fine sand.

0.5' Shale-as above, with 0.4' thick buff-grey ironstone concretion.

6.0' Sand-whitish to light grey, medium-grained, massive sand.

1.3' Shale-dark grey, crumbly shale with sandy lenses.

1.7' Sand-as above with lenses of black to dark grey chert and white quartz pebbles.

2.5' Shale-dark grey, crumbly shale with grey sandy lenses.

3.0' Sand-fine grey sand with dark grey shale lenses; shale becomes abundant towards base.

1.3' Shale-dark grey shale as above with very minor fine grey sand streaks; ironstone concretion at base.

2.0' Sand-very fine, yellowish-grey silty sand.

SPECIFIC ANALYSIS

Haplophragmoides sp.

Sample No.	Depth Using Top of Grand Rapids as 0 Datum	Corrected Totals (t)	A	cf cushmani	D	G	H	gigas	linki	MO	cf collyra	O	Q	P	(P)	R	T	U	V	W	X	Y	Z
B-62-81	+179	t					12																
B-62-70	+169	t					4																
B-62-60	+157	t					4																
B-70-6	+125	t	3		3																		
B-70-14	+117	t	2		8																		
B-71-0	+110	t	2																				
B-71-5	+105	t			2																		
B-71-10	+100	t	6																				
B-74-20	+90	t	16		211																		
B-74-25	+85	t			2														1				
B-74-30	+80	t	3		3														7	3		6	1
B-74-35	+75	t	2		2													1	1			2	
B-74-40	+70	t			1															4		2	
B-74-45	+65	t	10		10														10	20	10	40	10
B-72-0	+53	t	58		10			84			30	20										31	
B-72-6	+48	t		276		576		20						180									
B-72-10	+43	t																					
Z-1-22	+22	t	108			30		369	404	18	544		18										
Z-1-17	+17	t						8	22		17												
Z-1-12	+12	t	6	5				6	9						3								
Z-1-7	+7	t		3				1			51	7			2	30							
B-76-1	+1	t															2						
B-76-23	-23	t																					
B-76-32	-32	t																					

SPECIFIC ANALYSIS

Miliammina sp.

Sample No.	Depth Using Top of Grand Rapids as 0 Datum	Corrected Totals (t)	manitobensis Var-C	MB	MC	MD	ME	MF	MG	MH	MI	MJ	MK	ML	MM	MN	MO	MP	QB-76-23	MR	MS	MT	M1 B-62-81	M2	M3	M4
B-62-81	+179	t																					151	6		
B-62-70	+169	t					1																5			
B-62-60	+157	t																					9		12	4
B-70-6	+125	t	1				2																			
B-70-14	+117	t	8				9			2			2		12											
B-71-0	+110	t																								
B-71-5	+105	t	4	4	1	1	4	1																		
B-71-10	+100	t	3	1					5																	
B-74-20	+90	t	20	5						1																
B-74-25	+85	t	6	2						5	1	1														
B-74-30	+80	t	31				1						2	1												
B-74-35	+75	t	14				1				2		4		4	1										
B-74-40	+70	t	5								5		8			4										
B-74-45	+65	t	30										24													
B-72-0	+53	t											15													
B-72-6	+48	t																								
B-72-10	+43	t	10														1									
Z-1-22	+22	t															6	18								
Z-1-17	+17	t																								
Z-1-12	+12	t																								
Z-1-7	+7	t																								
B-76-1	+1	t									1		2													
B-76-23	-23	t																								
B-76-32	-32	t											10						76	2	8	8				

SPECIFIC ANALYSIS

Sample No.	Depth Using Top of Grand Rapids as 0 Datum	Corrected Totals (t)	Ammobaculites sp.										Ammobaculoides sp.	Bathysiphon sp.		Gaudryina sp.				
			fragmentaria	AH	tyrrelli var. AT	GB-72-0	H	I	cf I	KB-72-6	M	N	ABZ-1-7	B A	B B	G 1	G 2	canadensis var. A	G 6	G 7
B-62-81	+179	t							681											
B-62-70	+169	t							53											
B-62-60	+157	t							69		12	96								
B-70-6	+125	t																		
B-70-14	+117	t																		
B-71-0	+110	t																		
B-71-5	+105	t				30														
B-71-10	+100	t																		
B-74-20	+90	t															8			
B-74-25	+85	t														4				
B-74-30	+80	t																		
B-74-35	+75	t												2						
B-74-40	+70	t																		
B-74-45	+65	t	2			122								62	10	10				
B-72-0	+53	t	24			229								10						
B-72-6	+48	t				230														
B-72-10	+43	t					12	30		10						7	9			
Z-1-22	+22	t			49		10			6								156	30	
Z-1-17	+17	t								14								40	8	2
Z-1-12	+12	t			19													33	3	117
Z-1-7	+7	t		4			2	17					34					2		32
B-76-1	+1	t																		
B-76-23	-23	t																		
B-76-32	-32	t																		

SPECIFIC ANALYSIS

Sample No.	Depth Using Top of Grand Rapids as 0 Datum	Corrected Totals (t)	Hyperammina sp.			Glomospira sp.			Proteonina sp.			Reophax sp.	Leptodermella sp.		Trochammina sp.		Verneuilina sp.					
			H1	HA	HB	GA	GB	GC	PA	PB	PC	RAB-62-81	LA	LB	TA	TB	V1	V2	V3	V4	canadensis var. V5	V6
B-62-81	-179	t										47	39	30	74	4				13	84	12
B-62-70	-169	t										2		13	11	21				56	2	6
B-62-60	-157	t												3	28						20	
B-70-6	-125	t												1					2			
B-70-14	-117	t		22	22																	
B-71-0	-110	t	2																			
B-71-5	-105	t															5					
B-71-10	-100	t															1					
B-74-20	-90	t											6									
B-74-25	-85	t											1									
B-74-30	-80	t												1								
B-74-35	-75	t												1								
B-74-40	-70	t																				
B-74-45	-65	t		48	48									10					30			
B-72-0	-53	t			16														15			
B-72-6	-48	t		6																		
B-72-10	-43	t																				
Z-1-22	-22	t															10					
Z-1-17	-17	t							10													
Z-1-12	-12	t				3	18	18		3	3		3									
Z-1-7	-7	t									4											
B-76-1	-1	t																				
B-76-23	-23	t											6									
B-76-32	-32	t													2							

		28	1x												27						
B-71-10	#100	48	1x			6		2				7			5		1	1			
		80	2x			5		2				3						1			
		100																			
			Total	0	0	16	0	6	0	0	0	10	0	32	0	1	3	0			
		28	1x									1									
B-74-20	#90	48	2x					8				3									
		80	3/2x					23		5		7						1			
		100	8x			1		25				1						3			
			Total	0	0	8	0	251	0	7	0	25	0	0	0	0	25	0			
		28	1x			1		2		1		8									
B-74-25	#85	48	1x			2		1				1									
		80	5/4x			1						4									
		100																			
			Total	0	0	4	0	3	0	1	0	14	0	0	0	0	0	0			
		28	1x					10		1		15									
B-74-30	#80	48	10/9x					12				14									
		80	1x					1				5									
		100																			
			Total	0	0	0	0	51	0	1	0	35	0	0	0	0	0	0			
		28	1x					2		1		6									
B-74-35	#75	48	10/9x					5				10									
		80	2x					1				6									
		100	2x															1			
			Total	0	0	0	0	9	0	1	0	28	0	0	0	0	0	2			
		28	1x																		
B-74-40	#70	48	1x					3				9									
		80	1x					4				9									
		100	2x									2									
			Total	0	0	0	0	7	0	0	0	20	0	0	0	0	0	0			
		28	10x	12				8										4			
B-74-45	#65	48	1x	4																	
		80	10x			1		4		8		5					3		3		
		100	2x							8		2							1		
			Total	124	0	10	0	120	96	2	0	54	0	0	0	30	0	72			
		28	6x	24				2													
B-72-0	#53	48	6x	12				11	1												
		80	5x	5				23				1					3	1	2		
		100	10x	3				4	1			1									
			Total	271	0	0	0	233	16	0	0	15	0	0	0	15	5	10			
		28	20x	6				21													
B-72-6	#48	48	15x	17				27													
		80	10x					7													
		100	6x					27	1												
			Total	255	0	0	0	1047	6	0	0	0	0	0	0	0	0	0			
		28	1x	2								1									
B-72-10	#43	48	10x	5								1									
		80																			
		100																			
			Total	52	0	0	0	0	0	0	0	11	0	0	0	0	0	0			
		28	1x					9													
Z-1-22	#22	48	18x					48				1									
		80	10x	7		12		40								1	1				
		100	6x	1		15		38				1									
			Total	76	0	210	0	1508	0	0	0	24	0	0	0	10	10	0			
		28	1x																		
Z-1-17	#17	48	4/3x	10				8			2										
		80	2x	14		18		10													
		100	2x	4		7		9													
			Total	49	0	50	0	61	0	0	3	0	0	0	0	0	0	0			
		28	1x					8													
Z-1-12	#12	48	3x	5		6	1	7		1	2										
		80	3x	4		19	1														
		100	3x	1		26	12														
			Total	28	0	153	42	29	0	3	6	0	0	0	0	0	0	0			
		28	1x	1	1			4						1							
Z-1-7	#7	48	2x	12		10		23			2			6							
		80	2x	1	8	7		19						4							
		100			1			3													
			Total	26	18	34	0	88	0	0	4	0	0	21	0	0	0	0			
		28	1x									1									
B-76-1	#1	48	1x																		
		80	1x									3									
		100																			
			Total	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0			
		28	1x																		
B-76-23	-23	48	2x					1				19									
		80	6x									7						2			
		100	6x							1											
			Total	0	0	0	0	2	0	6	0	80	0	0	0	0	12	0			
B-76-32	-32	80	Total	0	0	0	0	0	0	0	0	7	0	0	2	0	0	0			

GENERIC ANALYSIS

Sample No.	Depth Using Top of Grand Rapids as 0 Datum	Mesh Size	Corrected Totals (t)	Ammobaculites	Ammobaculoides	Gaudryina	Glomospira	Haplophragoides	Hyperammina	Leptodermella	Proteonina	Miliammina	Reophax	"Spores"	Trochammina	Vermeulina	"Collophane Spheres"	Bathysiphon
		28	1x	1						1		1	19			3		
B-62-81	/179	48	10x	29		16				4		3	3			7		
		80	6x	55		14				3		3			3	6		
		100	4x	15				3		4		27			15			
		Total		681	0	244	0	12	0	75	0	157	49	0	78	109	0	0
		28	1x					1										
B-62-70	/169	48	1x	9						4		8	2		7	7		
		80	1x	35						3		2			4	17		
		100	3x	3						2		8			7	15		
		Total		53	0	0	0	1	0	13	0	34	2	0	32	69	0	0
		28	3x	19				1		1		1			2	6		
B-62-60	/157	48	2x	22								1			5	1		
		80	4x	19		1						4			3			
		100	1x									1						
		Total		177	0	4	0	3	0	3	0	22	0	0	28	20	0	0
		28	1x									1		10				
B-70-6	/125	48	1x					2				1		21				
		80	1x			6		4		1		1		9		2		
		100	1x															
		Total		0	0	6	0	6	0	1	0	3	0	40	0	2	0	0
		28	1x					8				1		7				
B-70-14	/117	48	2x						6			6		8				
		80	2x					5	16			10						
		100																
		Total		0	0	0	0	6	44	0	0	33	0	23	0	0	0	0
		28	2x											16				
B-71-0	/110	48	15x											35				
		80	2x					1	1					4				
		100																
		Total		0	0	0	0	2	2	0	0	0	0	465	0	0	0	0
		28	1x															
B-71-5	/105	48	1x											4				
		80	1x	1				2				10				4	2	
		100	1x	1								5				1	1	
		Total		1	0	0	0	2	0	0	0	15	0	4	0	5	3	0
		28	1x											27				
B-71-10	/100	48	1x			6		2				7		5		1	1	
		80	2x			5		2				3					1	
		100																
		Total		0	0	16	0	6	0	0	0	10	0	32	0	1	3	0
		28	1x									1						
B-74-20	/90	48	2x					8				3						
		80	3/2x					23		5		7					1	
		100	8x			1		25				1					3	
		Total		0	0	8	0	251	0	7	0	25	0	0	0	0	25	0
		28	1x			1		2		1		8						
B-74-25	/85	48	1x			2		1				1						
		80	5/4x			1						4						
		100																
		Total		0	0	4	0	3	0	1	0	14	0	0	0	0	0	0
		28	1x					10		1		15						

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