A Stratigraphical Study of the Coloradoan of the Manitoba Escarpment with Special Reference to Certain of the Calcareous Horizons.

by

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Presented in partial fulfilment of the requirements for the Master of Science degree in the University of Manitoba.

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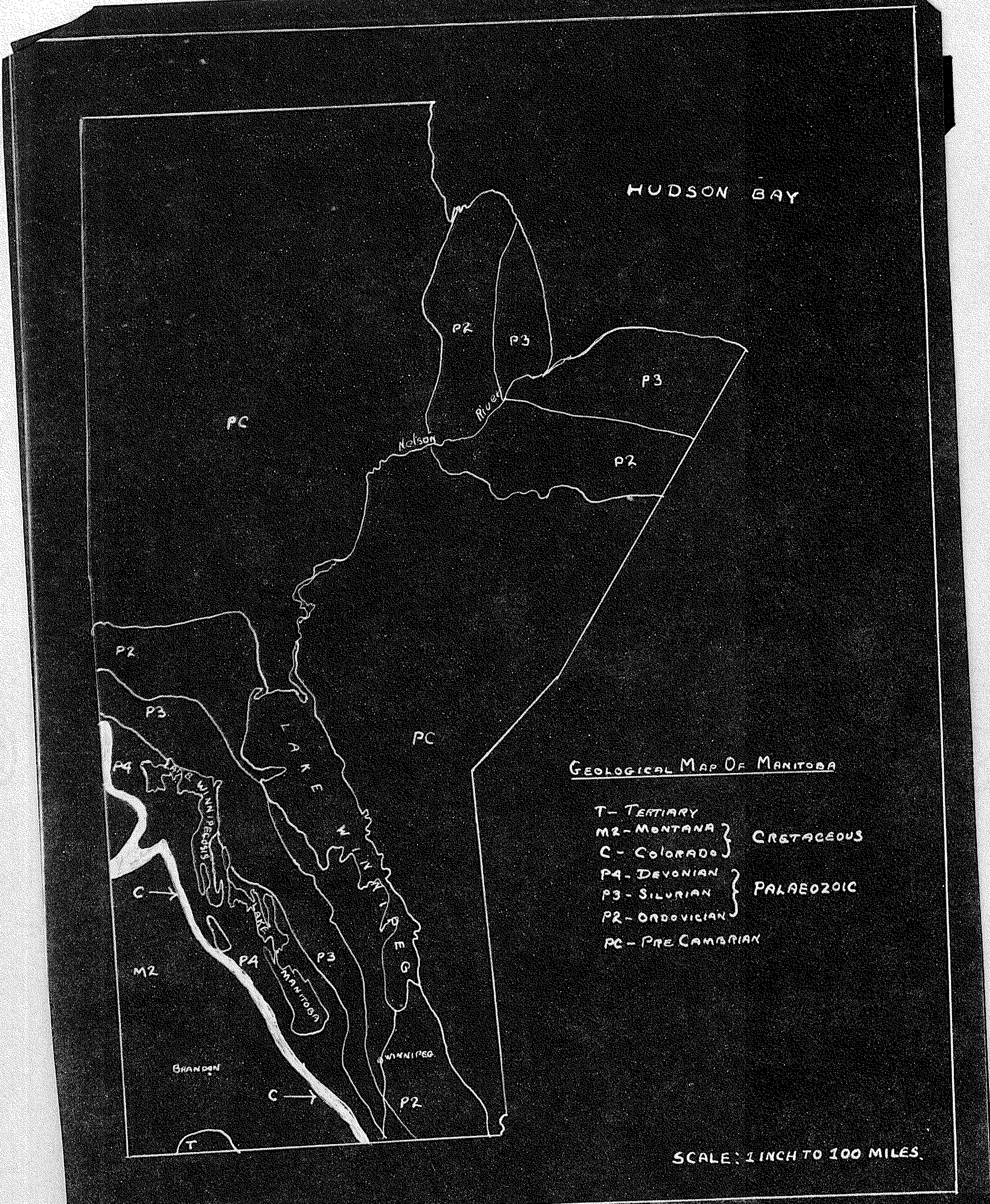
1. Acknowledgements

Dr. S.R. Kirk, under whose supervision this problem was carried out, spent part of the summer of 1928 with the Geological Survey of Canada examining Cretaceous Sections of Manitoba. The writer wishes to express his thanks to Dr. Kirk for suggesting the problem and for the use of his field notes with the samples collected during the field season.

To J.B. Reeside of the United States Geological Survey, J. Henderson of the University of Colorado Museum and F.H. McLearn of the Geological Survey of Canada, thanks are due for fossil specimens sent and opinions expressed on photographs of Manitoba specimens.

The writer is greatly indebted to C.M. Tosh of the Geology Department, University of Manitoba, for the photographic work.


HUDSON BAY
PC
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LAKE WINNIPEG
LAKE WINNIPEGOSIS
LAKE MANITOBA
P4
C
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T - TERTIARY
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CRETACEOUS
P4 - DEVONIAN
P3 - SILURIAN
P2 - ORDOVICIAN
PALAEOZOIC
PC - PRE CAMBRIAN
SCALE: 1 INCH TO 100 MILES.

Fig I.

11. Introduction

The geology of Manitoba was studied in a very general way by early explorers after De LaVerandrye's march across the prairies in 1734. It was not until 1875, however, that the Geological Survey of Canada inaugurated its systematic investigation in Manitoba and during the past fifty years the geology of the Province has been interpreted mainly through reconnaissance work. Thus many problems of stratigraphical succession still remain to be solved.

The geological column in Manitoba is by no means a complete one, many gaps in it being represented by unconformities. A tabular outline of the formations represented in Manitoba is given in Plate 1.

The Canadian Shield which extends into the northern and eastern parts of Manitoba consists of crystalline rocks of Pre-Cambrian age. Flanking the southwestern border of the Shield, Palaeozoic limestones, with a gentle southwesterly dip underlie the first prairie steppe, inthe region of the Manitoba lakes. To the west the Pembina, Riding, Duck and Porcupine Mountains rise steeply from the first prairie steppe as prominent erosion remnants of the Cretaceous escarpment of Manitoba. In this escarpment and to the west of it, underlying the plateau known as the second prairie steppe, the bed rock consists mainly of shales of upper Cretaceous Age. The Turtle Mountain outlier, in the southwestern part of the province, includes a sandstone and a lignite bearing group of which the latter, at least, may be Tertiary. Pleistocene de-

Quaternary.	Recent . Pleistocene.		
Tertiary.	Eocene(?) .		
Mesozoic	Upper Cretaceous	Montanan.	Boissevain Sandstone(?). Odanah Shale . } Pierre. Millwood Shale. }
		Coloradoan*	Niobrara Shale. Benton Shale.
			Dakota Sandstone.
Palaeozoic .	Devonian.		Manitoba Limestone. Winnipegosan Dolomite. Elm Point Limestone.
	Silurian.		Leperditia hisingeri zone. Gypsum Beds. Virgiana decussata zone.
	Ordovician.		Stony Mountain Shales . Upper Mottled Limestone. Cat Head Limestone. Lower Mottled Limestone. Winnipeg Sandstone.
Pre-Cambrian.			Algoman. Temiscamian . Laurentian(?). Keewatin.

<u>Plate 1.</u> Tabular Outline of Manitoba's Geological Formations.

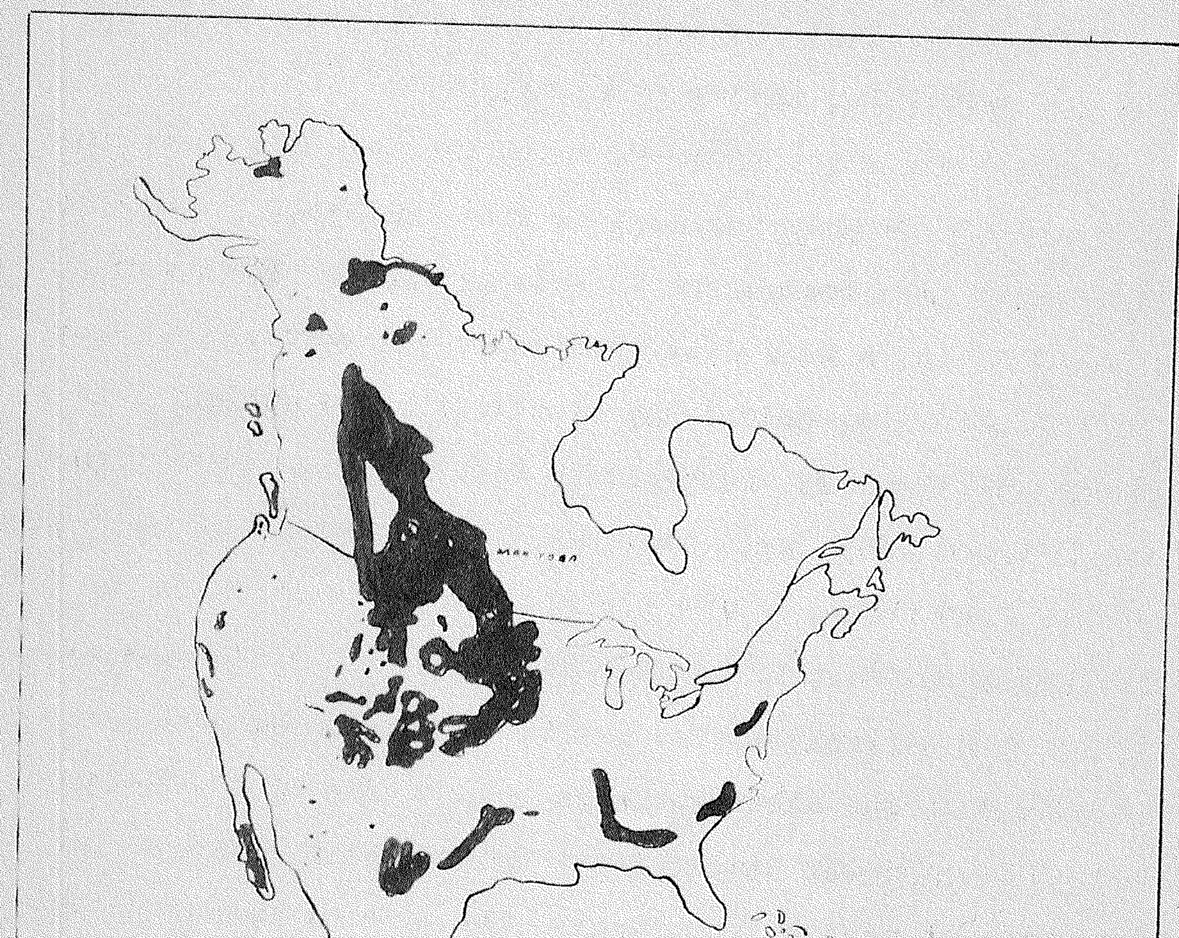

Fig 2. Distribution Of Upper Cretaceous Rocks After Bailey Willis

posits formed by the glaciers and glacial streams of the Great Ice Age form a superficial covering over the greater part of Manitoba. Deposits of Recent age are of minor importance.

The areal distribution of these formations is given in the Geological Map of Manitoba, Fig. 1.

The Cretaceous System in North America is divided into a lower and an upper series. So far only Upper Cretaceous rocks have been recognized in this province. The Upper Cretaceous has a wide distribution in the western interior of North America, underlying practically the whole of the western plains. By referring to Fig. 2 it can be seen that the Manitoba area forms only the eastern border of the Canadian plains Cretaceous. It is of importance to note that, in this eastern area (that is to say Manitoba), the Cretaceous deposits are entirely marine, while farther to the west, in Saskatchewan and Alberta, large thicknesses of continental and brackish water deposits are intercalated with the contemporaneous marine formations. The present recognized divisions in Manitoba are given in Plate 1.

Lying unconformably on the Devonian limestones is a white or reddish sandstone which is commonly known as the Dakota, although no definite correlation has been made with the standard Dakota sandstone sections of the United States. Overlying, a highly carbonaceous, unctuous feeling shale practically barren of fossils, has been called Benton. Higher in the section a series of calcareous shales with some limestones, probably deposits of clearer seas, has been called

Niobrara. These two shale groups together constitute the Coloradoan division. The Montanan division consists of shales deposited during the marine expansion of Pierre time and probably represent continuous deposition in Manitoba, even contemporaneous with the Belly River continental and brackish water deposition of the west. It has been suggested[1] that the Boissevain sandstone may be of Fox Hills age. If so this friable and diagonally bedded sandstone was probably formed during the retreat of the Pierre seas from Manitoba.

111. Object of Investigation

Up to the present time the Cretaceous Stratigraphy of the Manitoba Escarpment has not been fully understood, except in a general way. It is, however, of the utmost importance to obtain more information regarding it, for the purposes both of scientific interpretation and of determination of the economic possibilities.

The first and most important step seems to be the determination of distinctive and recognizable key horizons. Having once obtained these, accurate correlations, thickness determinations and any possible structures may be worked out. It is, therefore, towards this end that the present investigation has been directed.

The material studied is mainly from the more highly calcareous members of the Coloradoan division, which seems to afford the greatest promise of the establishment of definite horizons. This thesis deals, then, with the characters and correlation of these various limestones and marls.

1. Wallace, R. C., The Geological Formations of Manitoba, Nat. Hist. Soc. Manitoba, p. 32, 1925.

IV. Summary of Previous Work

Cretaceous rocks of Manitoba were first definitely recorded by Sir James Hector[2] in 1857. The following year, fossils collected by S. J. Dawson[2] below Fort Ellice were recognized as belonging to the Cretaceous by E. Billings, at that time palaeontologist to the Geological Survey of Canada. H. Y. Hind,[2] during the same year, recognized Cretaceous rocks in the Assiniboine River valley. R. Bell,[2,3], in 1873, examined Cretaceous rocks in the Riding Mountain and noted the occurrence of the same terrane in the valley of the Assiniboine River and Big Boggy Creek. Shortly afterwards J. W. Spencer[4] reported the occurrence of calcareo-arenaceous shales, bearing Inoceramus, Foraminifera and crystals of selenite, near the top of Thunder Hill. Below this, shales and limestones were found with traces of fossils. Ostrea, Ptychodus and fish scales were identified.

Dawson[5] who examined the limestones for Spencer, noted that they were composed of prisms of the pelecypod shell Inoceramus and tests of Foraminifera. He also pointed out the resemblance to the rocks from the Boyne River in southern Manitoba.

In the British North America Boundary Commission report for 1875, G. M. Dawson[6], describes the Cretaceous System of the Canadian Plains. In this report he makes the first definite

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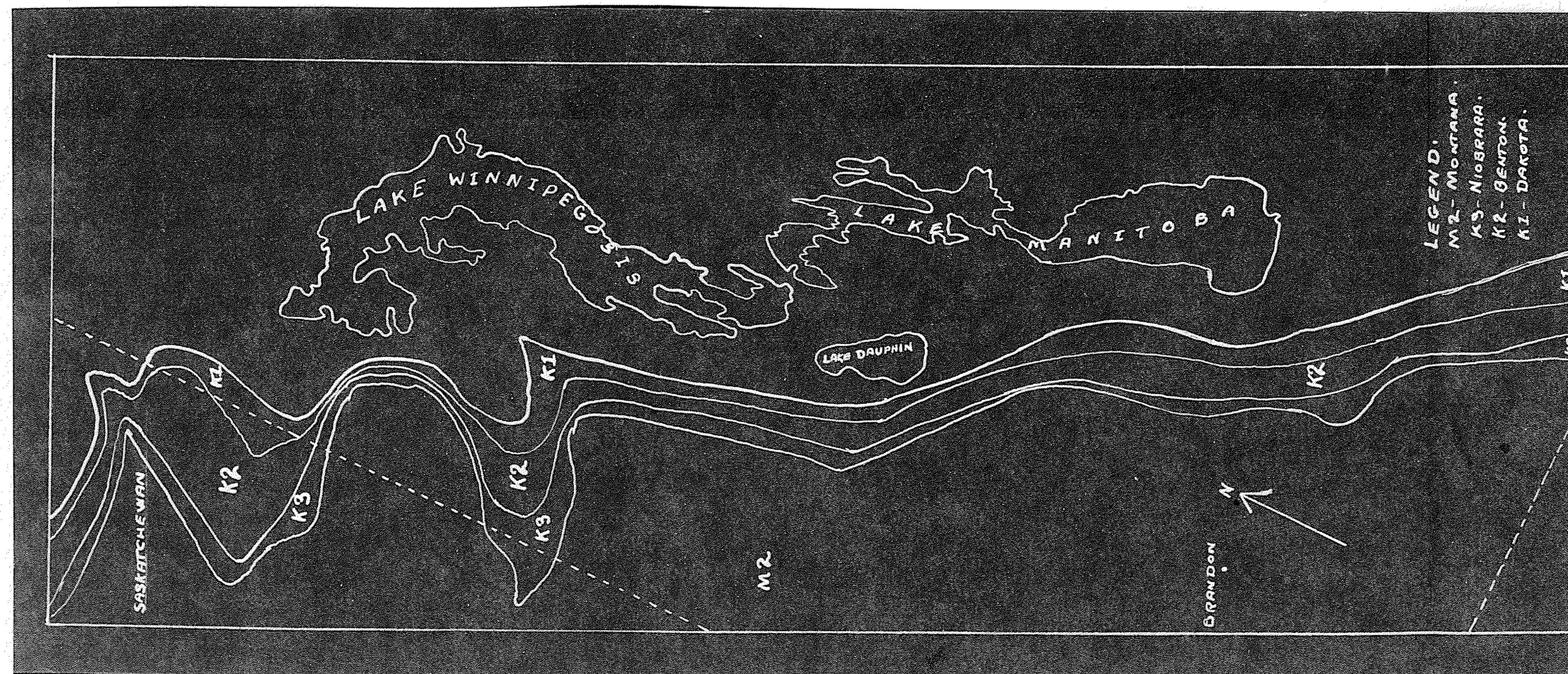
2. Tyrrell, J. B., Foraminifera and Radiolaria from the Cretaceous of Manitoba; Proc. and Trans., Roy. Soc. Canada, Vol. VIII, Sec. IV., pp. 111 - 112, 1890.

3. Bell, Robert, Report of Progress; Geo. Sur. Canada, p.83,1873-74

4. Spencer,J.W., Report of Progress; Geo. Sur.Canada,pp.64-65,1874-5

5. Dawson,G.M., Notes in the report of J.W.Spencer, idem,p.66.

6. Dawson,G.M., B.N.A.Boundary Commission;Report of the Resources of the forty-ninth parallel; pp 78 - 81 and 139 - 142.


LAKE WINNIPEGOSIS
LAKE MANITOBA
LAKE DAUPHIN
SASKATCHEWAN
BRANDON
N
K1
K2
K3
M2
LEGEND.
M2- MONTANA.
K3- NIOBRARA.
K2- BENTON.
K1- DAKOTA.

Correlation of the calcareous beds of the Manitoba Escarpment with "Cretaceous No.3" or Niobrara of Meek and Hayden[7]. He makes no clear statement, however, regarding the occurrence of "Cretaceous No.2" or Benton in Manitoba.

Dawson[8], in 1879, correlated the Thunder Hill and Swan river exposures with the Niobrara, the basis of this correlation being the similarity to the Sections at Boyne river. In this report he states that the subdivisions in the Missouri, according to Meek and Hayden, probably represents the Manitoba region with some approach to accuracy.

The work of J. B. Tyrrell[9] in the Manitoba sections of Niobrara and Benton is a classic in the stratigraphical interpretation of Manitoba's Cretaceous. Up to the present time the source of information on the Niobrara-Benton lithology, stratigraphy and palaeontology is due, mainly, to the efforts of Tyrrell. Through his field work he found it possible to map the Niobrara and Benton formations in the Manitoba escarpment as illustrated in Fig. 3. His conclusions on these formations will be discussed in the chapters on Palaeontology and Correlation of the Manitoba Sections.

In 1914 and 1915 MacLean[10] studied the Pembina Mountains section. His survey was more detailed than that of Tyrrell and he was able to propose a subdivision of the Niobrara for that region. His table is given on Plate 2 and will be referred to, later, in the correlation of the various horizons. He states in his unpublished manuscript that the shale exposures are few and in most of the beds fossils are entirely lacking.

7. Meek, F.B., and Hayden, F.V., Proc. Acad. Nat. Sci. Philad. Dec. 1861
8. Dawson, G.M., Report of Progress: Geo. Sur. Canada, p.15A, 1879-80.
9. Tyrrell, J.B., Northwestern Manitoba: Geol. Sur. Canada. Ann. Rept. Vol. V, Part 1, Rept. E.
10. MacLean, A., Pembina Mountains: Sum. Rept. Geol. Sur. Canada, pp.69-71, 1914; pp.131-133, 1915, and unpublished manuscript.

In the southern and southwestern portions of the field	Thickness in feet	In the northern portion of the field	Thickness in feet
Recent and Pleistocene			
Silt Beds. Lacustrine and beach deposits of Lake Agassiz	↓	North of the Tiger hills Assiniboine delta material	
Till		Till covered by delta material except in stream cuttings	
Pierre			
Odanah		Odanah	
Millwood		Millwood	
Pembina Beds		Pembina Beds	
Niobrara			
Cheval Beds "chalk" a bluish grey, highly calcareous shale, fairly consistent in texture. Weathers to a yellow or buff surface and breaks into columnar fragments.	25'	Cheval Beds: in the north the yellow or buff weathering is not so pronounced as in the south	20'
Boyne Beds: these may be divided into three parts: 1. Grey shales similar to "3".	25'	In the south	25'
2. Calcareous shale carbonaceous more consistent than "1" and "3" but similar in appearance; this is the cement bed.	8'		8'
3. Black calcareous shales, generally carbonaceous fairly well bedded and weathering to a grey surface speckled with white granules	80'		80'
Morden Beds: black carbonaceous shale, streaked with yellow clay and containing crystals of selenite and nodules and masses of pyrite, calcareous and clay concretions and septaria in bands and irregularly through it	250'	Morden Beds: exposures in north are few. Those on the Boyne (at Leary) represent the top of these beds and those on the Assiniboine represent the bottom, immediately overlying the limestone	
Assiniboine Limestone: a hard compact blue limestone very fossiliferous	4'	Assiniboine Limestone In the Assiniboine these beds are thicker, the upper laminae are granular where exposed and are known locally as sandstones	8'
Assiniboine Shale: there are no natural exposures of these beds in the south		Assiniboine Shale: grey shale much like the Boyne beds in appearance but much harder and more consistent, containing also a large number of fossils; only top beds are exposed	160'
Benton and Dakota not exposed.		Benton and Dakota not exposed	

Plate 2. Table of Formations in the Pembina Mountains by MacLean only the details of the Niobrara are given in full.

As a result his correlations are based on purely lithological evidence. MacLean correlates his Assiniboine limestone with a limestone horizon at Gilbert Plains, a distance of approximately 125 miles to the north, thereby implying its use as a datum plane in the escarpment.

R. C. Wallace[11] makes the following statement in his brief review of the Manitoba Cretaceous Stratigraphy:-

"A three to eight foot bed of limestone is placed by him (MacLean) at the base of the exposed Niobrara section. This seems to be the same bed as that placed by Tyrrell near the top of the formation."

It will be noticed from this quotation that the stratigraphical position of a supposed single limestone horizon within the Niobrara remains in considerable doubt.

V. Palaeontology of the Manitoba Coloradoan

A palaeontological study in the Coloradoan of Manitoba proves to be an interesting as well as useful one. While fossils of marine types occur throughout the greater part of the Coloradoan sections these do not appear, on a superficial study, to be of great variety and the fossil material is found to be largely of a fragmentary character. Comparatively few complete large fossil specimens can be obtained. Microscopic study, however, has shown that minute forms of plant and animal life are so abundantly represented, that in many of the horizons they make up the greater part of the rock.

So that at the present in this chapter fossils obtained from the specimens studied are described, while a list of others observed is appended. The significance of the fossils studied

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11. Op. cit. page 29.

will be discussed in the chapter on correlation.

Plant Kingdom

1. Coccoliths and Rhabdoliths

During the process of separating foraminiferal shells from the rock matrix a milky color is often imparted to the water in the beakers. (See page 10). A few drops of this milky colored water examined with the high power of the microscope shows it to be composed of very many, extremely minute forms.

These minute forms belong to a class of lowly pelagic vegetable organisms and have many different shapes. Since they are of no value in correlative work no further study was made. Plate 3 (after G. M. Dawson) shows the types found in the Manitoba Cretaceous.

Many of the softer marls and shales, which in some cases resemble chalk, are made up almost entirely from these minute organisms.

Animal Kingdom

1. Phylum Protozoa

2. Order Foraminifera

This order of single celled animals belonging to the Phylum Protozoa are mainly marine forms. They have a test either of agglutinated foreign material or of chitin or calcareous material secreted by the animal itself. Only in the lowest family, which has no fossil representatives, is the test lacking. As a fossil group they range from the Cambrian (and possibly the Pre-Cambrian), to the present becoming important as rock builders in certain periods, from the Carboniferous onwards.

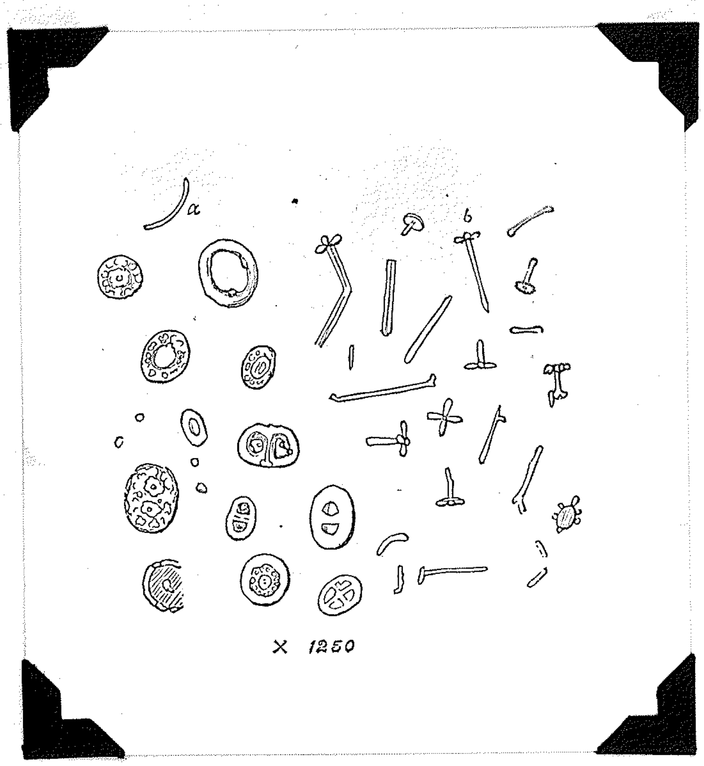

Plate 3. A- Coccoliths. B. Rhabdoliths. X 1250.

After G.M. Dawson, B.N.A. Boundary
Commission Report. 1875. Plate VII.

Reference to Foraminifera in Manitoba has been made by Spencer[12], Dawson[13], and Tyrrell[14].

The following Foraminifera were identified by Tyrrell:

Globigerina cretacea, d'Orb,
Globigerina bulloides, d'Orb,
Orbulina universa, d'Orb,
Discorbina globularis, d'Orb,
Anomalina ammonoides, Reuss,
Anomalina ariminensis, d'Orb,
Textularia agglutinans, d'Orb,
Textularia agglutinans, d'Orb. var. porrecta, Brady.
Textularia agglutinans, d'Orb. var. pygmea, d'Orb,
Textularia globulosa, Ehr,
Textularia turris? d'Orb,
Textularia sagittula, Defr,
Textularia sp,
Gaudryina pupoides, d'Orb,
Planorbulina sp,
Bulimina pupoides, d'Orb,

Sherborn[15] identified the following additional species for Tyrrell:

Cristellaria rotulata, Lam.,
Planorbulina ammonoides, Reuss,
Anomalina rotula, d'Orb.,
Bulimina variabilis, d'Orb.,
Verneuilina triquetra, d'Orb.,
Marginulina variabilis, Neug.,
Globigerina linnaeana, d'Orb.,
Dentalina pauperata, d'Orb.

Since Tyrrell's reference to Foraminifera there have been great advances in the detailed classification of the order. J. A. Cushman[16] of Harvard is followed in this thesis, for identification and classification.

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12. Spencer, J.W., Op. cit. p.64.

13. Dawson, G.M., Report of Progress; Geol. Sur. Canada. p.13A.1879-8

14. Tyrrell, J.B., Foraminifera and Radiolaria from the Cretaceous of Manitoba; Proc. and Trans. Roy. Soc. Canada, Vol.VIII, Sec.IV, pp.111-115, 1890.

15. Sherborn, C.D., quoted in Tyrrell idem, p. 115.

16. Cushman, J.A. Foraminifera - Their Classification and Economic Use; Cushman Lab. for Foraminiferal Research, Special Pub. No.1, April 1928.

The foraminiferal tests form a large constituent in many of the rocks and in order to study them they must be separated where ever possible. Since the tests are fairly delicate, care is necessary in preparing them for study. A preliminary study showed the Foraminifera in Manitoba to possess calcareous tests so that acids could not be used to clear away the matrix.

The following methods for separating the shells from the matrix have been adapted from Cushman[17].

1. Preliminary soaking of a small rock fragment in water, followed by boiling.
2. Addition of alkali reagents and boiling, in the cases in which the above method was unsuccessful.

It was found that many samples disintegrated readily when first placed in water, leaving the tests fairly free. Boiling with the addition of a few drops of ammonia water or sodium carbonate was found to improve the appearance of the tests greatly. With the more consolidated samples long continued boiling with potassium or sodium hydroxide solution and gentle crushing with a glass rod were employed successfully to loosen the matrix.

The next process was to concentrate the shells. The best method found for this was to fill the beaker (400cc), containing the tests and matrix, with water and to allow a certain time period for gravity settling. The lighter material, which contains numerous Coccoliths and Rhabdoliths, was decanted into another beaker. Successive stages in decanting separated the lighter material from the heavier foraminiferal tests. The time period allowed for settling was soon determined after a

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17. Op. cit. Chapters 111 and IV.

few trial separations had been made. The first separations usually required about two minutes and this time was gradually decreased till only a few seconds were necessary. Each beaker is then examined for foraminiferal shells. If the crop was productive then a further separation by decantation was made. During the process of separation the alkali of the reagents used was washed away leaving clean shells. The concentrates were then dried, on clock glasses, over a steam bath.

When the tests are large, hand picking is resorted to as a further means of separating them from remaining particles of rock matrix. For this the concentrate is placed under the binocular microscope and brightly illuminated. Using a "00" red sable bristle brush, which when moistened adheres to the shell, the individual tests are picked out. The hand picked concentrates are then filed away in small glass test tubes. The residue is mounted in Canada balsam on transparent slides and examined for the smaller shells.

Where hand picking is not practicable the whole concentrate is mounted on glass slides with Canada balsam.

The shells were prepared for study in several ways:

1. Unmounted for examination in strong light under the binocular microscope.
2. Mounted in Canada balsam on transparent glass slides, and
3. Mounted on specially prepared dark slides.

A note on the preparation of the dark slide.

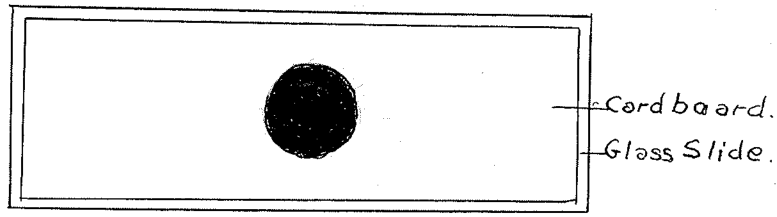

Illustration of the Dark Slide

First, a slip of smooth black paper is glued to a glass slide. A white piece of cardboard, slightly smaller in size than the glass slide, with a hole punched in the centre is glued over the black paper, allowing the black paper to show through the centre hole. Gum arabic is dissolved in water, a little glycerine is added to prevent cracking, and a drop or two is smeared over the black paper and allowed to harden.

Again with the aid of a fine pointed, moist brush the individual test is placed in any desired position on the gum arabic surface. The moisture from the brush is sufficient to dissolve the gum allowing the shell to settle slightly into it. On hardening, the gum holds the shell in position. The advantage of this material as a mount, is that if necessary the shell may be removed by redissolving the gum. A number of shells are placed in this manner and a cover slip is glued on to the slide.

Descriptive:

Separations of Foraminifera have been made from about 40 rock samples and these have been mounted on 150 transparent slides and 30 dark slides. Many thousands of individuals are included in these slides as well as in the unmounted collection which have also been studied. It is realized, however, that this does not represent by any means a complete representative collection.

The collection shows a great predominance of the two genera Gümbelina and Globigerina. In the absence of an adequate library of recent literature, and for other reasons which will be mentioned later, exact specific identification has not been attempted and the Foraminifera are here referred tentatively to "types" rather than to species.

Genus Gümbelina, Egger, 1889

Plate 5.

Genotype (designated by Cushman, Contrib. Cushman Lab. Foram. Res., vol. 3, pt. 4, 1927, p. 190). Textularia globulosa Ehrenberg, Abh. k. Ak. Wiss. Berlin, Math.-Phys. Cl., 1838 (1840), p. 135, pl. 4, fig. 8. (Upper Cretaceous, Pusskary, Poland.)
Gümbelina Egger, Abh. Math.-Phys. Cl. der König. Bay. Akad. Wiss., München, vol. 21, presented 1899, published 1902, p. 31, pl.14, fig. 43.- Cushman, Journ. Washington Ac. Sci., vol. 15, no. 6, 1925, p. 134. (Erroneously spelled "Guembelina".)
Pseudotextularia (part) Rzehak, Ann. k. k. naturhist. Hofmus., vol.10, 1895, p. 217, pl. 7, fig. 1, not figus. 2, 3, which is Pseudotextularia varians Rzehak. - Schubert, Jahrb. k. k. geol. Reichsanst., vol. 50, 1900 (1901) p. 660.
Gümbelina (Egger), Cushman, Foraminifera Their Classification and Economic Use: Cushman Laboratory for Foraminiferal Research Special Publication, No. 1., p. 230, pl. 33, fig. 3,4; pl. 34, fig. 3., 1928.
Gümbelina (Egger), White, 1929, Jour. Pal., vol. 3, no. 1, p. 34, pl. 4, figs. 7-14.
Textularia (part) of authors (not Defrance).

The test free, V-shaped, with early chambers planispiral, later chambers biserial; chambers globular, loosely or closely appressed; wall calcareous, finely perforate; aperture at base of the last chamber, semilunar in outline; size varies, mostly minute.

Type A. (cf. G. globifera (Reuss).).

The test is V-shaped and rather narrow; chambers slightly appressed and numerous; usually a large test; rather a common form.

Type B. (cf. G. globulosa (Ehrenberg).).

Test V-shaped, widens rather rapidly, with straight sides; chambers usually numerous, spherical and not appressed. Size varies from extremely minute to visible with the naked eye. This type is the most abundant of the Gümbelina that have been recognized in the Manitoba Coloradoan.

White, who describes G. globifera and G. globulosa makes the following statement: "

"It has been rather hard to determine the proper name for certain of these forms. The separation of these last two species (G. globifera and G. globulosa), especially from the literature, has bothered me. In solving the question I have included in G. globulosa the form in which the chambers are spherical, having suffered practically no appression; where the test is regular in its V-shape and not slightly curved; where the broadening of the V is rather rapid and where the chambers are few."

Precisely similar difficulties have been encountered in the case of the Manitoba specimens examined. The type under which a form is placed is often a matter of choice. There appears to be a gradation from the one type to the other which throws considerable doubt upon the specific differentiation of G. globifera and G. globulosa. It seems possible that these different types may not truly represent species but rather variations within a single species[x].

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x. This is largely the reason why no attempt is made in this paper to give exact specific determination and that the Foraminifera are referred instead to "types". The failure to refer these Foraminifera to definite species does not, of course, necessarily detract from their value in correlation.

Type C.

This type is the same as type B except that the test has a decided curvature often resembling a horn. Not a common type.

Type D. (cf. G. ultimatumida, White).

Test V-shaped in outline, chambers spherical and the last two very much enlarged. This is a rare type recognized only in a few of the samples studied.

Many G. type B have the last two chambers inflated to such an extent that they resemble this type.

Type E. (cf. G. pupa (Reuss),).

Test V-shaped in the early stages, later enlarged chambers form nearly parallel sides and are set at a slight angle to the early portion of the test giving a curvature to the shell; chambers slightly appressed. A rare type.

Many Gümbelina type B closely resemble this form but only those with nearly parallel sides have been referred to this type.

Type F. (compares more closely with G. decurrens (Chapman), Fig.3, Plate 13 in Cushman's "Foraminifera" than G. excolata described by White.)

This type is similar to type B except that the walls of each chamber are vertically striate. This is a very rare type found only in the Pembina Mountains "Cheval" beds which are described later.

Type G.

Test V-shaped, in early stages, in the later stages sides nearly parallel; chambers globular in the V-shaped, later becoming heart-shaped. A very rare form in the Pembina Mountains "Cheval" beds.

Genus Globigerina d'Orbigny, 1826

Plate 6.

Genotype (first species, designated by Parker, Jones and Brady, 1865) G. bulloides d'Orbigny, Ann. Sci. Nat., vol. 7, 1826, p. 277, Model no. 76;
Globigerina d'Orbigny, Ann. Sci. Nat., vol. 7, 1826, p. 277.
Rotalia (part) of authors.
Rhynchospira Ehrenberg, Bericht. k. preuss. Akad. Wiss. Berlin, 1845, p. 358 (genoholotype, Rhynchospira indica Ehrenberg)
Phanerostomum (part) Ehrenberg, 1854.
Ptygostomum (part) Ehrenberg, 1854.
Planulina (part) Ehrenberg, 1854 (not d'Orbigny)
Pylodexia Ehrenberg, Monatsber. k. preuss. Akad. Wiss. Berlin, 1858, p. 27 (genotype, by designation, Pylodexia tetratrias Ehrenberg).
Globigerina (d'Orbigny)1928, Cushman, Foraminifera Their Classification and Economic Use; Cushman Laboratory for Foraminiferal Research Special Publication, No. 1, p. 303, pl. 45, figs. 18-20, pl. 47, figs. 1-3, pl. 48, fig. 1,
Globigerina (d'Orbigny), 1928, White, Jour. Pal., vol. 2, no. 3, p. 191, pl. 27, figs. 13-18, pl. 28, figs. 1-5.

Test trochoid throughout; umbilicate; chambers globular, not closely appressed; walls finely to coarsely perforate. Adult portion of the shell usually degenerate in the manner of coiling and shape of chambers.

Type A. (cf. Globigerina cretacea, (d'Orbigny),)

The test is made up of chambers in a low trochoid spire, slightly appressed, chambers expand regularly; umbilicate; sutures deep. The coiling of the shell may be either right or left handed.

Type B.

Test trochoid; chambers increase regularly in size up to a certain stage when one becomes greatly enlarged, the following chambers does not attain the same size; this enlarged chamber is usually the second or third from the end. In one case the fifth chamber from the end was the enlarged one. This is the only difference between type A and type B. Abundant and typical, in both right and left handed coils.

Type C.

Test trochoid; the coiling is either right or left handed and may be described as ammonitic; the chambers increase regularly and fairly rapidly, with the last chamber expanded; shape is somewhat longer than broad and slightly flattened; size is about 1/5 of type A. It is a rather abundant form.

Type D.

This type is the same as type C except that the last chamber is not inflated out of proportion to the others.

Type E. (cf. Globigerina bulloides,(d'Orbigny),).

Test trochoid, with irregular expansion of the chambers; the low trochoid spire in the early stages becomes completely surrounded by the adult chambers; longer than broad; size is small in the specimens studied. A very rare form.

Tyrrell[a] describes Globigerina cretacea as the most common and typical form, the Globigerina bulloides being rarely found. This present investigation has shown the Globigerina type A,(cf.) (G. cretacea) and the nearly similar type B are the most abundant and typical. The Globigerina type E (cf. G. bulloides) is also of rare occurrence.

Many species of "Textularia" were described by Tyrrell. This genus, according to present classification is limited to biserial forms with typically arenaceous tests. Many Textularia - like forms from the samples studied have been identified as belonging to the genus Gümbelina described on page 13, which Galloway[b] calls the calcareous isomorph of Textularia.

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a. Tyrrell, J. B., op. cit. p. 115.

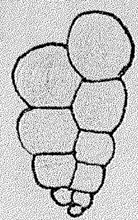
b. Galloway, J. J., quoted by Thomas, N. L., and Rice, E. M., in the Jour. of Pal. vol.1, no. 2, p. 141, 1928.

The genotype, by designation, of Gümbelina is Textularia globulosa Ehrenberg. Tyrrell reports T. globulosa as being very common. These facts together with the identification of Gümbelina types which include type B (cf. G. globulosa) strengthen the conviction that Gümbelina is the more important genus of the two in the Manitoba Coloradoan.

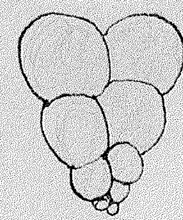
Textularia saggitula, Defr., which is a true Textularian, is listed by Tyrrell as a rare species. No specimens of this type have been observed in the collection studied.

Orbulina universa d'Orbigny, is reported by Tyrrell as rare. This species is not considered a true Orbulina when found below the Tertiary. Specimens which have the appearance of the genus Orbulina have not been identified. No recent literature is available on the other species described by Tyrrell.

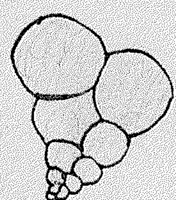
This preliminary study has shown that the Foraminifera in themselves constitute a very large problem, which with a complete collection of material from the Manitoba Coloradoan and more available literature many new species may be identified.



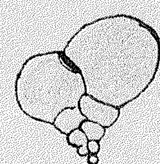
Type A. Edward's Creek



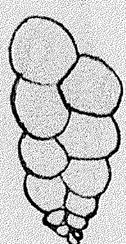
Type B. Edward's Creek



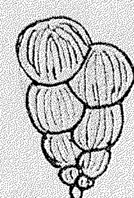
Type C. Edward's Creek



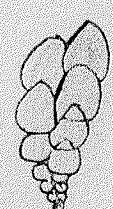
Type D. Ochre River.



Type E. Edward's Creek



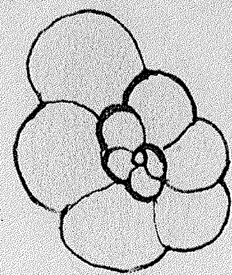
Type F. Pembina Mountains.



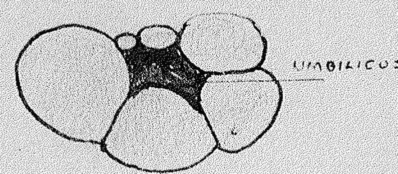
Type G. Pembina Mountains

× 50 Approx.

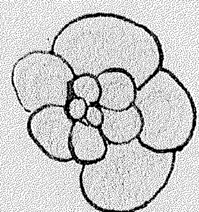
PLATE 5. GÜMBELINA TYPES.



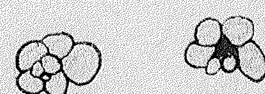
TYPE A. KELWOOD



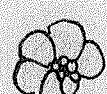
TYPE A KELWOOD



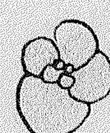
TYPE B. KELWOOD



TYPE C PEMBINA MOUNTAINS



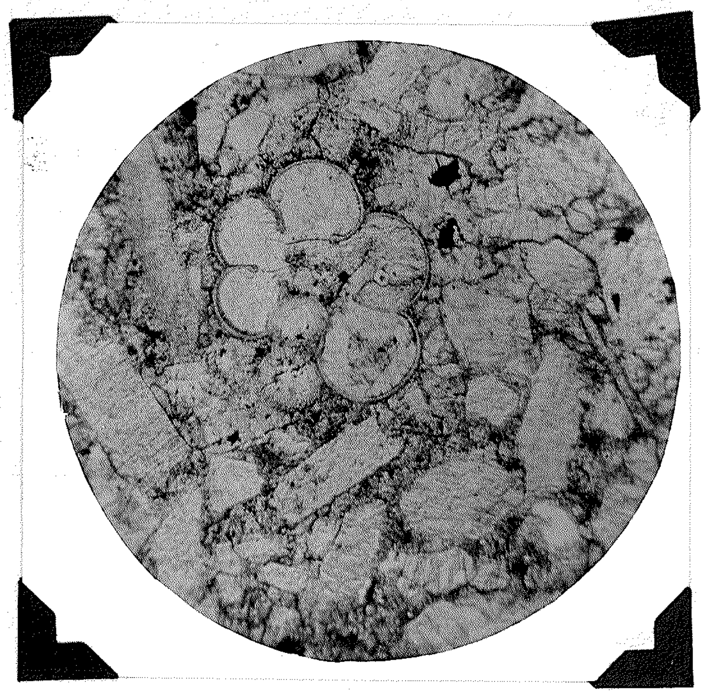
TYPE D. PEMBINA MOUNTAINS



TYPE E PEMBINA MOUNTAINS

X60 APPROX.

PLATE 6. GLOBIGERINA TYPES



<u>PLATE 6B.</u> Photomicrograph of the Limestone bed on Assiniboine River. Showing *Globigerina* type C. Magnification of 80 diameters.

Phylum Mollusca

Class Pelecypoda

Inoceramus labiatus Schlotheim
Plate 7; Plate 8, Figs.1-2; Plate 9, Figs.1-2.

Ostracites labiatus Schloth., 1813, Bronn's Jahrb., vol.V11, p. 93.
Mytulites problematicus Schloth., 1820, Petrefactenk,1,p.302.
Inoceramus mytiloides Mantell, 1822, Geol. of Sussex, p.215, Pl.28, Fig. 2.
?Inoceramus confertim-annulatus Schiel, 1855, Pacific R.R. Reports, vol.11, Pt.2, p.108, Pl.2, Fig.7.
?Inoceramus pseudo-mytiloides Schiel, 1855, Ibid., Pl.3,Fig.8.
Inoceramus mytiloides (Mantell) Roem., 1852, Kreide. von Texas, p.60, Pl.7, Fig. 5.
Inoceramus mytilopsis Conrad, 1857, U. S. Mexican Boundary Sur., vol.1, Pt.2, p. 152, Pl.5, Figs. 6a and 6b.
Inoceramus problematicus (Schloth.) Meek,1876,U.S.Geol. Sur. Terr., vol.lX,p.62,Pl.9, Figs. 3a and b.
Inoceramus aviculoides M. and H., 1860, Proc. Acad. Nat. Sci., Phila., p.181.
Inoceramus problematicus var. aviculoides Meek,1876,U.S. Geol. Sur. Terr., vol.lX,p.63, Pl.9, Fig.4.
Inoceramus labiatus (Schloth.), Stanton,1893,U.S.Geol. Sur. Bull. 106, p.77, Pl. X, Fig.4; Pl. XlV, Fig.2.
Inoceramus problematicus, mytiloides or labiatus of many authors.

Complete shells with the two values in position are not found, but molds of the interior and exterior of isolated valves are fairly common. Fragments of the original shell are also found.

The shell is obliquely elongate, oval shaped and rather compressed. In some shells a slight convexity is found. The original shell, when preserved, is very thin and fragile. The beaks are small and terminal rising just slightly above the level of the hinge line. The anterior margin forms a slightly convex curve, obliquely downwards and backwards from the beak. The surface ornamentation consists of somewhat irregular undulations between which are smaller growth lines. It will be noticed in Plate 7 that the undulations

Plate 7. Inoceramus labiatus Schlotheim . X½ Approx.

Vermilion River, Manitoba.

sweep in a gentle curve anteriorly and ventrally and straighten out along the posterio-dorsal part of the shell. The arrangement of these lines emphasizes the obliquity of the shell. The length of the specimens varies from two to six inches. The average size is approximately three to four inches. The greatest width, observed, at right angles to the longest diameter of the shell is three and three-quarter inches. Very characteristic is the crowded nature of this species in a yellow marl bed, (See Plate 8, Fig. 1).

Localities; Vermilion River, S.W., Sec. 12, tp. 24, range 20[18]
Norgate River, S.E., Sec. 33, tp. 19, range 15
Kelwood River, S.E. and N.E. Sec.15, tp.19, range 15

Horizon; Abundant in a yellow marl bed of the Manitoba Coloradoan.

Meek gives four inches as the maximum length of this species. However, size is of minor importance and specimens have been observed in the United States having considerably greater length[19].

Specimens of <u>I. labiatus</u> (Plate 9, Figs. 1-2) sent by Henderson and Reeside agree very closely with the Manitoba Inoceramus. In the Greenhorn limestone, which is characteristically developed over a very wide area in the central Great Plains region of the United States, the species occurs in a manner suggestive of a gregarious habit, while a similar concentration of the shells is found in the Manitoba collections.

After a careful comparison of the Manitoba species with

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18. All localities in the escarpment from which fossils mentioned were collected, are west of principal meridian.

19. Reeside, J.B., verbal communication with S. R. Kirk.

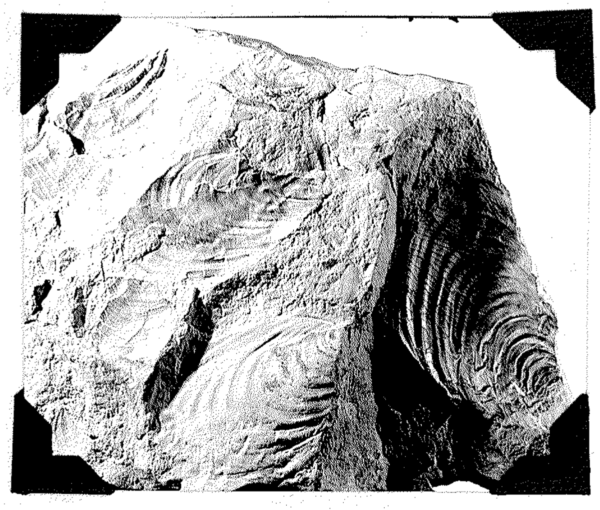

Figure 1. Inoceramus labiatus Schlotheim. x½.

Vermilion River ,Manitoba.

Figure 2. Inoceramus labiatus Schlotheim x2/3.

Kelwood, Manitoba.

PLATE 8.

Figure 1. <u>Inoceramus labiatus</u> Schlotheim x$\frac{3}{4}$.

Greenhorn Limestone.
Williams Creek, Huerfano Park, Colorado.
Specimen through the kindness of
J.B. Reeside Jr.

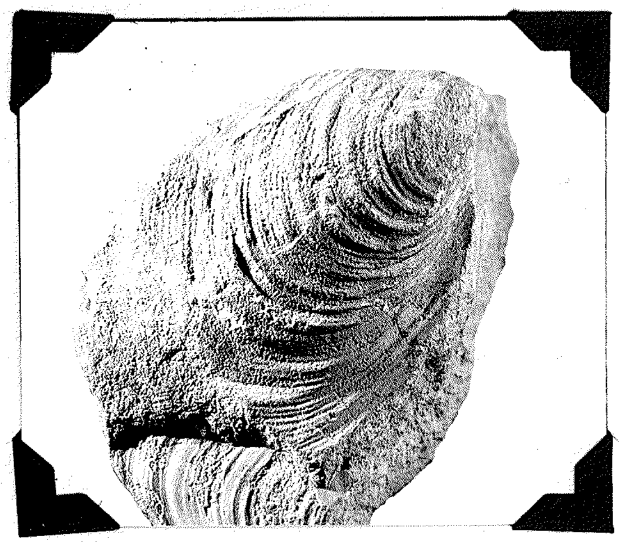

Figure 2. Inoceramus labiatus Schlotheim x1 approx

Greenhorn Limestone.
Fairpoint, Kansas.
Specimen through the kindness of
J. Henderson.

PLATE 9.

text figures in the North American literature and as well as with actual specimens from the States of Kansas and Colorado, there would appear to be no doubt about its identity with the species referred in America to I. labiatus.[20]

Inoceramus sp.
Plate 10, Figs. 1-2.

Fragments of a pelecypod shell, belonging to the genus Inoceramus are found abundantly in the limestones of the Manitoba Coloradoan. The fragments are flat and composed of calcite prisms, 2 to 8 mm. in length, arranged transversely to the surface.

These prisms are similar to those of the large, thick shelled species Inoceramus deformis which is found in the Niobrara formation of the United States Central Great Plains. None of the shell fragments, known, have a convexity which seems to be comparable with the very marked convexity of that well known species. On account of the very fragmentary character of all the specimens no specific identification is possible but this shell is of importance as a rock former, as will be shown later.

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20. It may be here noted that the American species has never been subjected to a rigid comparison with the European I. labiatus of Schlotheim.

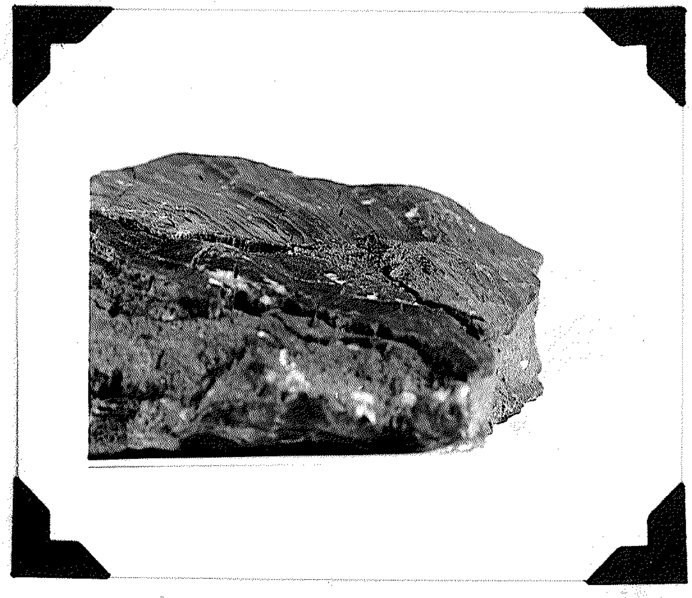


Figure 1. Inoceramus sp. x2/3.

Shell Fragment on Limestone.

Assiniboine River, Manitoba.

Figure 2. Inoceramus sp. x1.

Showing the fragmental nature.

Norgate, Manitoba.

PLATE 10.

Ostrea congesta, Conrad
Plates 11 and 12.

Ostrea congesta Conrad, 1843, Nicollet's Rept. of Explorations in the Northwest, p. 167; Hall, 1856, Pacific R. R. Reports, vol. 111, p. 100, Pl.1, Fig. 11; Meek, 1876, U. S. Geol. Sur., vol.IX, p.13, Pl. 9, Figs. 1a-f; White, 1884, 4th Ann. Rept. U.S. Geol. Sur., p. 294, Pl.39, Figs. 11,12,13; Whiteaves, 1889, Contributions to Canadian Palaeontology, vol. 1, Part 11, 4,C. Geol. Sur. Canada, 1889; Stanton, 1893, U.S.Geol. Sur., Bull. 106, p. 55, Pl. 11, Figs. 2,3, and 4.

This fossil pelecypod is represented by many shells forming a large part of the rock. The valves, the upper one being more abundant, are detached and very irregular in shape. A short deflected margin is found in a few lower valves. One lower valve, observed in a buff limestone on Wilson River, has the margin deflected upwards at right angles to the flat, tongue-shaped base. This deflection is ½ inch on the lateral margin at the extremity opposite the beaks.

The shell is thin with a comparatively smooth surface and a few obscure growth lines. Muscle scars are found in the interior of a few valves. The size is usually small but one or two specimens 1 inch or more in diameter were observed. The fact of its occurrence in the congested numbers suggests comparison with the O. congesta of Conrad and the general form of the shell is in agreement with that species.

Localities: Assiniboine River, S.W. Sec. 36, tp.8, range 11.
Vermilion River, S.E. Sec. 35, tp.23, range 20.
Wilson River, S.W. Sec. 19, tp.25, range 20.

Whiteaves reports this species and describes it as having, in some cases, a greatest diameter of 1¾ inches. He also states

Ostrea congesta Conrad $x1\frac{1}{2}$.

Showing the congested nature.

Assiniboine River, Manitoba.

PLATE II.

Figure1. <u>Ostrea congesta</u> Conrad. x1 approx.

Assiniboine River, Manitoba.

Figure2. <u>Ostrea congesta</u> Conrad x1 approx.

Ochre River, Manitoba.

Plate 12.

that he did not obtain any specimens with the abruptly deflected margin of the lower valve as described by Meek. Meek refers to this marginal portion of O. congesta as having a width as much as 1 inch. While the deflected margin is observed in many of the Manitoba specimens, at present being studied, the margin on the Wilson River specimen is the only one which nearly approaches such a size.

Ostrea cf patina, Meek and Hayden
Plate 13, Figs. 1-2.

Ostrea patina, Meek and Hayden (Nov. 1856) Proceed. Acad. Nat. Sci. Philad., 277; Meek, U. S. Geol. Sur. of Terr. Vol.1X (1876) p. 16, Plate 10, Figs 2-3, Plate 11.
Compare Ostrea prudentia White, 1876, U. S. Geol. Sur. West 100th Meridian, vol. 1V., p. 171, pl. 14, Figs. 2a-d; 1884, 4th Ann. Rept. U. S. Geol. Sur. p.299, Pl. 40, Figs. 5 and 6.

The shell is nearly circular or ovate and very neat and symmetrical in outline. The valves are fairly convex and faintly marked with obscure, concentric growth lines. The average diameter of the shells is 1¾ inches. The two valves are ~~both~~ found and are usually detached.

Localities: Vermilion River, S.E. Sec. 35, tp.23, range 20.
McCreary S.E. Sec. 1, tp.21, range 16.

Horizon: In buff limestones collected at these localities.

The shells differ from Ostrea congesta as typically developed, in that, they are larger, have a more pronounced convexity and are much more regular in form. In the buff limestone found near McCreary they occur in congested masses but this apparently has not affected their growth. The shells described agree with Stanton's description of Ostrea prudentia, White, and with the Ostrea patina - Meek and Hayden, except in size, which is given as about 2.4 inches in each case. Stanton believes O. prudentia, White is the same species as O. patina, Meek and Hayden, which is found in the Montanan. O. prudentia occurs in the Coloradoan. Comparing the plates given by both of the authorities mentioned those of Meek and Hayden agree more closely with the Manitoba specimens which may be tentatively referred to Ostrea cf patina, Meek and Hayden.

Figure 1. Ostrea cf. patina Meek and Hayden x1 approx.
Vermilion River, Manitoba.

Figure 2. Ostrea cf. patina Meek and Hayden x1 approx.
McCreary, Manitoba.

PLATE IX.

Phylum Vertebrata

Class Pisces

Fragments of fish skeletons and scales are found scattered through the limestones, marls and shales of the Manitoba Coloradoan and, are the most abundant and widely distributed fossils which can be recognized megascopically. Complete or nearly complete specimens have not been recorded, but individual bones, teeth and scales are, in some cases, so abundant as to give the containing rock the essential character of a fish bone bed. A good example of this is seen in the shaly limestone at the top of the five foot limestone on Ochre River. When this is examined closely a crowded and congested mass of fish remains is observed. In other rocks the fish remains form a minor part. The fish fragments have a distinctive brown color and ~~slimy~~ shiny surface which mades the larger ones readily recognizable. A brown carbonaceous shale, exposed on Wilson River, contains, along the thin bedding planes, many fish fragments and small, well-preserved fish scales. Plate 14, Fig. 1, illustrates a fish bearing bed from a buff limestone exposed near McCreary.

Skeletal Parts

Many bones and vertebrae are found in the Coloradoan of Manitoba. They are not usually large and a lens is required to study their specific characters. Some fairly well preserved vertebrae are found which may belong to the genus Ichthyodectes. They are of a deeply hollowed amphicoelus type suggesting the appearance of an hour glass. The average diameter is about one half inch.

A specimen from the Manitoba Coloradoan, in the geological collection of the university, shows three large vertebrae in position. This specimen is recorded on the label as having been collected from the "Niobrara?" on the Valley river three miles north of Ashville. In this the vertebrae have a diameter of 1¼ inches and the neural spines 2½ inches in length (Plate 15).

Fish Teeth

The collection under study contains only a few large specimens of fish teeth but numerous small ones can be detected in the rock specimens with the aid of a lens.

Lamma manitobensis, Whiteaves
Plate 12, Fig. 2.

Cf. Lamna macrorhiza, Cope. 1875, Vert. Cret. Form. West (Rep. U. S. Geol. Sur. Terr., vol. 11), p.297, pl. 42, figs. 9, 10; A. S. Woodward, 1889. Cat. Foss. Fishes Brit. Mus., p. 399.

Lamna manitobensis, 1889, Contributions to Canadian Palaeontology, (Geol. Sur. Canada) vol. 1, Part 4c.

A specimen, perfect except for the absence of one lateral denticle, was collected at Vermilion River S. E. Sec.35, tp. 23, range 20.

The principal cusp is acutely pointed and has thin, knife-like, lateral edges. Its faces are both convex, the convexity being more pronounced in the outer face. The cusp as a whole has a slight inward curvature in the lower 2/3 of its length, and a rather marked outward deflection in the upper third. The main cusp is flanked by two lateral denticles of which the anterior, alone, is perfectly preserved in the specimen, while the posterior is represented by the broken stump. The whole crown has the characteristic, shiny enamelled surface, of Elasmobranch teeth.

The root has a grooved and pitted surface and is bifurcated, with the two prongs not strongly divergent but lying nearly parallel. Of the two prongs the one to the rear is the shorter and has a flattened posterior surface.

Some very small teeth, seen best with the lens, have only the main cusp preserved and this is very similar in shape to the large species just described.

Ptychodus and Enchodus

One or two small teeth characterized by a very low crown and rapidly expanding at the base, may belong to genus *Ptychodus* but, for a conclusive identification of this genus, better material would be required than that available at present.

One large tooth, from a buff limestone on Wilson River, of which only a long narrow conical cusp is preserved, is comparable to *Enchodus gladiolus* Cope[21]. In this specimen the cusp is bluntly rounded and the whole has a length of 12 mm. It is also slightly curved.

x1¼.

Enchodus? tooth from Wilson River.

21. Cope, E. D., U. S. Geol. Sur. Terr. vol.11, Plate XLII, Fig.7, 1876.

Figure 1 Fish Fragments x1 approx.

Showing small size .

McCreary, Manitoba.

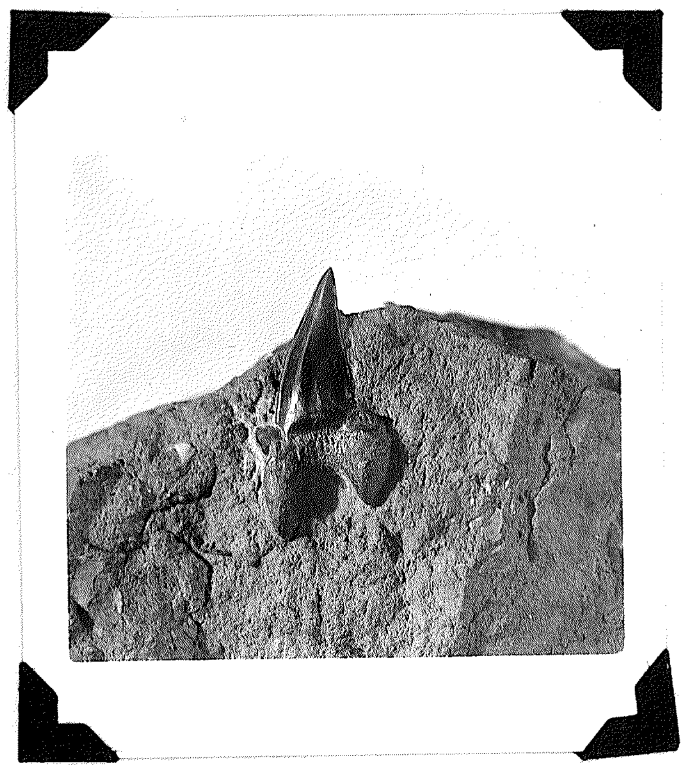
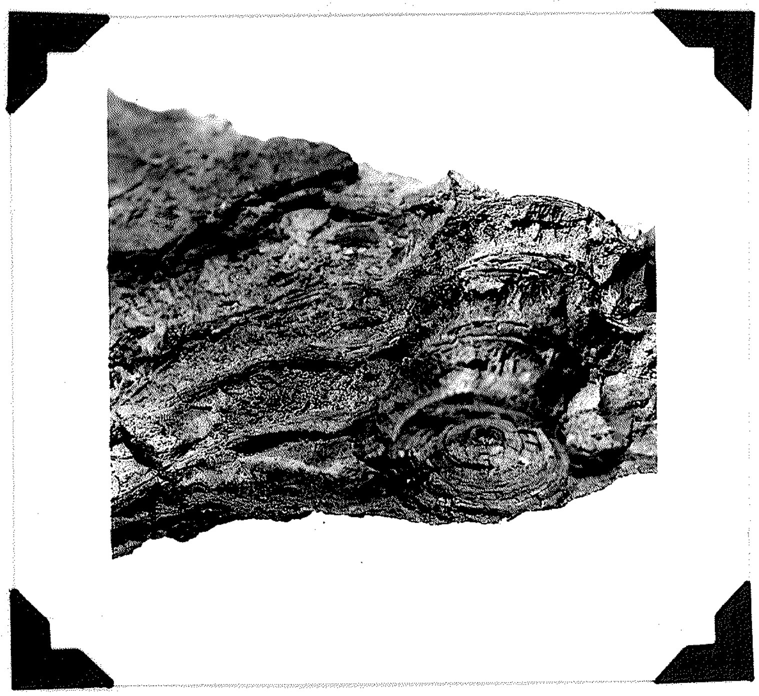


Figure 2 Lamna manitobensis Whiteaves. x1 1/3

Outer side.

Vermilion River, Manitoba.

PLATE I4.



Fish Vertebrae and Neural Spines. x½

Valley River, Manitoba.

Specimen in the geological collection,

University of Manitoba.

PLATE 15.

Fish Scales

Many fragmentary fish scales and some fairly perfect ones are found in the Manitoba Coloradoan. The identification of isolated fish scales has to be approached with caution, for a considerable variety is known to be possible in the scales from different parts of the body of a single individual.

Ichthyodectes occidentalis (Leidy)

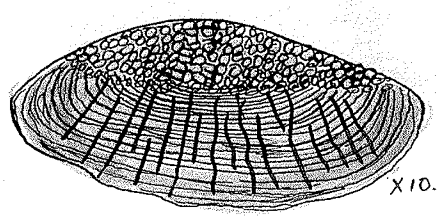
Ichthyodectes, Cope, 1870, November, Proc. of the American Philosophical Soc. Hayden's Geol. Sur. of Wyoming, 1871, p.421.
Cladocyclus occidentalis, Leidy, 1873, Contr. Extinct Vert. Fauna West. Terr. (Rep. U.S. Geol. Sur. Terr., vol.1) p. 288, pl. 17, Figs. 21-22, and pl. 30, Fig. 5.
Ichthyodectes, Cope, 1875, U. S. Geol. Sur. of Terr. Cretaceous Vertebrata, p. 205.
Cladocyclus occidentalis, Whiteaves, 1889, Contributions to Canadian Palaeontology, (Geol. Sur. Canada) vol.1, Part 4C.
Ichthyodectes, (Cope), Cockerell, 1919, U.S. Geol. Sur. Prof. paper 120-I, Some American Cretaceous Fish Scales, p.179, pl. XXXlV, Figures 3,4.

Most of the scales are small and cycloidal with the greatest dimension averaging less than ½ inch. One large specimen, in the geological collection of the university, locality unknown but definitely from the Manitoba Coloradoan, has a depth of 1-7/8 inches and a length of 7/8 inch.

These cycloidal scales are oval or in some cases nearly circular in outline, the inner portion has numerous radiating ridges not always visible on every specimen. Concentric ridges parallel to the margin are also characteristic of the inner part of the scale. A dendritic arrangement of these ridges was observed in some cases. The outer portion has a reticulated or granular appearance.

Localities and Horizon: Scales of the above type are found in practically all of the Coloradoan horizon in the Manitoba

Escarpment.



Ichythodectes occidentalis (Leidy)

It may be noted that most of the specimens are considerably smaller than these described by Whiteaves, who mentions two inches as the greatest diameter.

Cockerell[22] in his paper on Cretaceous fish scales does not list Cladocylus as a genus. He is inclined to believe that Cladocyclus and Ichthyodectes Cope are the same genus[23].

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22. Cockerell, T.D.A. Some Cretaceous Fish Scales, U.S.Geol. Sur. Prof. Paper 120-I, 1919, Page 178.

23. Cockerell,T.D.A. Idem. Page 178."Ichthyodectes scales also occur in Benton rock north of Boulder, Colo., where they were collected by Prof. J. Henderson(Colorado Univ. Mus. 459). One of these scales, 15 millimeters in transverse diameter and about 11 millimeters long, is from the lateral line and is remarkable for the complex, treelike system of branching canals, quite as complex as in the Brazilian Cladocyclus. This species tends to weaken our Conviction that Ichthyodectes and Cladocyclus are really different genera; but the scales of Cladocyclus gardneri differ in the basal region from those of Ichthyodectes, and in view of the difference of locality there is no great probability that the fishes are really congeneric.

Appendix;

The fossils collected by J. B. Tyrrell, from the Manitoba Coloradoan were identified by Whiteaves, who described the following species;

"Serpuls semicoalita, Whiteaves,
Lingula subspatulata (?) Hall and Meek
xOstrea congesta, Conrad
Anomia obliqua, Meek and Hayden
xInoceramus problematicus, Schlotheim
Modiola tenuisculpta, Whiteaves
Belemnitella manitobensis, Whiteaves
Loricula Canadensis, Whiteaves
Ptcyhodus parvulus, Whiteaves
xLamna manitobensis, Whiteaves
Enchodus Shumardi, Leidy
xCladocyclus occidentalis, Leidy[24]".

Dr. Kirk reports finding Seppula and Belemnite guards at Ochre River.

The types marked "x" have been described in the previous discussion on the palaeontology of the Manitoba Coloradoan. The other species occur very rarely and specimens have not been observed in the collection under study.

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24. Whiteaves, J. F., Cont. to Canadian Palaeontology. vol.1. 4C, Geol. Sur. Canada, 1889.

VI. Descriptive Geology

The exposures in the Manitoba excarpment are few and far apart so that continuous lateral tracing or "walking out" of the formations is impossible. As this, the most reliable method, is inapplicable other means of correlation have to be sought. Special attention has been given to the outcrops of limestone and marl as it is a recognized stratigraphical principle that limestone beds, especially those interbedded with thick shales, are least liable to be tangential in nature and are, therefore, much more likely to furnish reliable horizons.

The numeral preceding each locality in the following descriptions refers to the location number on Fig. 4, (on the back cover). All the localities are west of the principal meridian.

1.- 4 miles, South of Minitonas, S.W. Sec. 30, tp.35, range 25.

A two foot bed of bluish grey compact limestone with the feel and appearance of a sandstone is found at this locality. In thin section the fragmental nature of the limestone is very evident. (Plate 16, Fig. 1). Numerous separated prisms and shell fragments of Inoceramus, angular fish remains and a few scattered bits of the shell of Ostrea make up the entire rock. A fine darker material acts as a cement holding together the prisms and other fragments.

The fossil content is not large, the following having

Figure 1. Photomicrograph of the bluish grey limestone, south of Minitonas (1).

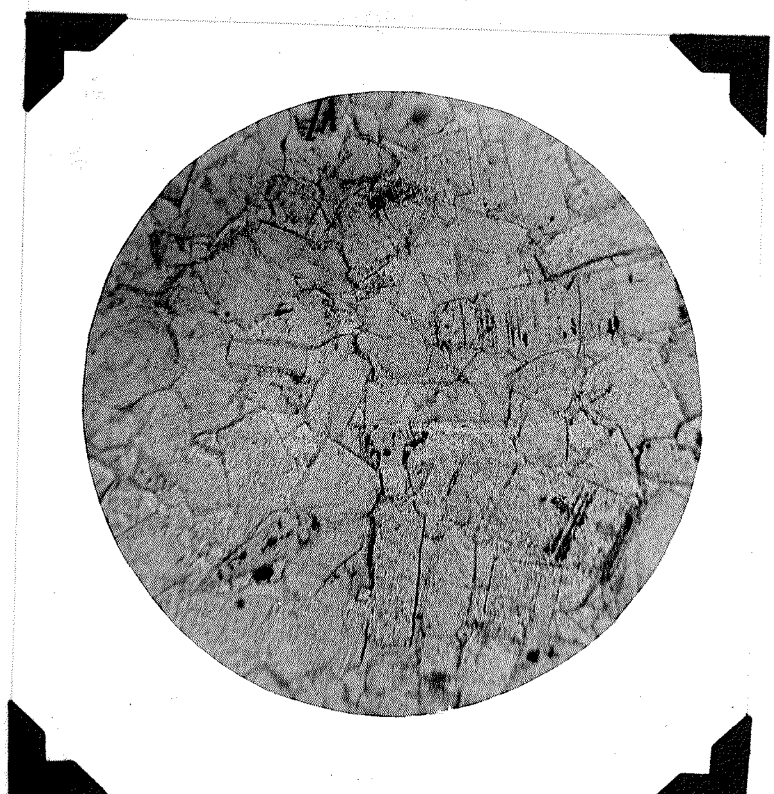

Figure 2. Photomicrograph of the buff limestone south of Ashville, (2).

Plate 16.

Note: All photomicrographs have a magnification of 80 diameters.

been identified:-

Inoceramus sp. (fragments)

Isolated prisms of an *Inoceramus*, probably belonging to the above.

Ostrea congesta, Conrad, small ovate forms not abundant nor crowded together

Ichthyodectes occidentalis, (Leidy) (scales)

Fish skeletal remains.

A small fragment of this rock when placed in hydrochloric acid gives off a very pronounced odour of petroleum indicating the presence of oil.

2. 1½ miles, south east of Ashville, (Wilson River) S.W. Sec.19, tp.25, range 20.

At this locality a very hard, medium grey coloured limestone occurs, which weathers to a buff colour and is underlain by a brown carbonaceous shale. This limestone, especially on the weathered surface, also has the appearance and feel of a sandstone. The thin section shows a different type of rock from the Minitonas (1) limestone. While it is composed entirely of prisms of *Inoceramus* they are much stouter and very closely packed. A characteristic feature of many prisms is the dotted dark inclusions which often completely replace the prism. See Plate 16, Fig. 2. Cementing material is not seen between the prisms. Fragments of shells of *Ostrea* and *Inoceramus* and fish remains are quite prominent.

The fossil identified from this locality are:

Inoceramus (prisms)

Ostrea congesta, Conrad, rare, One very well preserved specimen showing the deflected margin

Enchodus? cf gladeolus, Cope, (Fish tooth)

<u>Ichthyodectes occidentalis</u>, (Leidy) scales.

Fish vertebrae (<u>Ichthyodectes?</u>) and other skeletal parts.

3. <u>Edward's Creek.</u> 7 miles south west of Dauphin N.W.Sec. 4, tp. 24, range 19.

On Edward's creek, at the above locality, a bluff 40-50' in height has the following downward sequence.

Limestone 3 - 4 inches

Shale 25 feet highly calcareous

Soft white clay, 6 inches

Shale 25 feet.

The limestone is hard, compact and grey with a buff weathering. It is also characterized by its crystalline structure which gives it a superficial resemblance to a sandstone. Fish remains are the most abundant fossils. Fossils Identified are:

<u>Ichthyodectes?</u> vertebrae (quite abundant)

Small fish teeth.

<u>Fragmental fish scales</u>

<u>Ostrea</u> (fragments - scarce)

The fish remains are so abundant that the rock might almost be called a bond bed.

Below this limestone bed a very white chalky shale, with limestone affinities contains OSTREA (FRAGMENTS), abundant Coccoliths, Rhabdoliths and Foraminifera. The Foraminifera which have been recognized are:

<u>Gümbelina</u> type A
G. type B
G. type C
G. type D
G. type E

Globigerina type A
G. type B
G. type C

The Gümbelina and Globigerina are about equal in numbers and form a large part of the rock.

The white chalk or limestone grades down into a blue coloured shale. Below the 6 inch bed of white clay there is a brown carbonaceous shale with numerous selenite crystals, fish vertebrae, small Ichthyodectes occidentalis (Leidy) scales and many other bone fragments.

4.A. Vermilion River S. E. Sec. 35, tp.23, range 20.

The outcrop at this point consists of a limestone overlain by a shale. The former is a light bluish grey, compact rock which weathers buff. Megascopically it resembles the Wilson River (2), and McCreary (6) limestone but microscopically it is very similar to the Minitonas (1) bluish grey limestone and the Ochre River (8) five foot limestone. Plate 17, Fig. 1. is a photomicrograph of this rock.

Fossil remains are fairly abundant and the following have been identified:

Ostrea congesta, Conrad
Ostrea cf patina, Meek and Hayden
Inoceramus sp. (fragments).
Lamna manitobensis, Whiteaves
(one large specimen)
Fish scales (fragmentary)
Fish vertebra Ichthyodectes?
Fish bones.

The shale which overlies the limestone is light grey in colour and calcareous weathering yellow.

4.B. Vermilion River, S.W. Sec. 12, tp. 24, range 20.

On the west side of the Vermilion River valley at this point there is exposed, in the upper part of a bluff, 70 to 80 feet

Figure 1. Photomicrograph of the buff limestone on Vermilion River (4.A.)

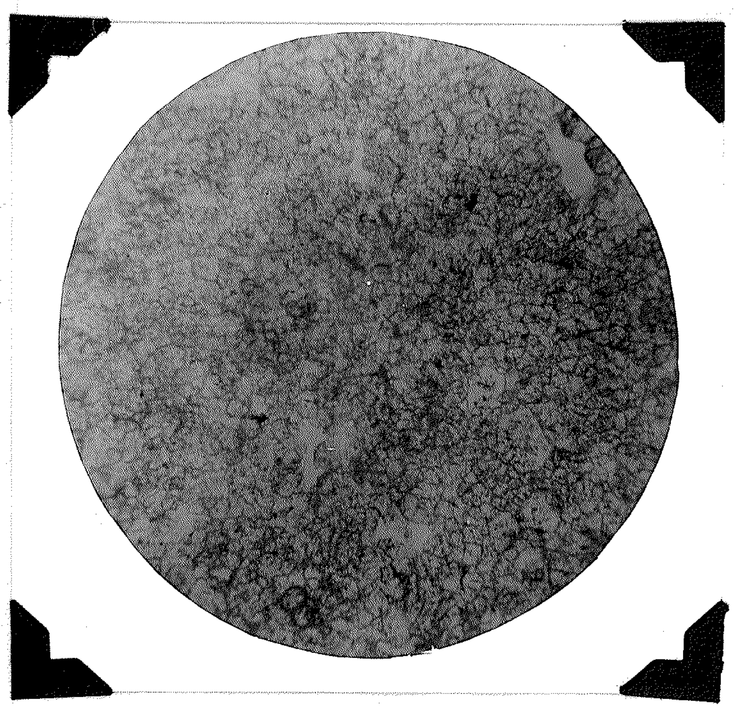

Figure 2. Photomicrograph of the compact limestone marl on Vermilion River (4.B.)

Plate 17

in height, the following downward sequence.

Brecciated limestone, 6 inches,
White chalky marl, 10 feet,
Limestone marl, 5 feet,
Shale, white and chalky, 10 feet,
Shale, dark bluish grey, 5 feet,
White chalky marl shale, 4 feet
Talus.

The white chalky marl shale at the base is fairly compact and contains many Coccoliths, Rhabdoliths and Foraminifera.

The Foraminifera identified in this shale are:

Gümbelina type A
G. type B
G. type E

Globigerina type A
G. type B
G. type C

The foraminiferal tests are very abundant in this marly-shale.

The conspicuous band in this exposure in the compact yellow limestone marl, Fig. 2, Plate 17, is a photomicrograph of this marl and shows the fine nature of the calcite particles bound by a matrix of the same material. Occasional larger calcite prisms of Inoceramus are found. This marl is characterized by the abundance of large valves of Inoceramus labiatus - Schlotheim (Plate 8, Fig. 1-2). A few Ichthyodectes occidentalis (Leidy) fish scales are scattered through the rock. The Foraminifera are ~~not~~ abundant; the following have been identified:

Gümbeline type A
G. type B
G. type E
Globigerina type A
G. type B
G. type C

The bed immediately above is of the same type only not so compact.

The following fossils have been observed:

Inoceramus labiatus, Schlotheim

Fish scales (fragmentary)

Coccoliths and Rhabdoliths,

Foraminifera (abundant)

Gümbelina type A
G. type B
G. type C
G. type E
Globigerina type A
G. type B
G. type C
G. type D

5. *Ochre River* N. E. Sec. 30, tp. 22, range 17.

Two prominent members, one a 5 foot limestone and the other a 6 inch shaly limestone crowded with *Ostrea congesta*, outcrop in high stream bluff sections along Ochre River.

The five foot limestone is very similar in appearance to the Minitonas (2) limestone. Under the petrographic microscope the thin section (See Plate 18 Fig 1) closely resembles those of the Minitonas (1) and Vermilion River (4A) limestones.

The following fossils have been identified:

Ostrea congesta, Conrad (complete valves and fragments)

Inoceramus sp. (fragments)

Ichyhyodectes occidentalis (Leidy) very common

Fish vertebrae *Ichthyodectes?*

Small fish teeth of the *Lamna* type

Many fragmentary skeletal bones.

Dr. Kirk reports finding *Serpula* and *Belemnites* from this bed. Near the top of the limestone the fish remains become so abundant in it, that it takes on the character of a bone bed.

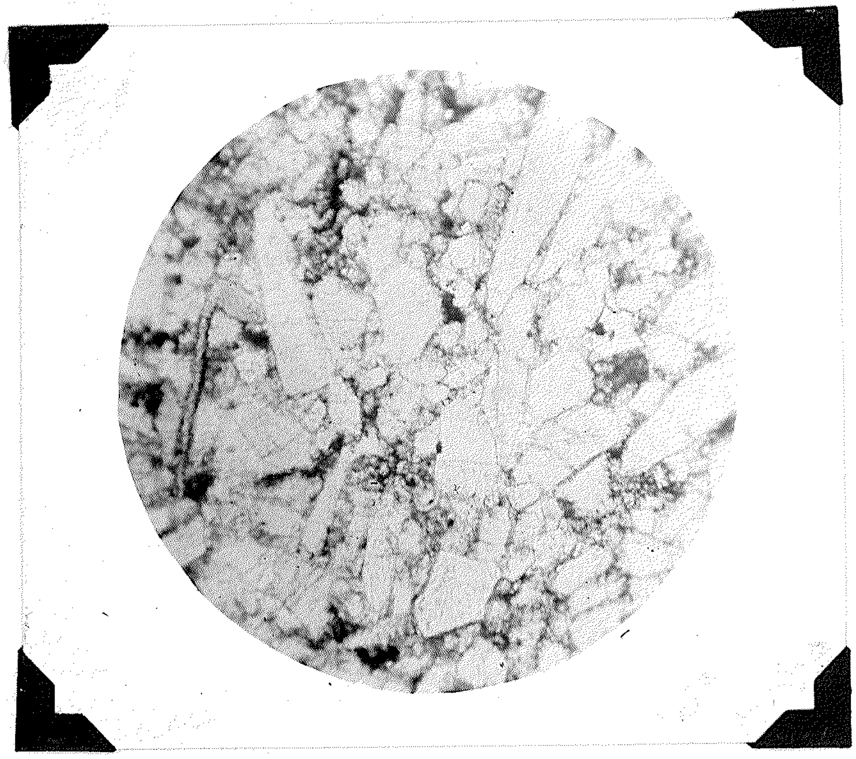

Figure 1. Photomicrograph of the five foot limestone on Ochre River (5).

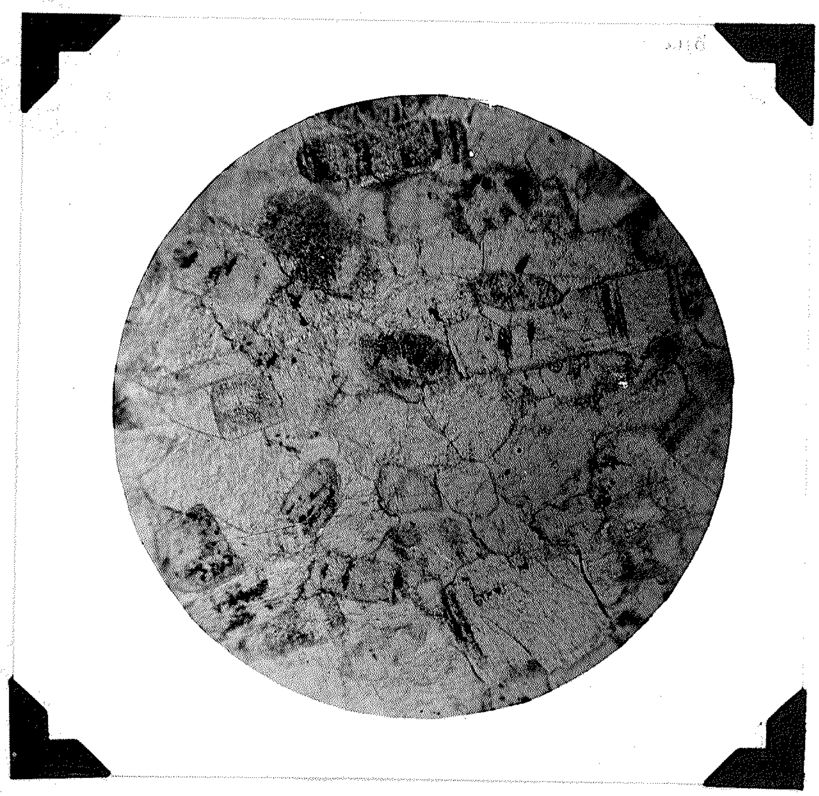

Figure 2. Photomicrograph of the buff limestone west of McCreary (6)

<u>Plate 18</u>

The lower 6 inch argillaceous limestone bed is separated by 20 to 25 feet of shale from the 5 foot limestone described above. It is a shaly bed with a large number of prisms probably belonging to Inoceramus sp. which in places give the rock an arenaceous appearance. Examined under the binocular miscroscope a large number of long prisms of Inoceramus are found loosely piled with calcareous shaly material filling the interstices. Fragmental shells of Ostrea congesta form an important constituent in building up the rock.

The following fossils have been observed:

Ostrea congesta Conrad (very abundant in congested masses)
Prisms of Inoceramus

Fish vertebrae and other fish remains.

Foraminifera (not abundantly represented)

Gümbelina type A
G. type B
G. type D

Globigerina type C

6. McCreary. S.E. Sec. 1, tp. 21, range 16.

A buff weathering, crystalline limestone is exposed 2 miles west of McCreary. The medium grey or light brown colour is well shown on any fresh fracture, and the rock has the prevalent sandy appearance of the other limestones. A thin section (Plate 18, Fig.2) shows, the compact arrangement of the prisms of Inoceramus, the dark inclusions in many of these prisms and the close resemblance to the Ashville (Wilson River) (2) limestone (Plate 16, Fig. 2).

This limestone is underlain by a dark brownish carbonaceous looking shale shot with a yellow powdery material.

The fossils identified from the limestone are:

Ostrea cf patina, Meek and Hayden (very abundant)

Prisms of Inoceramus

Numerous fish remains, among which teeth, vertebrae, Ichthyodectes occidentalis (Leidy) scales and bones are represented. (Plate 14, Fig. 1 is taken from this horizon).

7. Norgate

7A. S. E. Sec. 9, tp. 20, range 15.

A thin bed, buff weathering, limestone outcrops about 1½ miles north west of Norgate. It contains abundant fish remains and is of the same type as the buff limestone at McCreary(6) so that it needs no further description. It is also underlain by the same type of dark brownish carbonaceous shale as is found at McCreary(6). The fossil remains are the same with the exception of shells of Ostrea, which are scarce.

7B. S. E. Sec. 33, tp. 19, range 15.

A very good exposure of yellow chalky marl bed, underlain by a blue shale, is found 1 mile southwest of Norgate. Under the microscope the rock is seen to be fine grained and crystalline with a few patches of larger calcite crystals (prisms of Inoceramus) as illustrated on Plate 19, Fig. 1. The fine calcite particles appear to be derived from the complete breaking down of the thin and fragile shell of Inoceramus labiatus. This rock resembles the yellow marl bed on Vermilion River (4.B.)

Fossils observed in this bed include:

Inoceramus labiatus, Schlotheim (abundant and fragmentary)
Ostrea sp. indet.
Ichthyodectes occidentalis (Leidy)

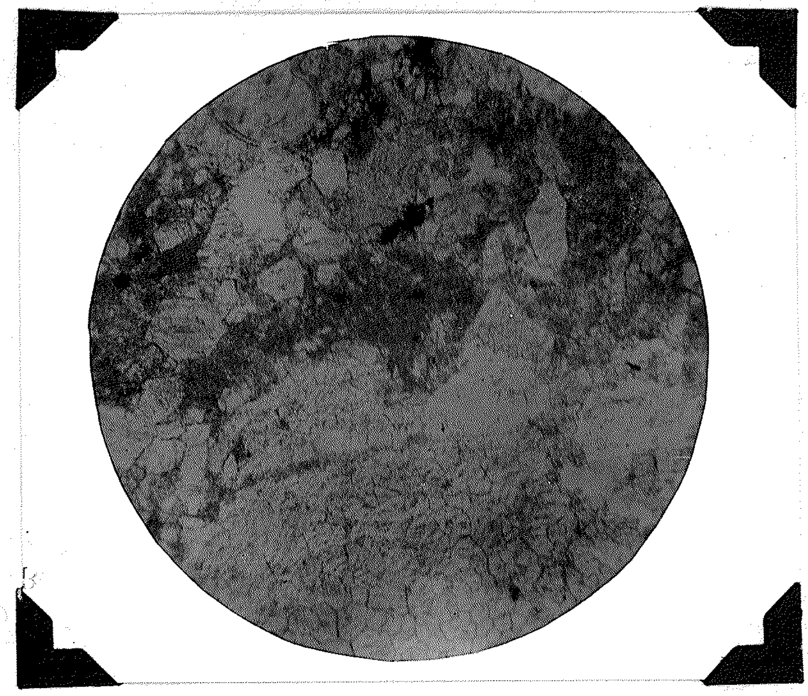

Figure 1. Photomicrograph of the yellow marl bed South of Norgate (7.B)

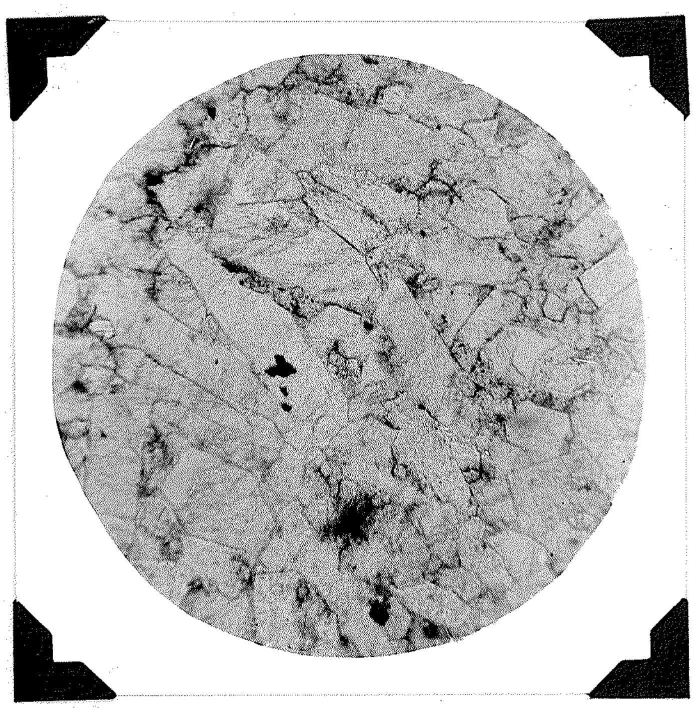

Figure 2. Photomicrograph of the limestone on Assiniboine River (9A).

Plate 19.

This rock does not disintegrate readily when boiled with alkali solutions and only a few Foraminifera were obtained by this process.The surface of the rock, when examined under the binocular microscope, shows an abundance of foraminiferal tests. The following have been identified,

Gümbelina type B
Globigerina type A
G. type C.

7C. N.W. Sec. 21, tp. 19, range 15.

A fragmental limestone, illustrated on Plate 10, Fig. 2, composed of shell fragments belonging to *Inoceramus sp.* is found 2 miles south west of Norgate. Small fragments of the shells of Ostrea have also been observed .

8. Kelwood

8A. N.W. Sec. 7, tp. 19, range 14, (2 miles east of Kelwood)

A buff limestone similar in lithology and fossil content to the McCreary (6) and Norgate (7A) limestone outcrops at the above locality.

8B. N.E. Sec. 22, tp. 19, range 14, (2 miles north of Kelwood)

At this locality a blue shale , which is similar to the blue shale at Norgate(7B), is interbedded with a white chalky shale. The white chalky shale contains a large number of foraminiferal shells and the following have been identified;

<u>Gümbelina</u> type A
G. type B
G. type D
G. type E
<u>Globigerina</u> type A
G. type B
G. type C

The blue shale examined under the binocular microscope shows many of the same foraminiferal tests as given in the above list.

8.C. N. E. Sec. 15, tp. 19, range 15. (1¼ miles north of Kelwood).

There is exposed at the above locality a white grey marl limestone which only differs in colour from the yellow marl bed at Norgate (7B). The shells of *Inoceramus labiatus*, Schlotheim are just as abundant.

The following types of Foraminifera (very abundant) are found in this marl;

<u>Gümbelina</u> type A
G. type B
G. type E
<u>Globigerina</u> type A
G. type B
G. type C.

9.A. Pembina Mountains

S. W. Sec. 36, tp.8, range 11.

On the south bank of the Assiniboine River there is exposed, at the above locality, a compact crystalline, bluish grey limestone, "locally known as sandstone"[25]. Shaly partings occur within the limestone. Examined in thin section the detrital nature is evident (Plate 19, Fig. 2) and it resembles the Minitonas (1), Vermilion River (4A) and Ochre River (5) five foot limestones. Dissolved in hydrochloric acid this rock gives off

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25. Plate 2, Assiniboine Limestone.

an odour of petroleum.

The species Ostrea congesta, Conrad (Plate 12. Fig. 1), in great abundance, characterizes the basal portion of this limestone. Within the upper more massive beds, large thick plates of Inoceramus sp. (Plate 10. Fig. 1) are very noticeable. A few fragmentary fish scales of Ichthyodectes occidentalis (Leidy), several vertebrae of Ichthyodectes? small fish teeth and numerous skeletal parts are the other fossils observed. Many Foraminifera were separated from a shaly portion of the rock, the following types being recognized:

Gümbelina type B
G. type C
G. type D
Globigerina type C

9.B. Southern Part of Pembina Mountains in Manitoba

Four samples of a chalky shale believed by Dr. Kirk to represent MacLean's[26] "Cheval" beds were collected, near the International boundary, in the Pembina Mountains. The foraminiferal tests are the only fossils observed and they are usually minute forms.

1. S. W. Sec. 4, tp. 2, range 7.

From a chalky shale, light cream in colour the following Foraminifera (fairly abundant) have been identified:

Gümbelina type B
Globigerina type C
G. type D.

2. S. E. Sec. 29, tp. 1, range 5.

In a blue, soft shale, at this locality, which weathers slightly buff in colour the following types of Foraminifera

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26. Plate 2.

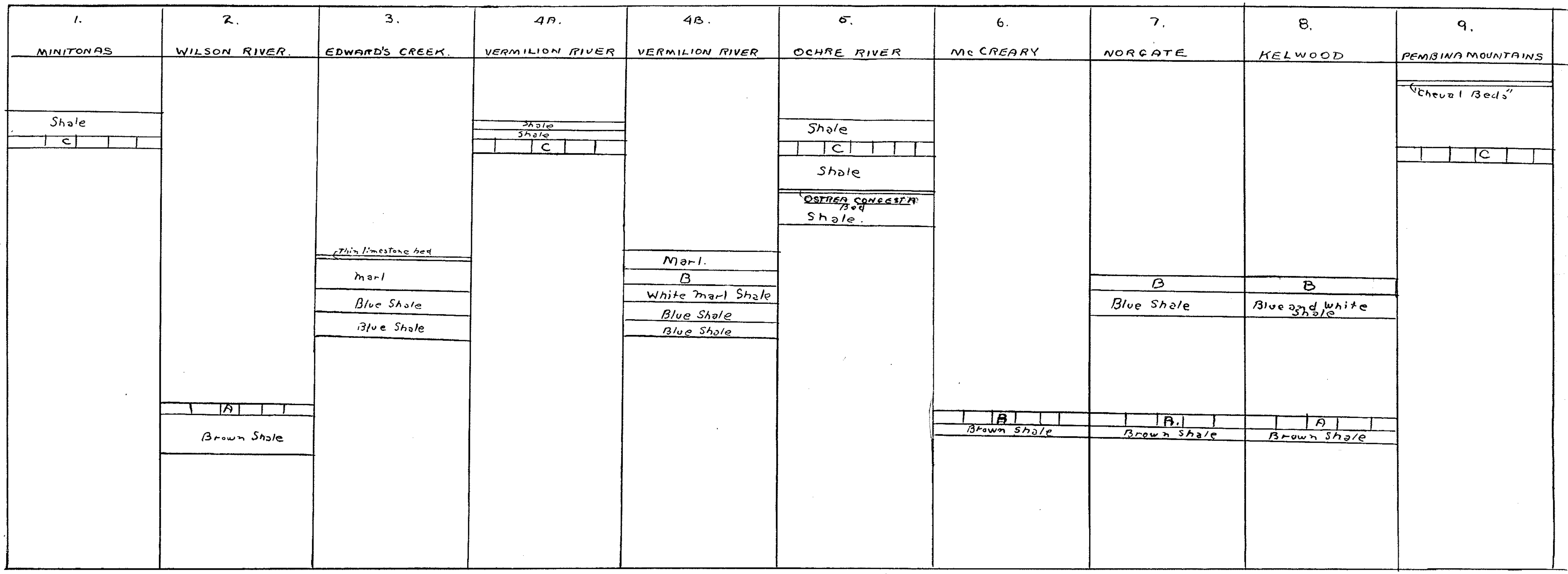
(abundant) were recognized:

> <u>Gümbelina</u> type B.
> G. type D.
> G. type F.
> G. type G.
> <u>Globigerina</u> type C.
> G. type E.

4. S. W. Sec. 18, tp. 1, range 6.

A brittle, white chalk shale, which splits readily into thin layers is exposed at the above locality. The following Foraminifera (not abundant) have been identified:

> <u>Gümbelina</u> type B.
> G. type F.
> Globigerina type C.
> G. type D
> G. type E.



C.- Blue grey limestone.

B. *Inoceramus labiatus* marl bed.

A. Buff limestone.

PLATE 20.

VII. Correlation of the Coloradoan Sections in the Manitoba Escarpment

In this chapter the stratigraphical relationships of the different limestones and marls are discussed. A comparison is made of the lithological and palaeontological characters of the various beds, which have been described in the previous chapters, in order to determine what basis exists for a regional correlation. The superposition, observed by Dr. Kirk in the field, is given on Plate 20.

A. Buff Limestone Beds on Wilson River(2), at McCreary(6), Norgate (7A) and Kelwood (8A).

The buff limestones found at each of the above localities are underlain by dark brown or grey shale, which is carbonaceous in appearance. As McCreary, Norgate and Kelwood are in close proximity, and as the limestone occurrences are all at about the same elevation, the similarity of lithology and abundance of fish fragments may be taken as proving beyond any possible doubt that the limestone is a continuous band in this vicinity. Although the Wilson River(2) outcrop lies approximately 40 miles north of McCreary it is evident that it too belongs to the same horizon. This is shown by the marked lithological similarity, both megascopically and microscopically (see pages 32,37,38,39), the abundance and character of its contained fish remains and the fact that it also overlies a dark shale.

B. Marl Beds at Norgate(7B), Kelwood (8C) and on Vermilion River(4B).

These compact marl beds in each case are characterized by the abundant remains of *Inoceramus labiatus* Schlotheim,(pages 20-21). The lithology (pages 35, 38, 40) and foraminiferal content (pages 35,39,40) are similar in each case. At each of the localities a highly calcareous shale containing Foraminifera underlies the marl bed. This shale (and possibly another lower unexposed member) separates the Inoceramus labiatus beds from the buff limestone (A) which is seen near Norgate and Kelwood. There seems to be no doubt that this zone characterized by Inoceramus labiatus is a continuous horizon.

Edward's Creek (3)

At the top of the section on Edward's Creek a thin hard limestone (page 32) band 3 to 4 inches thick overlies a marly shale. This limestone resembles the buff limestone (A) lithologically but it occurs in a different lithological sequence, being underlain by shales of the type found below the Inoceramus labiatus bed (B) discussed above.

It will be noticed that this limestone is only a very thin band. It is here interpreted as being only a local hard band within the marls.

The underlying marly shale agrees closely in lithology, (pages 33, 35) and foraminiferal content (pages 33, 35) with the rather softer marl which overlies the compact Inoceramus labiatus marl (B) on Vermilion River (4B).

The blue shale which underlies this marly shale is calcareous and closely resembles the blue shale which is seen under the Inoceramus labiatus marl (B) at Norgate (7), Kelwood (8) and on the Vermilion River (4B). It is, accordingly, correlated with the zone of Inoceramus labiatus (B).

C. The bluish grey limestones, south of Minitonas(1), on Vermilion River (4A) and the five foot bed on Ochre River(5), Assiniboine Limestone, Pembina Mountains (9A).

The limestones which outcrop at these localities have the same colour and degree of compactness. In each case the limestone is largely detrital and composed of Inoceramus prisms, along with a few valves of Ostrea congesta Conrad. This combination of characters seems to indicate that they represent another continuous horizon.

Using this correlation, it can be seen that the outcrop of this limestone rise in elevation towards the north. On Ochre River (5) and also on Vermilion River (4A) the elevation is approximately 1100 feet above sea level while at Minitonas (1), 80 miles further north the elevation is approximately 1300 feet. That is to say, the line of the Cretaceous escarpment does not quite represent the true strike of the formations.

On Ochre River a thin band of argillaceous limestone with crowded masses of Ostrea congesta, Conrad, occurs some 20 to 25 feet below the five foot limestone. This strongly resembles the shaly bottom layers of MacLean's Assiniboine limestone,(see plate2) which are also characterized by congested masses of Ostrea congesta, Conrad. The fact that Ostrea congesta, Conrad occurs in both cases below the heavy bed of limestones may be of some significance. The upper more massive portion of this Assiniboine limestone with its large fragmentary plates of Inoceramus sp. agrees very closely with the limestone which have been correlated between Ochre River (5), Vermilion River (4A) and Minitonas(1).

If the correlation is well founded then this thick bed of limestone is probably the most significant horizon marker in the Coloradoan sections of Manitoba. In any of the other sections the lithological types can be referred as occuring above or below the limestone. In the north, Riding and Duck Mountains, most of the exposures are below while in the Pembina Mountains to the south, the sections exposed are at higher elevations. Apart from the limestone itself the lithological sequences do not seem to agree so MacLean's lithological members cannot be applied and fossil evidence alone can be appealed to. The Foraminifera identified from the "Cheval" samples do not show agreement with the marly chalky beds in the north. This may be taken as corroboration of the limestone key horizon.

VIII. Coloradoan Sections in the United States and Alberta

The Upper Cretaceous was subdivided by Meek and Hayden into "Cretaceous No. 1, No. 2, No. 3, No. 4, and No. 5". "Cretaceous No.2" and "Cretaceous No.3" were later renamed Fort Benton and Niobrara respectively. Their Niobrara division is described as follows:

"As developed along the Missouri at the typical localities this group or division is a heavy bedded pure chalk marl, being almost entirely composed of calcareous matter .....
.....The most common fossils of this group here are Ostrea congesta, Inoceramus problematicus, fragments of a small compressed Baculite, and large scales of cycloid fishes. ....
.....The specimens of Inoceramus problematicus are usually most abundant in the harder layers that sometimes assume the character of a whitish limestone, in which the much more rarely seen little Baculite also occurs".[27]

The Fort Benton is described as consisting of dark grey laminated clays or shales. The characteristic fossils being Ostrea congesta, Inoceramus problematicus and Prionocyclus woolgari.

Further detailed work in the Coloradoan has shown that not only the Niobrara but also the Benton includes calcareous beds. Todd[28] states that Meek and Hayden took a limestone within the

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27. Meek, F.B., Invertebrate Palaeontology: U.S. Geol.Sur.Terr. vol.IX, p. XXXI, 1876.

28. Todd, J.E., Benton Formation in Eastern South Dakota: Bull.Geol. Soc. America, vol. 15, p. 572, 1904.

Benton, known as the Greenhorn, for the Niobrara and that later investigators accepted this conclusion and continued the error.

The following is a summary in downward sequence of the Colorado formation as known in the central Great Plains region of United States:

Niobrara:

Chalk, limy shale and limestone. Ostrea congesta, Conrad is a distinctive fossil when it occurs in large colonies. Inoceramus deformis is also characteristic.

Benton:

Carlile: grey shale. Distinct zone containing Scaphites warreni, Meek and Hayden, and several species of Prionotropis and Prionocyclus. Inoceramus labiatus rarely found.

Greenhorn Limestone: characterized by the abundance of Inoceramus labiatus Schlotheim. (note that Inoceramus deformis replaces Inoceramus labiatus in the Carlile and Niobrara). Darton[29] describes the deposition of the Greenhorn limestone as follows:

"Another marked episode was that which resulted in the deposition of the thin Greenhorn limestone inthe middle of the Benton sediments along the east front of the Rocky mountains from the Black hills to New Mexico and far eastward into Iowa. The great extent of this highly characteristic limestone is an impressive feature, for it indicates a uniform condition of sedimentation over an area of many thousands of square miles."

Graneros: dark shaly clay, brown carbonaceous shale and sandy shale. Nearly barren of fossils.

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29. Darton, N. H., Paleozoic and Mesozoic of Central Wyoming: Bull. Geol. Soc. America, vol. 19, p. 467, 1919.

From a palaeontological study Warren and Rutherford[30] have subdivided the Coloradoan in Alberta and proposed a correlation with the Coloradoan of United States. They also hint at correlations with the Manitoba Coloradoan sections. The descriptions and correlations of the formations given below are taken from their paper.

The following is the section and correlation which is proposed for Alberta:

Alberta	United States
Baculites ovatus zone Scaphites zone Cardium sandstone	Telegraph Creek, Niobrara
Prionotropis zone	Carlile.
Inoceramus labiatus zone	Greenhorn
Barren zone	Graneros and Thermopolis

From the stratigraphic position of the "so-called Benton" in Manitoba they believe it to be the same as their Barren zone. They also refer to the occurrence of Inoceramus labiatus zone in the "so-called Niobrara" of Manitoba.

The lower 200 feet of the Coloradoan in Alberta is practically barren of fossils, fish scales including Ichythodectes sp. and a few other fossils have been collected in it.

The Inoceramus labiatus zone is easily recognized in Alberta on account of the abundance of this species. It is correlated with the Greenhorn of United States because of the occurrence of this typical fossil.

Prionotropis woolgari, Mantell and P. hyatti Stanton? occur

30. Warren, P.S., and Rutherford, R. L., Fossil Zones in the Colorado Shale of Alberta: Reprint Amer. Jour. Sci. vol.XVI, pp. 129-136, 1928.

in the beds above the Inoceramus labiatus zone, but they are not abundant. On this evidence Warren and Rutherford[31] correlate the zone with the Carlile as described by Reeside[32].

The Cardium sandstone is not a true fossil zone but it is named from the occurrence of this species in large numbers.

The zone which contains Scaphites is easily recognized and bears a Niobrara fauna.

The Baculites ovatus zone is the highest zone in the Alberta Coloradoan and is correlated with the Telegraph Creek of Montana.

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31. op. cit. p. 135.

32. Reeside, J.B., A New Fauna from the Colorado Group of Southern Montana: U.S. Geol. Sur., Prof. Paper 132-B, p.25, 1923.

It is evident from these quotations that any calcareous shale, marl or limestone found in the escarpment was placed in the Niobrara while darker non calcareous (which in most cases clearly underlie beds of the calcareous type) were placed in the Benton.

Whiteaves[35], who identified and described the fossils of the Niobrara-Benton collected by Tyrrell states in a foot note:

"Mr. Tyrrell who is at present making a geological examination of this region states that although, the rocks seen are precisely (author's italics) similar to those described by Messrs. Meek and Hayden as "No. 2" and "No. 3" of their typical section, they are so intimately associated together that *it is practically impossible to draw any line of demarcation between them*(author's italics)."

Thus up to the present time the Coloradoan in Manitoba has been described as consisting of Benton and Niobrara similar to those groups in Meek and Hayden's typical section. It has also been stated that a definite line between the two can not be recognized.

In the chapter on Correlation of the Manitoba Sections, (pp. 43-46) three definite terranes were established, namely:

1. The buff limestone, (A)
2. The marl bed with *Inoceramus labiatus* (B) and
3. The bluish grey limestone (C).

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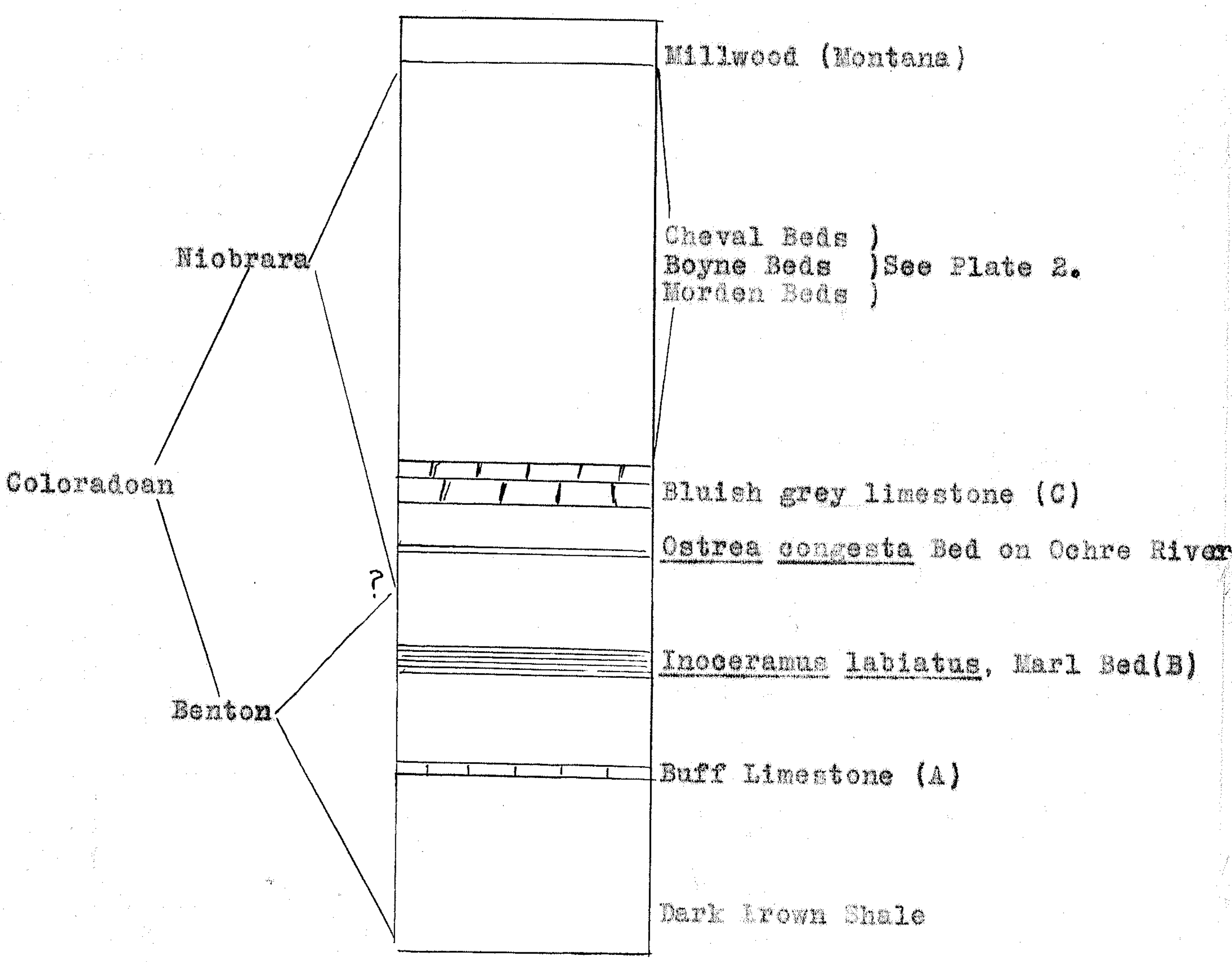
35. Whiteaves, J. F., On Some Cretaceous Fossils from British Columbia, The North West Territories and Manitoba: Contributions to Canadian Palaeontology, vol. 1, 4 C, 1889.

A generalized columnar section for the Coloradoan in Manitoba, determined through the field work of Dr. Kirk and this present investigation is given below.



Note: Thickness of beds only approximate.

The lowest zone in this columnar section is the dark shale which is practically barren of fossils, except for fish remains including Ichthyodectes occidentalis (Leidy) scales. The comparison with the Graneros shale of United States and the Barren zone of Alberta is justifiable. Its stratigraphic position, lithology and lack of fossils are evidence in favor of this correlation.

The buff limestone over the dark shale, while a definite band in the Riding Mountain district appears to be local.

The compact marl bed, that is to say, the Inoceramus labiatus zone, because of the abundance of this species is correlated with the Greenhorn Limestone of the United States and the Inoceramus labiatus zone of Alberta. The wide-spread distribution of the Greenhorn limestone over thousands of square miles showing a uniform condition of sedimentation, as stated by Darton (see page 47) adds further evidence to the correlation of the Inoceramus labiatus marl bed of Manitoba with the Greenhorn limestone of the United States.

At the present time, no definite statement can be made on the occurrence of Carlile shale equivalent in Manitoba. The genus Prionotropis, characteristic of the Carlile, has not been found in the Manitoba Coloradoan.

Ostrea congesta, Conrad, when found in large colonies, is usually a characteristic fossil in the Niobrara of the United States. This species has been recognized, in the Assiniboine limestone and in the thin argillaceous limestone 25 feet below the Ochre River (5) five foot bed, where it also occurs in large colonies. This fact and its position above the Inoceramus labiatus zone justifies a correlation with the Niobrara.

If the descriptions of Tyrrell, Meek and Hayden, (see pages 46, 50), were followed in this investigation the Benton-Niobrara would have to be placed below the base of the buff limestone (A).

However, it has been shown that the *Inoceramus labiatus* zone is equivalent to a Benton formation and the *Ostrea congesta* zone, stratigraphically higher, is equivalent to the Niobrara. The boundary, therefore, occurs somewhere between these two zones.

MANITOBA.	UNITED STATES.	ALBERTA.	EUROPEAN STAGES
NIOBRARA	Telegraph Creek	Baculites ovatus zone	Santonian
Shales- calcareous and non-calcareous(that is, the upper beds; equivalent to MacLean's Cheval, Boyne and Morden beds of the Pembina Mountain district)	Niobrara	Scaphites zone	
Limestone- Assiniboine Limestone (C) .			Coniacian
Shales- calcareous- including beds of Ostrea congesta			
BENTON Shales? (not studied)	Carlile	Prionotropis zone	
Marls and shales- zone of Inoceramus labiatus (B)	Greenhorn	Inoceramus labiatus zone	Turonian
Shales- dark, mainly non-calcareous, unfossiliferous except for fish remains. Norgate Limestone(A) near the top is fossiliferous.	Graneros	Barren zone.	

Plate 21.

X. Summary and Conclusions

This investigation has been concerned with the stratigraphical study of the Manitoba Coloradoan from laboratory collections and from field notes. The work has been concentrated on the more indurated calcareous beds exposed in the Manitoba Escarpment.

Through the study of the lithological and palaeontological characters correlations of the various beds has been made possible and the following distinctive key horizons have been determined-

1. Assiniboine Limestone (C)
2. Inoceramus labiatus zone (B) and
3. Morgate Limestone (A).

The continuity of these terranes within the Manitoba area having been established, tentative correlations, as shown in Plate 21, with the Coloradoan sections of United States and Alberta are suggested.

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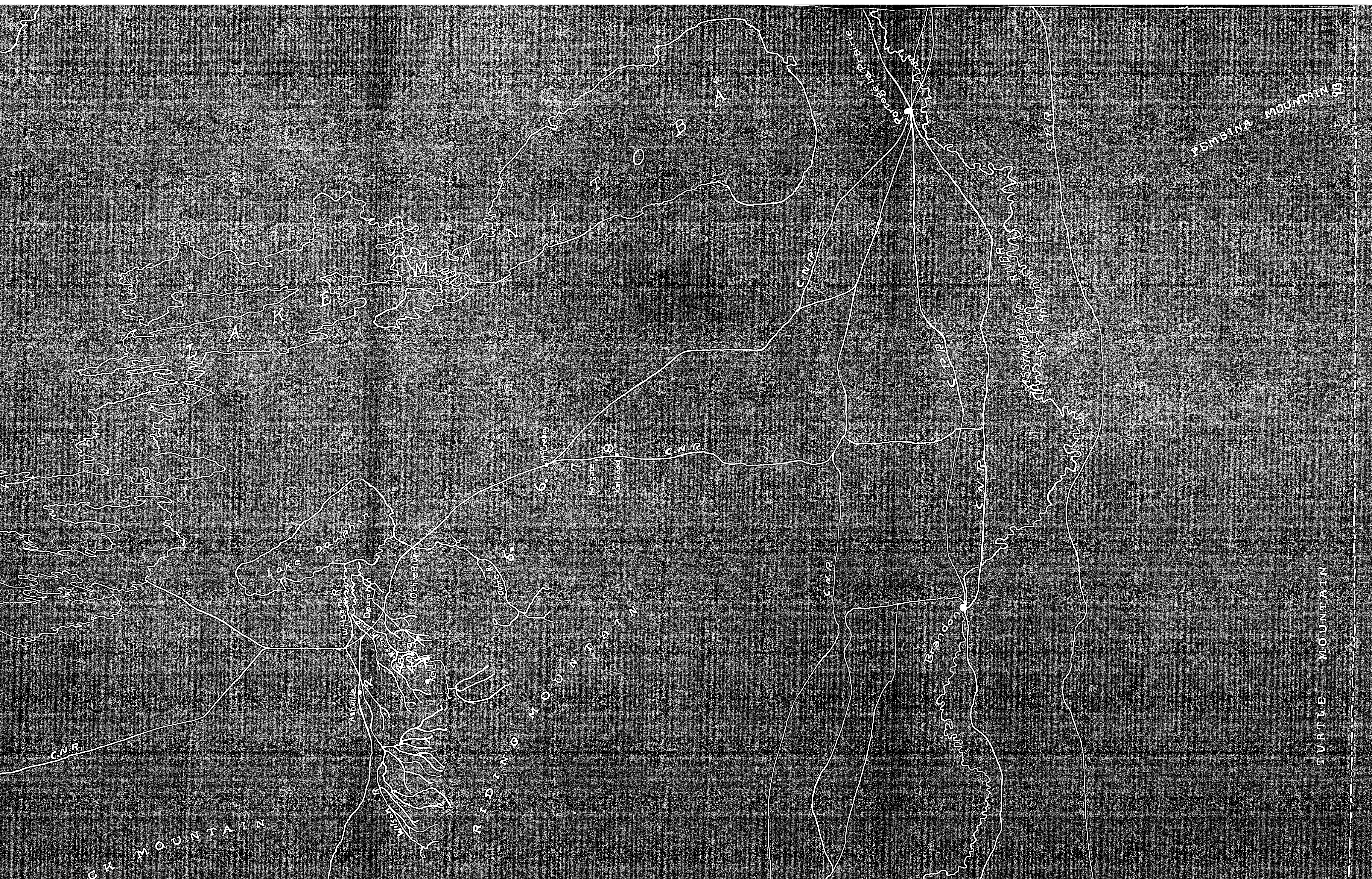
LAKE MANITOBA
Portage la Prairie
PEMBINA MOUNTAIN
9B
C.P.R.
C.N.R.
ASSINIBOINE RIVER
9A
C.P.R.
C.N.R.
McCreary
6
7
Norgate
8
Kelwood
C.N.R.
Lake Dauphin
Ochre River
Ochre R.
6
Wilson R.
Dauphin
Ashville
2
C.N.R.
C.N.R.
Brandon
RIDING MOUNTAIN
CK MOUNTAIN
Wilson R.
TURTLE MOUNTAIN