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PAPER 44-32

REVISION OF THE PALAEOGEOGRAPHY OF THE LOWER CRETACEOUS OF THE WESTERN INTERIOR OF CANADA

(Report and Figure)

BY

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OTTAWA

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CONTENTS

Illustrations

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THE LOWER CRETACEOUS OF THE WESTERN INTERIOR OF CANADA

INTRODUCTION

In his search for source beds the petroleum geologist is concerned with the distribution of ancient lands and seas. The prevalent view is that the source beds of petroleum were laid down in the sea and that the ancient shores provided a favourable environment. It is important, therefore, that some attempt should be made to outline the extent of the Lower Cretaceous seas and their shorelines in the western interior of Canada, where Hume (1933, page 216)[1], referring to the site of the central plains of Alberta, has noted that the Lower Cretaceous "shorelines with their embayments and lagoons are regarded as being very favourable for the deposition of source material for oil and gas".

[1] A list of references is given at the end of this report.

The Lower Cretaceous is also an important source of coal in the Canadian western interior. Coal swamps covered parts of the alluvial plains in both Kootenay and Lower Blairmore times.

Beds of Lower Cretaceous age are exposed in the Foothills of western Alberta and northeastern British Columbia; in the northern Plains; along the lower parts of Peace and Athabaska Valleys; and on the Manitoba escarpment. They are deeply buried beneath sediments of Upper Cretaceous and Paleocene age in southeastern Alberta and southern Saskatchewan, where they can only be studied in samples taken from deep wells.

As early as 1915 palaeogeographical maps of the western interior of Canada were prepared by D.B. Dowling. Very little, however, was then known of our Lower Cretaceous formations and nothing whatever of the vast area of marine deposits of this age in northern Alberta. Dowling did not, therefore, attempt to depict the geological record of this epoch. In 1923 Schuchert published a map of North America in Lower Cretaceous time, and in 1931 Crickmay prepared a similar map of the very early Lower Cretaceous. The writer's views on Lower Cretaceous palaeogeography of the Canadian western interior have been set forth in three papers (McLearn, 1931, 1932, 1935). The first (1931) was illustrated by one palaeogeographic map and the second (1932) by four maps. Recent field studies by the Geological Survey and new data on correlation require a revision of these maps.

In 1919 it was noted that a sea of Aptian (late Lower Cretaceous) or Albian (latest Lower Cretaceous) age, recorded by deposits on the lower Peace and lower Athabaska Rivers, "probably came in from the north or northeast". It was also pointed out that the Lower Cretaceous formations of this area showed "no resemblance ---- either to the Lower Cretaceous of the Pacific coast and Alaska or to the Comanchean of the south", indicating "the presence of barriers of some nature in these directions" (McLearn, 1922). This interpretation was accepted by Schuchert and made use of in the preparation of his 1923 map. It became established that the known Lower Cretaceous interior

LOWER CRETACEOUS

Region	Neocomian	Barremian	Aptian	Albian
EUROPE	Neocomian	Barremian	Aptian	Albian
BLAIRMORE	Kootenay		Blairmore group	
MOUNTAIN PARK	Nikanassin		Blairmore group: Cadomin, Luscar	Blairmore group: Mountain Park
PINE VALLEY	Bullhead group: Dunlevy		Bullhead group: Gething	Fort St. John group: Moosebar, Commotion, Hasler, Goodrich, Cruiser
WEST PEACE VALLEY	Bullhead group: Dunlevy		Bullhead group: Gething	Fort St. John group: Moosebar, Gates, Hasler, Goodrich, Cruiser
SIKANNI CHIEF RIVER	Bullhead group		Bullhead group	Fort St. John group: Buckinghorse; Sikanni (1st. ss., 2nd. ss., 3rd. ss., 4th. ss.)
LIARD RIVER				Fort St. John group: Garbutt, Scatter, Lepine
EAST PEACE VALLEY			McMurray ?	Fort St. John group: Loon River; Peace R. (ss., sh.); Cadotte ss.; Shaftesbury
EAST ATHABASKA VALLEY			McMurray	Fort St. John group: Clearwater, Grand Rapids, 'Pelican shale'
AMMONOID ZONES				*Lemuroceras* and *Beudanticeras affine*; *Gastroplites*; *Neogastroplites*
PELECYPOD ZONES			*Elliptio biornatus*; *Elliptio hamili*; *'Astarte' natosini*	*Inoceramus dowlingi*; *Inoceramus cadottensis*; *Posidonomya nahwisi*; *Posidonomya nahwisi var. goodrichensis*

Figure 1

Table showing correlation of LOWER CRETACEOUS formations and their stratigraphic positions with relation to certain known fossil zones.

Canadian seas were invasions from the Arctic and did not unite with northward extensions of the southern or gulf seas. This interpretation still stands for most of Lower Cretaceous time, but some reservation is made, pending more evidence, for the latest or Shaftesbury Sea, which is coeval with the sea recorded in southern Canada by the beds with the Haplophragmoides gigas micro-fauna. The writer (1932, 1935) has noted that the fauna of the lowest Upper Cretaceous, Dunvegan formation is the first of the Cretaceous faunas to show resemblance to those in the southern United States and is the first to record coalition of the northern sea with the southern. This interpretation, too, still holds except for some reservation pending further knowledge of the underlying Goodrich and Cruiser faunas of the Shaftesbury Sea.

It is not claimed that the revised maps of this paper are complete or without error. Like all palaeogeographic maps they involve much speculation. They are what the evidence now at hand justifies and nothing more. Like all previous maps they are subject to revision and addition as new facts are collected. It is thought, however, that very definite progress is being made and that each generation of maps comes nearer to the truth. Moreover, it seems advisable to issue these revised maps from time to time because they focus attention on unsolved problems of correlation and sedimentation and so stimulate investigation.

CORRELATION

A prerequisite to studies of this kind is a reliable correlation of strata. A revision of the correlation of the Lower Cretaceous formations exposed at the surface in the Canadian interior (See Figure 1) has recently been completed (McLearn, 1944) and it is assumed that this has been read. In addition some notes on subsurface beds are herewith given, based on reports by Wickenden and Yarwood.

Kootenay Formation

The Kootenay formation and its correlatives are not considered to extend much farther east than the outer border of the present day Foothills. Yarwood (1931a) doubts whether it extends as far east as the site of the Spring Coulée well, in tp. 4, rge. 23, W. 4th mer. He does not believe that any Kootenay is present in the Red Coulée oil field in tp. 1, rge. 16, W. of 4th mer. (Yarwood, 1931). About 150 miles to the northwest, in the vicinity of Turner Valley, Hume (1933) has long insisted that the Kootenay is rapidly thinning to the east. More than 400 miles to the northwest, in the Guardian well in Pouce Coupé district, Allan and Stelck (1940) present evidence to support their conclusion that beds equivalent to the Gething formation rest directly on beds correlated by them with the Jurassic, Fernie formation, implying that the Kootenay or lowermost Lower Cretaceous equivalent, the Nikanassin, does not extend this far out on the Plains.

Blairmore Group

The Blairmore group has been recognized in Flathead Valley in the western part of the southern Canadian Rocky Mountains where it forms a succession of conglomerates, sandstones, and shales (Mackenzie, 1916). Varicoloured beds of sandstone and of grey, greenish, and reddish shales, with rare, very thin coal seams, have been encountered in the deep wells of the southern Alberta plains lying above Jurassic strata and below beds correlated with the Alberta group. These varicoloured beds are also correlated with the Blairmore group, partly on a basis of lithological resemblance, including similar greenish and reddish shales and a common conglomerate at the base, and partly on the reported presence of two species of the Lower Blairmore fauna, Unio hamili and Sphaerium onestae ? (Yarwood, 1931, 1931a). The varicoloured beds extend into southern Saskatchewan where they underlie a dark grey shale and have been recognized lithologically in deep wells (Wickenden, 1932). It has not yet been shown what part of the Blairmore group is represented by the varicoloured beds, but if the Unio and Sphaerium are correctly identified, and are of short range, the presence of at least the lower part of the Blairmore in southernmost Alberta is indicated.

In the northern plains, in the core of the Guardian well near Pouce Coupé, a thick section of sandstone and shale is correlated on lithological grounds with the Gething formation (Allan and Stelck, 1940), which, in turn, has been correlated with the Luscar and a lower part of the Blairmore group (See Figure 1). Some differences are noted, however, recording, from west to east, an average decrease in grain size and the possible transition, at some horizons, from non-marine to marine beds. Thus the percentage of shale is higher and the percentage of sandstone lower than in the true Gething, and some thin glauconitic layers, absent in the Gething, are said to be present. Coal is extremely rare and in very thin layers.

The Clearwater formation of lower Athabaska River, and the Cadotte sandstone north of the town of Peace River (See Figure 1) are correlated with lower parts of the Upper Blairmore and may be equivalent to part of the varicoloured beds of southern Alberta and southern Saskatchewan. In 1932 the Clearwater was correlated with the dark grey shale of southern Saskatchewan, the shale with the Haplophragmoides gigas micro-fauna. It has been shown recently, however, that this micro-fauna is in the 'Pelican shale' and not the Clearwater formation (R.T.D. Wickenden and M. Feniak, personal communication).

A few observations on the correlation of the Shaftesbury formation may be added to what has been said in a previous paper (McLearn, 1944). The time of deposition of this formation may have been long, during which the fauna may have changed considerably. Tentatively two faunas are recognized, the Neogastroplites and Posidonomya nahwisi var. goodrichensis faunas. Later work will show whether these are two separate faunas or only phases of one. These faunas, or phases of the one fauna, are not widely distributed and so only aid, to a moderate extent, in correlation. Other means of correlation must, therefore, be resorted to, including use of micro-faunas, lithological resemblance, and stratigraphic position. The Shaftesbury formation on Peace River is compared with the 'Pelican shale' on Athabaska River on the basis of a similar position in the stratigraphic succession and a similar lithology. The 'Pelican shale' is correlated with the 'dark grey shale' of southern Saskatchewan on the basis of the Haplophragmoides gigas micro-fauna (Wickenden, 1932). What part of the Shaftesbury section this faunal zone represents is not known; it may be of the lower part rather than the upper part and possibly lower than Cruiser in the equivalent section in the west. The dark grey shale appears to be absent in southern Alberta. If equivalent beds are present they may be represented by the base of the Alberta group. In southwestern Alberta, only the very basal part of this group could be of late Lower Cretaceous age, as even the basal 110 feet is said to contain Upper Cretaceous fossils, namely Inoceramus corpulentus (capulus) and Acanthoceras albertense (Webb and Hertlein, 1934). The Fort St. John group is much thicker than equivalent beds in the south and southwest, where deposition must have been slower and interrupted or even possibly marked by local erosion at times.

PHYSIOGRAPHIC SETTING

Cordilleran Geanticline

Canadian geologists, beginning with Tyrrell (1886), have looked to the west for the source of the Cretaceous sediments deposited in the Rocky Mountain geosyncline and to an inferred, at times lofty, mountainous mass, west of the Rocky Mountain trench and partly on the site of the present-day Selkirk Mountains. This is the "Land Area" of Dowling (1915), the Columbia-Selkirk range of Schofield (1922), the Eastern Jurassic Highland of Schofield and Hanson (1922), the Cordilleran Intermontane geanticline of Schuchert (1923), and Zephyria of Crickmay (1931). Others who also have looked to this source for the Cretaceous sediments are F.H. McLearn (1932), M.Y. Williams (1932), and P.S. Warren (1938). In the following pages this old landmass will be referred to as the "Upland area" or "Cordilleran geanticline".

That most of the Cretaceous sediments came from the west, and only a small amount from the east, is inferred from the decrease in grain size from west to east, and the gradation from non-marine to marine deposits in the same direction. This is particularly well marked in Upper Cretaceous formations. It is mainly true, also, in those of Lower Cretaceous age, although more sediment appears to have come from the east than in Upper Cretaceous time. Moreover, in Lower Cretaceous time, certain factors entered that produced gradations from non-marine to marine, and decrease in grain from south to north, changes that tend to obscure the west to east changes.

That the sediments did not come from the site of the present Rocky Mountains is inferred from several sources of evidence. There is no angular unconformity between the Cretaceous and earlier sedimentary rocks in the Foothills, the Cretaceous strata being folded with those of Jurassic, Triassic, and Palaeozoic ages. Nor, as pointed out long ago by Tyrrell (1886), are there any known igneous rocks in the Rocky Mountains that could be expected to furnish the abundant feldspars in the Cretaceous sandstones. Moreover, Lower Cretaceous sedimentary rocks occur within the Rocky Mountains, for in the southwest, in Elk and Flathead Valleys, the Kootenay formation is present and is overlain by beds correlated with the Blairmore group on the eastern side of the mountains (MacKenzie, 1916). These Lower Cretaceous formations lie without angular unconformity on the older rocks and are infolded with them, so that, in the south at least, Lower Cretaceous sediments spread across the present site of the Rocky Mountains.

Although the source of much of the Cretaceous sediments in the Canadian interior appears to have been west of the present Rocky Mountains, the actual boundaries of the upland area have never been established. Indeed they may have changed during Cretaceous time. In the south, the eastern boundary has been drawn at the western margin of the Rocky Mountain trench. The reasons for so placing it have been: in part the Cretaceous sediments in Elk Valley, the nearest to the trench, were quite coarse, indicating proximity to the source; no Cretaceous strata have been found in the Selkirk or Purcell Mountains and the old rocks outcropping there record a great deal of erosion; and igneous rocks present in the Selkirk Mountains represent a likely source for the feldspar in the feldspathic Cretaceous sandstones. The western boundary of the upland area lay east of the site of Ashcroft. Williams (1932) assumed the watershed between the eastern and western drainage to be on the site of the Arrow Lakes. To the north, or northwest, no definite boundaries have ever been set for the old landmass. On palaeogeographic maps it has been drawn west of the Rocky Mountains and west of what is inferred to be the northwestern extension of the Rocky Mountain trench. There has, however, been little evidence for this and the position or positions of the Cretaceous upland area there must await further studies in the field. In fixing this position it must be borne in mind that large areas of igneous rocks are required to supply the necessary feldspar for the Cretaceous sandstones laid down in the geosyncline to the east. It should also be considered whether the northern upland area was a continuation of the upland in the south or a separate diastrophic element, and whether any additions in breadth to it were made during Cretaceous time.

The eastern source, which seems to have supplied a smaller, but appreciable, amount of sediment, was probably a low-lying western part of the Canadian Shield.

Rocky Mountain Geosyncline

The site of Lower Cretaceous deposition is the Rocky Mountain geosyncline (as defined by Schuchert, 1923), a great area of subsidence lying east of the upland area or Cordilleran geanticline and extending, in later Cretaceous time, at least as far east as the Manitoba escarpment. A section drawn by Dowling (1915) shows how asymmetric the profile of the Rocky Mountain geosyncline is - the combination of a deep trough in the west on the site of the present Rocky Mountains and Foothills and a thick wedge, thinning to the east, on the site of the present Plains.

It may also be noted that in Lower Cretaceous time there appears to have been less, and therefore slower, subsidence in the south than in the north. It is thought that this was a large factor in preventing the confluence of the Lower Cretaceous northern and southern seas across northern Montana and southern Alberta. In Upper Cretaceous time, on the other hand, greater and more rapid subsidence on the site of the southern Canadian plains maintained seaway communication across this area with the southern sea, which had advanced north from the Gulf of Mexico.

PALAEOGEOGRAPHIC MAPS

Kootenay Time

Figure 2A is assumed to represent the period of deposition of the upper parts of the Kootenay and Nikanassin formations, and also of the upper part of the Dunlevy, but below the uppermost conglomerate-bearing part of that formation. It is a map of Barremian time in European chronology (See Figure 1). The sediments appear to have accumulated in a relatively narrow geosynclinal belt, in front of the newly uplifted Cordilleran geanticline, in Canada from the International Boundary to at least as far north as Sikanni Chief River.

The environment appears to have been that of an alluvial plain receiving sediment from numerous streams heading into the newly upraised mountains of the upland area. The sediments consisted of both sand and mud and on the average were coarser in the north. Coal-forming swamps were present at times, but were confined mostly to the south. Abundant plant remains were embedded in the sediments, particularly ferns, cycads, and conifers.

Lower Blairmore Time

In later Lower Cretaceous (Blairmore) time, the delineation of geographic features was very different from that which had prevailed earlier. The new features included seas in the north and alluvial plains in the south (See Figures 2B - 2E). The sediment deposited increased greatly in volume and spread farther to the east.

The 'new order' began with the deposition of the lower part of the Blairmore group and its correlatives, the Cadomin and Luscar, the top of the Dunlevy and all of the Gething, the McMurray, the beds in the Guardian well correlated with the Gething, and, if of Lower Blairmore age, some part of the varicoloured beds in southern Alberta and southern Saskatchewan. These deposits were not confined to a comparatively narrow belt in the west, as presumably the Kootenay deposits were, but extended out onto the site of the Plains (Figure 2B). In the north they may have extended as far east as the present lower Athabaska River. In the south they may have extended across part or all of southern Saskatchewan, if some part of the varicoloured beds are of Lower Blairmore age.

The environment appears to have been mainly that of an alluvial plain extending from the front of the mountains of the upland area eastwards across the present site of the Rocky Mountains, Foothills, and at least some of the site of the present Great Plains. Although it is not possible to infer all of the geographic features and varieties of environment on this alluvial plain, some isolated examples can be given where the local conditions can be adjudged from the nature of the beds and the enclosed fossils. Deposition began with a great inundation of gravel, which spread from the upland area over the western part of the alluvial plain as a fairly thick layer. It is recorded by the Cadomin conglomerate of earliest Blairmore time. Deposition was preceded in a few places by erosion of the underlying Kootenay or Nikanassin sediments, but only in rare instances was this erosion at all marked. Gravels were deposited at many levels in the extreme western part of the alluvial plain close to the mountains of that time. They are more rare and occur at fewer levels a little farther east, on the site of the Foothills, and finally disappear on the site of some part of the present Plains, the distances to which they extend to the east varying considerably. On the whole there is a decrease in grain size from west to east. At times coal swamps lay in the western part of the alluvial plain, but they were mostly absent in the southwest, which had been the site of coal swamps in Kootenay time. Calcareous beds in the southwest, carrying Unio and freshwater snails, probably record fairly persistent ponds or shallow lakes. Reddish and greenish shales in southern and southwestern Canada, if of this age, record well-drained and aerated soils, possibly related to reduced rainfall, but not to actual aridity or even semi-aridity. In the north and northwest grey and black shales are more common, recording a higher level of groundwater on the alluvial plain, due to lower slopes or increased precipitation. Thick zones of thin-bedded siltstone or fine sandstone and shale in the northwest - that is, on the site of contemporary northeastern British Columbia - record temporary, probably seasonal, shallow ponds and lakes that in dry seasons became mud flats; the siltstones have wave ripple-marks and the shales are mud-cracked (McLearn 1931a). It was across these flats that the dinosaurs walked and left their footprints (McLearn, 1922, 1931a; Sternberg, 1932). Some massive sandstones 25 feet or more thick and at least 2 miles long may record great floods and rapid aggradation. Forests may be inferred from fossil stumps, prostrate logs, fossil wood fragments, and roots. There are also fronds of cycads and ferns and conifer needles and finely comminuted plant debris. Dicotyledons, that is plants with "leaves", made their first appearance at this time, but their remains are extremely rare (McLearn, 1915, 1922, 1929; Berry 1929). The forest landscape, at least on the alluvial plains, was mostly dominated by the older kind of Mesozoic flora, by conifers, cycads, and ferns.

In spite of all this evidence of a non-marine, subaerial, alluvial plain environment, there is fragmentary evidence of temporary, brackish water or restricted marine conditions. Thus '*Astarte*' *natosini* and associated shells occur near the bottom of the Luscar formation and near the top of the McMurray formation. Russell (1932) even considers that the dominantly non-marine fauna described by him from the McMurray formation indicates, in part, estuarine conditions. Yarwood (1931a) records marine fish remains from the varicoloured beds of southern Alberta. The beds in the Guardian well correlated with the Gething contain glauconitic layers (Allan and Stelck, 1940). If the alluvial plain were flooded by the sea at any time, or times, it must have been for only short periods, so short that only fragmentary records are left. It might be assumed that such a sea would leave a more permanent record in some part of the western interior and, from analogy with succeeding stages, this record would most probably be left in the north, as, for example, on the site of the present Mackenzie Valley. Although this record has not been found, it is possible that further investigations will disclose the presence of Aptian (early Blairmore) deposits in the north.

Clearwater Time

The next stage is recorded by the Clearwater formation and its correlatives and is of early Albian time in the European chronology. The sediments now cover a very large area, as much as, if not more than, the area receiving the Lower Blairmore, Luscar, and Gething deposits. Marine deposits are definitely recognizable and occur in the north, recording a sea that invaded the geosyncline from the Arctic and extended at least as far south as the town of Athabaska and west at least as far as the site of the outer edge of the present Foothills (Figure 2C). In the south and southwest there was a marginal alluvial plain, or in places there may have been no deposition of sediment. It is possible, however, that at some time, or times, parts of this plain were flooded and that the Clearwater Sea then penetrated farther south than indicated.

The Clearwater Sea is recorded by the marine sediments of the Clearwater formation and basal Grand Rapids on lower Athabaska River, by the Loon River and lower sandstone member of the Peace River formation on lower Peace River, by the Moosebar and probably the Gates on west Peace River, the Moosebar and probably lower part of the Commotion formation on Pine River, by probably some lower part of the Buckinghorse formation on Buckinghorse and Sikanni Chief Rivers, possibly by some higher part of the Garbutt formation on Liard River, and by the as yet unnamed beds with *Beudanticeras affine* in lower Mackenzie River Valley and on Great Bear Lake. The southern alluvial plain is recorded by the non-marine sediments of some lower part of the Upper Blairmore, a part of the Mountain Park formation, and possibly some part of the varicoloured beds.

In the Clearwater Sea lived the *Beudanticeras affine* or *Lemuroceras* fauna. On the alluvial plains, new variety and beauty was added to the forest landscape, for the dicotyledons - including poplars, figtrees, magnolia, and sassafras - now appeared. The new forests must have looked very different from those of the older Lower Cretaceous, with their conifers, cycads, and ferns, and much more like those of the present day.

The sediments were mostly sands and mud in southern Alberta and Saskatchewan and muds on the site of northern Alberta and northeastern British Columbia.

Cadotte Time

The Gastroplites or Cadotte Sea is recorded by the sediments of the Cadotte member of the Peace River formation and its correlatives. The time is mid-Albian in the European chronology (See Figure 1). The palaeogeographic pattern is much like that of the Clearwater map. A sea lay in the north and extended far to the west. A marginal alluvial or delta plain lay in the south. The sea, however, had now receded a little to the north and the Grand Rapids delta plain had advanced in the same direction (Figure 2D).

The sea of this time is recorded by the sediments of the Cadotte member of the Peace River formation on the lower Peace River, by the upper part of the Commotion and possibly the basal part of the Hasler formation on Pine River, by the lower part of the Hasler on Peace River, by probably the upper part of the Buckinghorse on Buckinghorse and Sikanni Chief Rivers, by the Scatter and lower part of the Lepine on Liard River, and by unnamed beds near San Sault Rapids in the northern part of Mackenzie Valley. The alluvial or delta plain is recorded by the upper part of the Grand Rapids formation on lower Athabaska River, by the southern and non-marine phase of the Cadotte member on Peace River, by beds correlated with the Commotion at Monkman Pass, at times possibly by parts of the Commotion on Pine River, by part of the Mountain Park formation in the Mountain Park area, by part of the Upper Blairmore in southwestern Alberta, and possibly by some part of the varicoloured beds in southern Alberta and southern Saskatchewan.

In central Alberta and in northeastern British Columbia, between Monkman Pass and Peace River, and from south to north, the beds of this time tend to change from non-marine and from coarse to fine grain. As usual in Cretaceous deposits of our interior the non-marine deposits tended towards sand and mud in composition and the marine towards mud only. In the Monkman Pass area, beds correlated with the Commotion contain no marine shells, but a few plants are present and the environment may have been largely, if not entirely, non-marine. To the northwest, in Pine Valley, the Commotion contains some marine fossils as well as plants, and is at least partly marine. To the north, in the lower part of Peace River Canyon, what appears to be only a remnant of the sandstones of this formation remains as the at least partly marine Gates formation. The conglomerates and sandstones of the upper part of the Commotion appear to pass over into the shale of the lower part of the Hasler formation. Thus what was partly, if not entirely, non-marine in Monkman Pass area changes over into marine beds on the site of Peace River Canyon and the conglomerate and sandstone are mostly replaced by shale, with the exception of the lower part where sandstone persists. Farther east, near the town of Peace River, the Cadotte member of the Peace River formation consists of massive sandstone with a coal seam, indicating probably non-marine deposition. Not far north, near the mouth of Cadotte River, this massive sandstone passes over into thin-bedded very fine sandstone and shale with marine fossils (McLearn, 1918). The old front of the marginal alluvial plain must at one time have lain between the site of the town of Peace River and the mouth of Cadotte River. The massive sandstone of the upper part of the Grand Rapids formation on lower Athabaska River contains coaly beds and rootlets and records non-marine conditions in part at least. The Gastroplites or Cadotte Sea lay north of the outcrops of the Grand Rapids formation.

Shaftesbury Time

The sea shown on the Shaftesbury map is recorded by the 'dark grey shale' with Haplophragmoides gigas in southern Saskatchewan, a part of the 'Pelican Shale' on lower Athabaska River, probably some part of the Ashville formation on the Manitoba escarpment, some lower or middle part of the Shaftesbury formation in lower Peace River, some higher part of the Hasler or some part of the Goodrich in the Foothills of Peace and Pine Rivers, some part of the marine sandstones or shales of the Sikanni formation, and some part of the shales of the Lepine on Liard River. There may not have been any deposition in southern Alberta at this time.

The geographic outlines still partly followed the Lower Cretaceous pattern: a sea lay in the north and extended far to the west, but does not extend into southern Alberta (Figure 2E). Other outlines, however, anticipate the Upper Cretaceous pattern: for on the site of southern Saskatchewan the sea extended at least as far south as the International Boundary and probably as far east as the present Manitoba escarpment. It is not positively known whether or not this sea united with the sea of southern origin in the southern United States interior. If it did it was not for long; otherwise the fauna would show a greater resemblance to the southern faunas.

SEQUENCE OF PALAEOGEOGRAPHIC PATTERNS

A review of the foregoing paragraphs shows that the geographic pattern of the earlier Lower Cretaceous in the western interior differed considerably from that of the later Lower Cretaceous. It is true that the major physiographic setting was the same: a long belt of mountains, lofty at times, lay to the west; a great plain, not far above sea-level, stretched far to the east; rivers heading into the mountains debouched on the plain, where they deposited their load of sediment. Minor shiftings in the setting, however, produced somewhat different environments. In early Lower Cretaceous time aggradation appears to have been mostly confined to a comparatively narrow belt in front and to the east of the mountains of that time. No interior sea is as yet known. The monotony of the geographic pattern was unrelieved except where coal swamps formed in the south. The later Lower Cretaceous scene not only differed geographically from that in earlier Cretaceous time but offered greater variety. Aggradation spread widely over the plains of the western interior and seas appeared in the north. The shifting of the shoreline between sea and marginal alluvial plain added variety from stage to stage, so that we can draw up four palaeogeographic maps each of different pattern, for the later half, whereas one map suffices to define the one monotonous pattern of the earlier Lower Cretaceous.

Thus we can recognize a sequence of Cretaceous palaeogeographic patterns in the Canadian western interior, on the site of the Rocky Mountain geosyncline: in the earlier Lower Cretaceous a narrow alluvial plain in the west, but no seas; in the later Lower Cretaceous, marginal alluvial plains in the south, seas of boreal origin in the north; in the Upper Cretaceous, marginal alluvial plains in the west, gulf or gulf-boreal seas in the east. One of the latest Lower Cretaceous patterns, that of the Shaftesbury Sea, is transitional between those of the Lower and Upper Cretaceous.

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