Digitized by the Internet Archive
in 2011 with funding from
University of Toronto

LORIS S. RUSSELL

LIBRARY
 ROYAL ONTARIO MUSEUM
 UNIVERSITY OF TORONTO
 100 QUEEN'S PARK
 TORONTO 5 - ONTARIO - CANADA

*Cretaceous Non-marine
 Faunas of Northwestern
 North America*

ROYAL ONTARIO MUSEUM - UNIVERSITY OF TORONTO

ROYAL ONTARIO MUSEUM LIBRARIES

3 1761 05013 6746

ROM

Contribution No. 61

LIFE SCIENCES

ROYAL ONTARIO MUSEUM

UNIVERSITY OF TORONTO

LORIS S. RUSSELL *Cretaceous Non-marine
Faunas of Northwestern
North America*

LORIS S. RUSSELL is Chief Biologist, Royal Ontario Museum, University of Toronto.

PRICE: 75 cents

© The Governors of the University of Toronto, 1964

PRINTED AT THE UNIVERSITY OF TORONTO PRESS

INTRODUCTION

In the northwestern plains and adjacent foothills of the United States and Canada, particularly in Montana and Alberta, the Cretaceous sequence is characterized by an alternation of marine and non-marine deposits. This condition has resulted from fluctuating shore lines in the Cretaceous interior seas. In the case of the marine formations, the invertebrate faunas permit a reasonably good correlation with the standard scale of western Europe, and the stage names of that region can be applied here with some success. For the non-marine deposits the position in the time scale has to be inferred from the relationships with the marine formations, a less accurate basis for correlation.

It is the purpose of the present account to consider the Cretaceous non-marine formations of the northwestern interior of North America, and their contained faunas, and to propose a local sequence of stages based on these parts of the succession. Such a system has been of great value in the study of the continental Tertiary of North America, based almost exclusively on mammalian faunas. In the present study the stages will be established on the basis of their molluscan as well as their vertebrate faunas. Subjacent and superjacent marine faunas permit a somewhat better correlation with the European standard scale than is possible for the non-marine faunas of the North American Tertiary.

BLAIRMORE FORMATION

The oldest non-marine Cretaceous rocks of the region under consideration occur in southwestern Alberta and western Montana. The Alberta development is best known from the Crowsnest Pass area (McLearn, 1929A). The lowest Cretaceous formation here is called the Kootenay, which does not correspond precisely to the Kootenai of Montana (see below). The Kootenay formation of the Crowsnest Pass consists of about 200 metres of sandstone and shale, with coal seams and abundant plant fossils. No animal fossils have been found except some very large ammonites in the basal beds. These fossils indicate that the lowest portion of the Kootenay is of Late Jurassic age. The Kootenay is overlain by a thick bed of conglomerate, which is the basal part of the Blairmore formation. Above this are some 600 metres of sandstone and shale, without coal seams. In addition to important floras that include angiosperms in the upper part, the Blairmore has yielded fresh-water mollusks (McLearn, 1929B), the revised identification of which follows.

Fresh-water molluscan fauna of the Blairmore formation

Pelecypoda

Eupera onestae (McLearn)

Corbula? *palliseri* McLearn

Protelliptio douglassi (Stanton)

P. hamili (McLearn)

Tritigonia natosini (McLearn)

Gastropoda

Campeloma? sp.

Planorbis? sp.

Fossil vertebrates have not yet been obtained from the Blairmore formation. Some years ago a small dinosaur foot skeleton was discovered in supposed Blairmore beds (Gilmore, 1924), but later studies revealed that the specimen was from Upper Cretaceous rocks (Russell, 1949).

KOOTENAI FORMATION

The history of this name has to be considered in dealing with the formations to which it has been applied. The name Kootanie series was proposed by G. M. Dawson (1886, pp. 162–165) for plant-bearing rocks in the Crowsnest Pass area of southwestern Alberta. Upper and lower limits of the series were poorly defined. For this reason Dawson's concept has been interpreted differently in Canada and in the United States. The Canadian Kootenay formation, as redefined by Leach (1912), has been briefly described above. The term Kootenai formation was introduced in Montana by Fisher (1909) for coal-bearing rocks below the Colorado shale in the Great Falls area. The Kootenai of western Montana is approximately the equivalent of Kootenay plus Blairmore in the Crowsnest Pass area of Alberta.

In south-central and southeastern Montana the rocks to which the name Kootenai has been applied are different from those of western Montana and southwestern Alberta. In the former region the predominant materials are soft, clayey sandstone and clay, ranging in colour from bright maroon to nearly white. The basal portion consists of massive sandstone, frequently conglomeratic. Platy sandstones occur at or near the top. Significant coal seams are absent. In this region the thickness of the formation is about 100 metres. Very similar rocks are known in the Bighorn Mountains of Wyoming, under the name Cloverly formation (Darton, 1904). In view of the varying usages of Kootanie, Kootenay and Kootenai, it would seem desirable to extend the use of the name Cloverly to those Lower Cretaceous rocks of south-central and southeastern Montana that resemble the type Cloverly of Wyoming, and to restrict the use of Kootenai to the more westerly development, predominantly hard sandstone and shale, with coal seams.

The Kootenai/Cloverly beds have yielded dinosaur bones and supposed gastroliths at a number of localities. A good series of skeletons was collected from the Crow Indian Reservation south of Hardin, Montana, by Barnum Brown. This fauna has not been fully described as yet, but the predominant genus is known to be the small ornithomimid *Camptosaurus*, which also occurs in the Upper Jurassic. Identifiable dinosaur remains have also been obtained from the Musselshell River valley near Harlowton. This area has also yielded a rich fauna of fresh-water mollusks from the "Kootenai" beds, mostly from one locality southwest of Winnicook, where the Lower Cretaceous rocks have been brought to the surface in a well-defined dome. This locality was discovered by A. C. Silberling, and the

fauna has been described by Stanton (1903) and Yen (1951). The following list is based on that of Yen, with some modifications to conform to the present author's ideas of relationships.

Fresh-water molluscan fauna of the Cloverly formation of Montana

Pelecypoda

- Eupera onestae* (McLearn)
- Protelliptio douglassi* (Stanton)
- Tritigonia natosini* (McLearn)
- Lampsilis farri* (Stanton)

Gastropoda

- Mesoneritina nebrascensis* (Meek and Hayden)
- Reesidella montanaensis* (Stanton)
- Stantonogyra silberlingi* (Stanton)
- Mesochilina cretacea* Yen
- Campeloma harlowtonensis* Stanton
- Circamelania ortmanni* (Stanton)
- Physa montanensis* Yen
- Gyraulus* cf. *veternus* (Meek and Hayden)
- Carinulorbis* sp.

The shells of *Tritigonia natosini** do not occur in the same bed as the remainder of the fauna, but in an indurated bed about one-quarter mile to the west. The presence of *Tritigonia natosini*, *Protelliptio douglassi* and *Eupera onestae* in the Blairmore formation of Alberta indicates that the mollusk-bearing portion of the Blairmore is of about the same age as the Cloverly of south-central Montana. What this age is in terms of the European standard section cannot be determined precisely as yet. The stratigraphical relationships of the molluscan fauna to the floras of the Kootenay-Blairmore sequence suggests that the fauna is rather high in the Lower Cretaceous, and not older than Aptian, possibly as young as Albian.

MC MURRAY FORMATION

The Cretaceous section in northeastern Alberta (McLearn, 1917) begins with a non-marine unit known as the McMurray formation, or more popularly, the Alberta tar sands. The sediments consist almost entirely of quartz sand, held together by a bituminous cement. Maximum thickness of the formation is about 60 metres. The base rests upon eroded Devonian rocks, and the top passes conformably into the marine Clearwater formation (Mellon and Wall, 1956), which contains a Middle Albian ammonite fauna. The McMurray may therefore be dated as Early or Middle Albian. In places the McMurray sands contain a wealth of fossil shells, which can be freed from the tarry matrix with appropriate solvents. This fauna was described some years ago (Russell, 1938), and a revised list follows.

*The systematic position of *Unio natosini* McLearn will be discussed in a forthcoming paper on fossil Unionidae.

Fresh-water molluscan fauna of the McMurray formation

Pelecypoda

Protelliptio biornatus (Russell)

Murraia naiadiformis Russell

Gastropoda

Viviparus murrei Russell

Lioplacodes bituminis Russell

Goniobasis? multicarinata Russell

Melania multorbis Russell

Melampoides athabaskensis (Russell)

The differences between the McMurray molluscan fauna and that of the Cloverly and Blairmore could be the result of geographical separation, but it is more likely that some age difference is involved. If so, the Cloverly/Blairmore fauna is probably the older.

DUNVEGAN FORMATION

Sandstones and shales in irregular alternation make up the Dunvegan formation of northwestern Alberta and northeastern British Columbia. Good exposures occur on Peace and Smoky Rivers in Alberta, along Pouce Coupé River on the Inter-provincial Boundary, and on Pine River in British Columbia. The formation is about 160 metres thick in its eastern development, and thickens to the west. It rests on the Shaftesbury shale of the Fort St. John group, which is probably late Albian in age, and is overlain by the Kaskapau shale of the Smoky River group, mainly Turonian, but Cenomanian in its lowest part (Warren and Stelck, 1955). The age of the Dunvegan formation is probably Cenomanian.

The fossils of the Dunvegan formation are mostly marine and brackish water pelecypods, predominantly species of *Inoceramus*. In places, however, fresh-water forms occur, and the formation is evidently a large-scale deltaic accumulation, in which estuarine and fluvial conditions alternated. The non-marine mollusks recognized to date are as follows.

Non-marine molluscan fauna of the Dunvegan formation

Pelecypoda

Protelliptio sulfuriensis (McLearn)

Pleurobema? dowlingi (McLearn)

Gastropoda

Melampoides caurinus (McLearn)

Vertebrate remains from the Dunvegan formation consist as yet of obscure bone fragments, presumably dinosaurian. It is hoped that future work will make known a vertebrate fauna from this formation, as little is known of the vertebrates in the basal part of the Upper Cretaceous.

EAGLE/MILK RIVER FORMATION

Above the Dunvegan formation, or farther south, above the Blairmore and equivalents, there is a thick series of marine strata variously designated as

Colorado, Alberta, Smoky River, etc., covering a time span from Cenomanian to early Santonian. These beds, mostly dark shales, grade upward into sandstones of predominantly non-marine deposition. In the western plains of Montana these sandstones make up the Eagle formation, which is divisible into a lower, massive sandstone, called Virgelle, and an upper portion of clayey sandstones and sandy shales, with thin coal seams. Irregular massive sandstones occur near the top. Total thickness of the formation is in the order of 100 metres. In southern Alberta the same formation is recognized under the name Milk River. The lower part of the Virgelle carries the Telegraph Creek marine fauna, of early Santonian age, but fossils in the Upper Eagle and Upper Milk River are mostly non-marine. However, the invertebrates listed by Stanton and Hatcher (1905, p. 12) from the Upper Eagle on Missouri River are all marine forms and closely related to members of the overlying Claggett fauna. Vertebrate fossils were also recorded from this area, including the type of a large theropod dinosaur, "*Ornithomimus*" *grandis* Marsh. In Alberta the Upper Milk River beds carry vertebrate fossils, which are not well enough preserved to indicate more than genus or family. The following have been recorded (Russell, 1935).

Vertebrate fauna of the Upper Milk River beds

Chondrichthyes

Myledaphus sp.

Actinopterygii

Lepidosteus sp.

Reptilia

Basilemys sp.

Compsemys sp.

Aspideretes? sp.

Lacertilia

Crocodylia

Deinodontidae

Ornithomimidae

Stegoceras sp.*

Hadrosauridae, cf. *Kritosaurus* sp.

Ceratopsidae, cf. *Brachyceratops* sp.

Nodosauridae, cf. *Palaeoscincus* sp.

This fauna suggests that of the overlying Oldman formation, but there are important differences not obvious in a faunal list, which indicate that if better known the assemblage would be distinctive. As the Alberta exposures have been well prospected, it is likely that any future discoveries will be made in Montana. The Upper Milk River beds of Alberta have also yielded a few well preserved fresh-water mollusks, which have been named as follows.

*Found by a Royal Ontario Museum expedition in 1949.

Fresh-water molluscan fauna of the Upper Milk River beds

Pelecypoda

Rhabdotophorus gracilis Russell

Anodonta johnseni Russell

Gastropoda

Viviparus conradi (Meek and Hayden)

Physa lacteana Russell

As in the case of the vertebrates, this assemblage has suggestions of the fauna of the Oldman formation, but it is mostly distinctive, and has not been recognized as a unit elsewhere.

JUDITH RIVER FORMATION AND EQUIVALENTS

Fossil vertebrates and fresh-water mollusks were obtained from the Judith River formation along Missouri River in Montana by F. V. Hayden in 1855 and by E. D. Cope in 1876. The real stratigraphical position of the formation was not understood until after the studies of Stanton and Hatcher (1905). The Judith River formation is the next non-marine unit above the Eagle formation, and is separated from the latter by the marine Claggett formation.

The Judith River formation of the type area, the Missouri River valley south of the Bearpaw Mountains, consists of light-coloured clayey sandstones and brown and grey shales. Coal seams occur at various levels, but especially near the top. The thickness in this area is about 160 metres. In the lower part and at the top of the formation there are brackish water and even marine fossils, but the predominant faunas are non-marine. The following lists of mollusks is based upon that of Stanton (op. cit.), with some changes in generic reference.

Non-marine molluscan fauna of the Judith River formation

Pelecypoda

Anodonta propatoris White

Plesiellptio subspatulatus (Meek and Hayden)

P. abbreviatus (Stanton)

Rhabdotophorus senectus (White)

Fusconaia? danae (Meek and Hayden)

Quadrula? primaevus (White)

Q.? supenawensis (Stanton)

Sphaerium planum Meek and Hayden

S. recticardinale Meek and Hayden

Valvata montanensis Meek

Viviparus conradi (Meek and Hayden)

Lioplacodes vetula (Meek and Hayden)

L. judithensis (Stanton)

Hydrobia subconica Meek

Goniobasis sublaevus (Meek and Hayden)

G. invenusta (Meek and Hayden)

G. gracilenta Meek
G.? omitta (Meek and Hayden)
G.? subtortuosa (Meek and Hayden)
Menetus amplexus (Meek and Hayden)
Physa copei White
Aplexa subelongata (Meek and Hayden)
A. atava (White)
Vitrina obliqua Meek and Hayden

The vertebrate fauna of the Judith River formation is known mostly from incomplete or fragmentary specimens collected under pioneer conditions. On the basis of knowledge gained from the much better preserved vertebrates of contemporary formations we have to regard many of the species and even some of the genera described from Judith River specimens as undeterminable. Even further collecting in the Judith River beds, while most desirable, probably would not help to establish these genera and species on a firm basis. The last comprehensive list of Judith River vertebrates was that given by Hatcher (Stanton and Hatcher, 1905). This was accompanied by critical annotations, many of which have been proven incorrect by later discoveries. Hatcher also included the forms described by Lambe (1902) from Alberta; these are here listed separately under the Oldman formation. A revised list of the Judith River vertebrates would be somewhat as follows, but this must be understood to include species based on such inadequate material that they cannot be defined below the family level.

Vertebrate fauna of the Judith River formation

Chondrichthyes

Myledaphus bipartitus Cope

Dipnoi

Ceratodus eruciferus Cope

C. hieroglyphus Cope

Actinopterygii

Lepidosteus occidentalis (Leidy)

L. haydeni Cope

Hedronchus sternbergii Cope

Amphibia

Scapherpeton tectum Cope

S. laticolle Cope

S. excisum Cope

S. favosum Cope

Hemitrypus jordanianus Cope

Reptilia

Polythorax missouriensis Cope

Basilemus variolosa (Cope)

B. imbricaria (Cope)

Plastomenus costatus Cope

Aspideretes foveatus (Leidy)

Uronaites cetiformis Cope
Ischyrotherium cf. *antiquum* Leidy
Champsosaurus annectens Cope
C. profundus Cope
Crocodylus? *humilis* Leidy
Troödon formosus Leidy
Deinodon horridus Leidy
D. explanatus (Cope)
Ornithomimus? *tenuis* Marsh
Trachodon mirabilis Leidy
Pteropelyx grallipes Cope
Monoclonius crassus Cope
M.? *sphenocerus* Cope
Ceratops montanus Marsh
C.? *recurvicornis* (Cope)
Palaeoscincus costatus Leidy

About 100 miles northwest of the Judith River badlands lies the valley of Milk River in the southern edge of Alberta. Here, and along the South Saskatchewan and Red Deer Rivers farther north, the equivalents of the Judith River formation are extensively exposed. These are divided by Canadian geologists into two formations, a lower Foremost and an upper Oldman. The Foremost is a sombre-coloured formation, with numerous coal seams. The fauna is predominantly brackish water in habitat, and includes thick accumulations of *Ostrea glabra* Meek and Hayden, but some fresh-water mollusks do occur. A representative list of these has been given by Russell (1940) and is repeated here with slight change.

Fresh-water molluscan fauna of the Foremost formation

Pelecypoda

Plesiellptio priscus (Meek and Hayden)
P. abbreviatus (Stanton)
P. supragibbosus (Whiteaves)
Rhabdotophorus senectus (White)
Fusconaia? *danae* (Meek and Hayden)
F.? *cryptorhynchus* (White)
Quadrula? *subprimaevus* (Dyer)
Proparreisys mclearni (Dyer)
Sphaerium recticardinale Meek and Hayden

Gastropoda

Viviparus conradi (Meek and Hayden)
V. nidaga Dyer
Lioplacodes vetula (Meek and Hayden)
L. praecursa (Dyer)
Goniobasis williamsi Dyer
G.? *subtortuosa* (Meek and Hayden)
Menetus? *paucivolvis* (Whiteaves)
Physa canadensis Whiteaves

Some vertebrate material occurs in the Foremost formation, but it is too fragmentary to be identified below the family level.

The overlying Oldman formation, corresponding to the upper part of the Judith River formation, is predominantly of fresh-water deposition. Coal seams are restricted to the top, as are such brackish water mollusks as are present. The characteristic rock is a pale grey clayey sandstone, interbedded with grey and brown shales. Lenticular beds of hard, calcareous sandstone occur. The formation is exposed in extensive badlands along Milk River and to the north, along Saskatchewan River and particularly on Red Deer River. A representative list of non-marine mollusks of the Oldman formation was given by Russell (1940) and is repeated here with minor changes.

Non-marine molluscan fauna of the Oldman formation

Pelecypoda

- Anodonta propatoris* White
- Rhabdotophorus senectus* (White)
- Quadrula? primaevus* (White)
- Pleurobema? humei* (Dyer)
- Lampsilis? consueta* (Whiteaves)
- Sphaerium recticardinale* Meek and Hayden
- Corbula confiniensis* Russell

Gastropoda

- Viviparus nidaga* Dyer
- Lioplacodes praecursa* (Dyer)
- L. judithensis* (Stanton)
- Micropyrgus higdoni* (Russell)
- Goniobasis sublaevus* (Meek and Hayden)
- G. gracilenta* (Meek and Hayden)
- Physa canadensis* Whiteaves
- Polygyra venerabilis* Russell
- Prograngerella sperata* Russell

The known vertebrate fauna of the Oldman formation is large, mostly as a result of discoveries made in the badlands of Red Deer River, in east-central Alberta. Significant specimens have also been obtained in south-eastern Alberta, in the Comrey district. The following is a composite list, based on the collections from both areas.

Vertebrate fauna of the Oldman formation

Chondrichthyes

- Myledaphus bipartitus* Cope

Dipnoi

- Ceratodus eruciferus* Cope

Actinopterygii

- Acipenser albertensis* Lambe
- Lepidosteus occidentalis* (Leidy)
- Diphyodus longirostris* Lambe

Amphibia

Scapherpeton tectum Cope

Reptilia

Baëna pulchra Lambe

B. antiqua Lambe

B. fluviatilis Parks

Boremys albertensis Gilmore

Neurankylus eximius Lambe

Basilemys variolosa (Cope)

Adocus? lineolatus Cope

Aspideretes foveatus (Leidy)

A. maturus Lambe

A. latus Gilmore

A. rugosus Parks

A. allani Gilmore

?*Cimoliasaurus magnus* Leidy

Champsosaurus natator Parks

C. inelegans Parks

C. inflatus Parks

Palaeosaniwa canadensis Gilmore

Leidyosuchus canadensis Lambe

Troödon formosus Leidy

T. brevis Lambe

Gorgosaurus libratus Lambe

G. sternbergii Matthew and Brown

Dromaeosaurus albertensis Matthew and Brown

Chirostenotes pergracilis Gilmore

Macrophalangia canadensis Sternberg

Struthiomimus altus (Lambe)

S. samueli Parks

S. elegans Parks

Kritosaurus? marginatus (Lambe)

K. notabilis (Lambe)

K. incurvimanus Parks

Brachylophosaurus canadensis Sternberg

Prosaurolophus maximus Brown

Lambeosaurus lambei Parks

L. clavinitialis Sternberg

L. magnicristatus Sternberg

Corythosaurus casuarius Brown

C. excavatus Gilmore

C. intermedius Parks

Tetragonosaurus praeceps Parks

T. erectifrons Parks

T. cranibrevis Sternberg

Parasaurolophus osborni Parks

Stegoceras validus Lambe

S. brevis Lambe

S. lambei Sternberg
Eoceratops canadensis Lambe
Brachyceratops? dawsoni (Lambe)
Chasmosaurus belli Lambe
C. kaiseni Lull
C. russelli Sternberg
Monoclonius lowei Sternberg
M.? nasicornus Brown
M.? cutleri Brown
Centrosaurus apertus Lambe
C. longirostris Sternberg
Styracosaurus albertensis Lambe
Palaeoscincus costatus Leidy
P. asper Lambe
Edmontonia rugosidens (Gilmore)
Panoplosaurus mirus Lambe
Euoplocephalus tutus (Lambe)
Dyoplosaurus acutosquameus Parks

Aves

Caenognathus collinsi R. M. Sternberg

Mammalia

Cimolomys primaevus (Lambe)
C. major Russell
Eodelphis cutleri (Woodward)
Delphodon? praesagus Russell

It is quite clear from the stratigraphical evidence that the Oldman formation is the equivalent of the upper part of the Judith River formation. However, a comparison of the two faunal lists of vertebrates from these formations does not suggest close similarity. The resemblance is probably much greater than appears, the differences being largely a matter of nomenclature. The vertebrates from the Oldman formation, known in most cases from excellent skeletons, cannot be closely compared with those of the Judith River, represented by isolated teeth or bones. It is probable but incapable of proof that *Gorgosaurus* is *Deinodon*, *Ornithomimus? tenuis* is a species of *Struthiomimus*, *Corythosaurus* or *Lambeosaurus* is *Trachodon*, and *Centrosaurus* is *Ceratops*.

In northwestern Montana the marine Claggett formation is replaced by non-marine strata and the series Upper Eagle to Judith River is represented by a continental sequence which is not readily divisible, and which is known as the Two Medicine formation. From the upper part of this formation, in beds corresponding to the Oldman formation of Alberta, a small vertebrate fauna has been obtained (Gilmore, 1917). The published list requires revision in the light of more recent discoveries. The best known member of the fauna is the small ceratopsian *Brachyceratops montanensis* Gilmore. It is possible that this is based on immature individuals of *Monoclonius* sp. In any case, the age of the Two Medicine formation is not in doubt.

Analogous to the Two Medicine formation is the Wapiti formation of

northwestern Alberta. This overlies marine shales of early Santonian age and may include in its upper part beds that are younger than Judith River. A few vertebrate remains have been found in the Wapiti formation, including the lizard *Chamops*, cf. *segnis* Marsh (Sternberg, 1951B).

EDMONTON FORMATION AND EQUIVALENTS

From Montana to central Alberta the Judith River equivalents are overlain by marine shales to which the name Bearpaw formation is generally applied. Stratigraphical evidence shows clearly that the top of this marine formation is progressively younger from northwest to southeast; in other words, the retreat of the Bearpaw sea in that direction was slow and oscillatory. The post-Bearpaw non-marine deposits on the north and west are therefore older in their lower part than those farther south and east. From a palaeontological viewpoint the most important of these post-Bearpaw formations is the Edmonton formation of central Alberta. Lithologically this resembles both the Foremost and Oldman formations, consisting of light grey and brown clayey sandstones and shales, with numerous coal seams. Massive sandstone lenses occur at various levels. Brackish water fossils are present in the basal beds and at about the middle of the formation. In the upper part there is a zone of white and grey clays, with a persistent tuff bed at the top (Kneehills tuff). Beds above the tuff are distinguished as Upper Edmonton, and their fauna will be discussed in a subsequent section. The Edmonton formation is best exposed in the valley of Red Deer River from Drumheller northward. It also appears on Bow River and farther south, where it merges into the St. Mary River formation, as discussed below.

Fresh-water mollusks occur in the Edmonton formation, often associated with brackish water species. The following list is that published by Tozer (1956, p. 15), with slight modifications.

Fresh-water molluscan fauna of the Edmonton formation

Pelecypoda

- Fusconaia? stantoni* (White)
- Lampsilis? sandersoni* (Warren)
- Sphaerium heskethense* Warren

Gastropoda

- Viviparus prudentius* White
- V. tasgina* Dyer
- V. westoni* Tozer
- Campeloma edmontonensis* Tozer
- Liplacodes tenuis* (Warren)
- L. sanctamariensis* (Russell)
- L. whiteavesi* (Russell)
- Goniobasis webbi* Dyer
- Valvata filosa* Whiteaves
- Pleurolimnaea mclearnii* Tozer

This molluscan fauna has little in common with that of the Judith River

formation and equivalents. The vertebrate fauna of the Edmonton formation is second only to that of the Oldman formation in wealth of genera and species, particularly of the dinosaurs.

Vertebrate fauna of the lower and middle parts of the Edmonton formation

Chondrichthyes

Myledaphus sp.

Lamna sp.

Actinopterygii

Acipenser sp.

Lepidosteus sp.

Diphyodus longirostris Lambe

Reptilia

Basilemys sp.

Aspideretes sp.

Leurospondylus ultimus Brown

Champsosaurus albertensis Parks

Leidyosuchus? sp.

Albertosaurus sarcophagus Osborn

A. arctunguis Parks

Struthiomimus brevitertius Parks

S. currellii Parks

S. ingens Parks

Ornithomimus edmontonensis Sternberg

Anatosaurus edmontoni (Gilmore)

Edmontosaurus regalis Lambe

Saurolophus osborni Brown

Hypacrosaurus altispinus Brown

Cheneosaurus tolmanensis Lambe

Parksosaurus warreni (Parks)

Stegoceras sp.

Anchiceratops ornatus Brown

A. longirostris Sternberg

Arrhinoceratops brachyops Parks

Edmontonia longiceps Sternberg

Anodontosaurus lambei Sternberg

As the Edmonton beds are traced southward from Bow River they are seen to merge into the formations of southwestern Alberta. Tozer (1956) has shown that the white clay and the Kneehills tuff occur at the top of the St. Mary River formation, so that this may be regarded as the equivalent of the Lower and Middle Edmonton, while the Upper or Lance equivalent passes into the lower part of the Willow Creek formation. The St. Mary River beds consist mainly of hard, calcareous sandstone, interbedded with friable grey and green shale. They are very different lithologically from the typical Edmonton beds. Briackish water fossils occur only at the base, but there is a large fauna of non-marine mollusks scattered throughout the formation. Tozer's (1956, p. 10) list is approximately as follows.

Non-marine molluscan fauna of the St. Mary River formation

Pelecypoda

- Fusconaia? stantoni* (White)
- Sphaerium heskethense* Warren
- S. livingstonensis* Russell
- S. gietzi* Tozer
- Pisidium squamula* Russell

Gastropoda

- Dimorphoptychia mokowanensis* Tozer
- Reesidella* cf. *protea* (Yen)
- Valvata filosa* Whiteaves
- Viviparus westoni* Tozer
- Campeloma edmontonensis* Tozer
- Lioplacodes tenuis* (Warren)
- L. sanctamariensis* (Russell)
- L. whiteavesi* (Russell)
- Goniobasis webbi* Dyer
- Pleurolimnaea mclearnii* Tozer
- Physa canadensis* Whiteaves
- Oreohelix? obtusata* (Whiteaves)
- O. angulifera* (Whiteaves)
- Polygyra parvula* (Whiteaves)
- Holospira dyeri* Tozer

This fauna, while more varied, and including some terrestrial genera, is essentially the same as that of the Edmonton formation.

Fossil bones are widespread in the St. Mary River formation, but seldom are well enough preserved for specific identification. From north-western Montana the incomplete skeleton of a small ceratopsian was described as *Leptoceratops cerorhynchus* Brown and Schlaikjer (1942). C. M. Sternberg (1951A) has produced evidence to show that this species differs markedly from the typical *Leptoceratops*, and has proposed for it the generic name *Montanoceratops*. Near Cardston, in Alberta, a large number of hadrosaur bones have been found in St. Mary River beds. At Scabby Butte, east of Nobleford, the lower St. Mary River beds are exposed in a small area of badlands, but the lithology is more like that of the Edmonton formation. From a small but rich bone bed, several incomplete skulls of the peculiar ceratopsian *Pachyrhinosaurus canadensis* Sternberg have been collected, as well as much other dinosaurian material now under study. Nearby some isolated mammalian teeth have been found, apparently representing placental orders (Russell, 1962). A tooth of the multituberculate *Cimolomys* has been found in St. Mary River beds in the foothills farther west.

The distinctive molluscan and vertebrate faunas of the Edmonton and St. Mary River formations do not occur to the east and south, where, as explained previously, the non-marine deposits are replaced by those of brackish water and marine origin. These equivalents make up an upper part of the Bearpaw formation and the Fox Hills formation of central and

eastern Montana. Going farther afield, the dinosaur fauna of the Mesaverde formation of southern Wyoming is analogous to that of the Edmonton formation, while the vertebrates of the Kirtland, Fruitland and Ojo Alamo formations of northeastern New Mexico have resemblances to both the Edmonton and the Oldman fauna.

LANCE EQUIVALENTS

The typical Lance formation of eastern Wyoming is somewhat outside the region here under discussion, but it contains a characteristic vertebrate fauna that is recognizable over a wide area. In eastern Montana this fauna occurs in the Hell Creek formation, which overlies the Fox Hills formation of brackish water deposition. The Hell Creek beds are composed of grey and brown sandstones and shales, without coal seams. In the Missouri River valley the formation has yielded such characteristic Lance dinosaurs as *Tyrannosaurus rex* Osborn, *Anatosaurus annectens* (Marsh), *Triceratops serratus* Marsh, *Triceratops maximus* Brown, and *Ankylosaurus magniventris* Brown. Also in this area Brown discovered a remarkable fauna of fresh-water pelecypods, which were described by Whitfield (1903, 1907). These were said to be from the Laramie group, 37 and 120 metres above the Pierre shale. In modern stratigraphical terminology this would be well within the Hell Creek formation.

Fresh-water molluscan fauna of the Hell Creek formation

Pelecypoda

- Quadrula cylindricoides* (Whitfield)
- Fusconaia? danae* (Meek and Hayden)
- F.? gibbosoides* (Whitfield)
- Pleurobema? cryptorhynchus* (White)
- Plethobasis aesopiformis* (Whitfield)
- Rhabdotophorus aldrichi* (White)
- Proparresysia holmesiana* (White)
- P. barnumi* Pilsbry
- P. verrucosiformis* (Whitfield)
- P. retusoides* (Whitfield)
- P. percorrugata* (Whitfield)
- P. pyramidatoides* (Whitfield)
- P.? letsoni* (Whitfield)
- Corbicula subelliptica* (Meek and Hayden)
- Sphaerium planum* Meek and Hayden

Gastropoda

- Viviparus plicapressus* White
- Lioplacodes limnaeiformis* (Meek and Hayden)
- Physa rhomboidea* (Meek and Hayden)

Whitfield also reported *Unio vetustus* Meek in this fauna, but the identification is improbable, as that species is based on specimens from the Bear River formation, near the base of the Upper Cretaceous.

The Hell Creek formation extends northward into Saskatchewan, where it is known as the Frenchman formation. This rests unconformably on the Whitemud and Battle formations, which are the equivalents of the clay beds that mark the top of the Middle Edmonton. The Frenchman formation may be very thin, or where pre-Frenchman erosion has been deep, may reach a thickness of 100 metres. In the latter case the rocks may weather in the form of badlands, and in such areas good vertebrate fossils have been discovered.

Vertebrate fauna of the Frenchman formation

Chondrichthyes

Myledaphus bipartitus Cope

Actinopterygii

Lepidosteus occidentalis (Leidy)

Platacodon sp.

Pappichthys sp.

Amphibia

Scapherpeton tectum Cope

Reptilia

Baëna hatcheri Hay

B. longicauda Russell

Basilemys sp.

Adocus sp.

Thescelus sp.

Aspideretes spp.

Champsosaurus sp.

Iguanavus teres Marsh

Leidysuchus? sp.

Tyrannosaurus? sp.

Ornithomimus sp.

Anatosaurus saskatchewanensis (Sternberg)

Thescelosaurus neglectus Gilmore

Triceratops prorsus Marsh

The Lance vertebrate fauna has also been found in the upper part of the Edmonton formation, above the white clay and the Kneehills tuff. The Upper Edmonton beds do not differ much from the middle and lower parts of the formation, except for the presence of massive sandstone lenses, which resemble the sandstones of the overlying Tertiary. No identifiable invertebrate fossils have been found as yet in the Upper Edmonton beds. The vertebrate fauna is unmistakably the same as that of the Lance formation, and contains the following species.

Vertebrate fauna of the Upper Edmonton beds (Lance equivalent)

Chondrichthyes

Palaeospinax ejuncidus Lambe

Myledaphus sp.

Actinopterygii

Lepidosteus sp.

Acipenser sp.

Kindleia fragosa Jordan

Stylomyleodon sp.

Reptilia

Champsosaurus sp.

Tyrannosaurus sp.

Anatosaurus sp.

Thescelosaurus edmontonensis Sternberg

Leptoceratops gracilis Brown

Triceratops albertensis Sternberg

Ankylosaurus sp.

Mammalia

Diaphorodon? sp.

Stagodon sp.

As noted previously, the white clay and Kneehills tuff occur at the top of the St. Mary River formation in southwestern Alberta, and the lower part of the overlying Willow Creek formation is correlated with the Upper Edmonton beds. Diagnostic vertebrates have not been found in the Willow Creek formation, although a dinosaur bone was found in the transition beds (Edmonton/Willow Creek) on Little Bow River. There is a good fauna of non-marine mollusks in the Lower Willow Creek beds, and this may be used as the standard for the Lance equivalents in Alberta. However, as listed by Tozer (1956, p. 24) this fauna has no peculiar elements, being mainly a survival of the St. Mary River fauna with some suggestions of the Paleocene fauna of the Upper Willow Creek.

Non-marine molluscan fauna of the Lower Willow Creek beds

Pelecypoda

Fusconaia? stantoni (White)

Sphaerium heskethense Warren

S. gietzi Tozer

Gastropoda

Dimorphoptychia cf. *rutherfordi* (Russell)

Valvata filosa Whiteaves

Reesidella cf. *protea* (Yen)

Viviparus prudentius prudentius White

V. prudentius willovensis Tozer

V. westoni Tozer

Campeloma edmontonesnsis Tozer

Lioplacodes limnaeiformis (Meek and Hayden)

L. sanctamariensis (Russell)

L. cf. *tenuicarinata* (Meek and Hayden)

Hydrobia sp.

Pleurolimnaea mclearnii Tozer

Physa canadensis Whiteaves
Ferrissia sp.
Polygyra parvula (Whiteaves)
Pseudocolumna? spitzia Tozer

If, as seems well established on stratigraphical grounds, the Lower Willow Creek beds are the Lance equivalent, it is difficult to understand the absence from the molluscan fauna of the peculiar unionids described by Whitfield from the Hell Creek beds of Montana. *Proparreysia holmesiana* (White) does occur at one locality within the disturbed belt just east of the Rocky Mountains, associated with *Fusconaia? stantoni* (White), *Plesielliptio brachyopisthus* (White), and *Viviparus westoni* Tozer. Also found here was a mammalian premolar identified as *Stagodon* sp. Although originally thought to be well down in the Edmonton equivalent, this fossil bed may well be within the Lance equivalent. There are other occurrences of fossil mollusks in the disturbed belt of western Alberta in beds that must be part of the Edmonton equivalent but whether or not they represent the Upper Edmonton or the Middle and Lower, it is not possible to determine at present. The mollusks resemble those of the St. Mary River and Lower Willow Creek beds.

SUMMARY

On the basis of the palaeontological and stratigraphical data presented herewith, it is proposed to recognize seven provincial stages in the non-marine Cretaceous of the northwestern great plains and disturbed belt. These are named and defined as follows.

Cloverlyan stage. Type section, the "Kootenai" formation of southeastern Montana, particularly that of the Musselshell Valley southeast of Harlowton. Equivalents occur in the Kootenai formation of northwestern Montana and the Blairmore formation of southwestern Alberta. Characterized by the mollusks *Protelliptio douglassi*, *Tritigonia natosini*, and *Reesidella montanaensis*. Vertebrates include several species of *Camptosaurus* and the armoured dinosaur *Nodosaurus*. Represents late Aptian or Albian of the European section.

Murrayan stage. Type section, the McMurray formation of northeastern Alberta. Characterized by the mollusks *Protelliptio biornatus* and *Liopacodes bituminis*. Vertebrates unknown. Represents part of the Albian stage.

Dunvegania stage. Type section, the Dunvegan formation of northwestern Alberta and adjacent British Columbia. An approximate equivalent is the Bear River formation of western Wyoming. Characterized by the mollusks *Protelliptio sulfuriensis* and *Pleurobema? dowlingi*. Vertebrates unknown. Corresponds to part of the Cenomanian stage.

Aquilan stage. Type section, the Upper Eagle beds of the Missouri Valley in Montana, near the mouth of Judith River. The Upper Milk River beds of southern Alberta are equivalent, and corresponding beds occur in the lower part of the Two Medicine formation of northwestern Montana. Characterized by the mollusks *Rhabdotophorus gracilis* and *Physa lacteana*,

and by a peculiar vertebrate fauna, the characteristic genera of which are still unnamed. Corresponds to part of the Santonian substage.

Judithian stage. Type section, the Judith River formation of the Missouri Valley in Montana, in the vicinity of Cow Creek. The Foremost and Oldman formations of southern Alberta are equivalent, and corresponding beds occur in the upper part of the Two Medicine formation of northwestern Montana. Characterized by the mollusks *Plesielliptio abbreviatus*, *Rhabdophorus senectus*, *Proparreysia mclearni*, *Lioplacodes vetula* and *Goniobasis sublaevis*, and by numerous genera of dinosaurs, such as *Gorgosaurus*, *Corythosaurus*, *Lambeosaurus*, *Kritosaurus*, *Chasmosaurus*, *Monoclonius*, *Centrosaurus* and *Panoplosaurus*. Corresponds to part of the Campanian substage.

Edmontonian stage. Type section, the Lower and Middle Edmonton beds, up to and including the Kneehills tuff, of Red Deer River valley, near Drumheller, Alberta. The St. Mary River formation of southwestern Alberta and adjacent Montana is equivalent. Characterized by the mollusks *Fusconaia? stantoni*, *Sphaerium heskethense*, *Viviparus westoni*, *Lioplacodes sanctamariensis*, and by the dinosaur genera *Albertosaurus*, *Edmontosaurus*, *Hypacrosaurus*, *Saurolophus* and *Anchiceratops*. Probably equivalent to part of the Maestrichtian stage.

*Lancian stage.** Type section, the Lance formation of Niobrara County, eastern Wyoming. Approximate equivalents are the Hell Creek formation of eastern Montana, the Frenchman formation of southern Saskatchewan, the Upper Edmonton beds of central Alberta, and the Lower Willow Creek beds of southwestern Alberta. Characterized by the mollusks *Quadrula cylindricoides*, *Proparreysia barnumi*, *Proparreysia holmesiana*, and by a number of species persisting from the Edmonton fauna. The characteristic dinosaurian genera are *Tyrannosaurus*, *Anatosaurus* (also in the Edmontonian), *Thescelosaurus*, *Triceratops*, *Leptoceratops*, and *Ankylosaurus*. Believed to represent an upper part of the Maestrichtian stage.

*This corresponds to the "Lancian age" proposed by Dorf (1948, p. 105).

REFERENCES

- BOWEN, C. F. 1918
Anticlines in a part of the Musselshell valley, Musselshell, Meagher, and Sweetgrass Counties, Montana. *U.S. Geol. Survey, Bull.* 691-F, pp. 185-209, pl. 25.
- BROWN, B., AND E. M. SCHLAIKJER, 1942
The skeleton of *Leptoceratops* with the description of a new species. *Amer. Mus. Novitates*, No. 1169, 15 pp., 10 figs.
- DARTON, N. H., 1904
Comparison of the stratigraphy of the Black Hills, Bighorn Mountains, and Rocky Mountain Front Range. *Geol. Soc. America, Bull.*, vol. 15, pp. 379-448, pls. 23-36.
- DAWSON, G. M., 1886
Preliminary report on the physical and geological features of that portion of the Rocky Mountains between latitudes 49° and 51° 30'. *Geol. Surv. Canada, Ann. Rept.*, n.s., vol. 1, pt. B, 169 pp., 2 pls.
- DORF, ERLING, 1942
Upper Cretaceous floras of the Rocky Mountain region II: Flora of the Lance formation at its type locality, Niobrara County, Wyoming. *Carnegie Inst. Washington, Publ.* No. 508, pp. 79-159, figs. 1-3, pls. 1-17.
- FISHER, C. A., 1909
Geology of the Great Falls coal field. *U.S. Geol. Survey, Bull.* 356, 85 pp., 2 figs., 12 pls.
- GILMORE, C. W., 1917
Brachyceratops, a ceratopsian dinosaur from the Two Medicine formation of Montana, with notes on associated fossil reptiles. *U.S. Geol. Survey, Prof. Paper* 103, 45 pp., 57 figs., 4 pls.
- 1924
A new species of *Laosaurus*, an ornithischian dinosaur from the Cretaceous of Alberta. *Trans. Roy. Soc. Canada*, ser. 3, vol. 18, sec. 4, pp. 1-6, pls. 1, 2.
- LAMBE, L. M., 1902
New genera and species from the Belly River series (Mid-Cretaceous). *Geol. Surv. Canada, Contrib. Canad. Palaeont.*, vol. 3, pt. 2, pp. 25-81, figs. 1-24, pls. 1-21.
- LEACH, W. W., 1912
Geology of Blairmore map area, Alberta. *Geol. Surv. Canada, Summ. Rept.* 1916, pp. 193-200.
- MCLEARN, F. H., 1917
Athabaska River section, Alberta. *Geol. Surv. Canada, Summ. Rept.* 1916, pp. 145-151.
- 1929A
Stratigraphic palaeontology [of the Blairmore region]. *National Mus. Canada, Bull.* No. 58, pp. 80-107.

- 1929B
Cretaceous invertebrates [of the Blairmore region]. *National Mus. Canada, Bull.* No. 58, pp. 73–79, pls. 13–19.
- 1945
The Upper Cretaceous Dunvegan formation of northwestern Alberta and northeastern British Columbia. *Geol. Surv. Canada, Paper* 45–27, 5 pp., 6 pls.
- MELLON, G. B., AND J. H. WALL, 1956
Geology of the McMurray formation. *Res. Coun. Alberta, Rept.* No. 72, 42 pp., 4 pls.
- RUSSELL, L. S., 1932
Mollusca from the McMurray formation of northern Alberta. *Trans. Roy. Soc. Canada*, ser. 3, vol. 26, sec. 4, pp. 1–5, pl. 1.
- 1935
Fauna of the Upper Milk River beds, southern Alberta. *Trans. Roy. Soc. Canada*, ser. 3, vol. 29, sec. 4, pp. 115–128, pls. 1–5.
- 1940
Geology of the southern Alberta plains Part 1 Stratigraphy and structure. *Geol. Surv. Canada, Mem.* 221, pp. 1–128, figs. 1–21, 3 maps.
- 1949
The relationships of the Alberta Cretaceous dinosaur “*Laosaurus*” minimus Gilmore. *Jour. Paleont.*, vol. 23, pp. 518–520.
- 1962
Mammal teeth from the St. Mary River formation (Upper Cretaceous) at Scabby Butte, Alberta. *National Mus. Canada, Nat. Hist. Papers*, No. 14, 4 pp., 6 figs.
- STANTON, T. W., 1903
A new fresh-water molluscan faunule from the Cretaceous of Montana. *Proc. Amer. Philos. Soc.*, vol. 42, pp. 188–199, pl. 4.
- AND J. B. HATCHER, 1905
Geology and paleontology of the Judith River beds. *U.S. Geol. Survey, Bull.* 257, pp. 1–123, pls. 1–13.
- STERNBERG, C. M., 1924
Notes on the Lance formation of southern Saskatchewan. *Canad. Field-Naturalist*, vol. 38, pp. 66–70.
- 1949
The Edmonton fauna and description of a new *Triceratops* from the Upper Edmonton member; phylogeny of the Ceratopsidae. *National Mus. Canada, Bull.* No. 113, pp. 33–46, fig. 1, pls. 2–7.
- 1950
Pachyrhinosaurus canadensis, representing a new family of the Ceratopsia, from southern Alberta. *National Mus. Canada, Bull.* No. 118, pp. 109–120, fig. 5, pls. 17–23.
- 1951A
Complete skeleton of *Leptoceratops gracilis* from the Upper Edmonton member on Red Deer River, Alberta. *National Mus. Canada, Bull.* No. 123, pp. 225–255, figs. 47–57.
- 1951B
The lizard *Chamops* from the Wapiti formation of northern Alberta: *Polydontosaurus grandis* not a lizard. *National Mus. Canada, Bull.* 123, pp. 256–258, figs. 58, 59.

- TOZER, E. T., 1956
Uppermost Cretaceous and Paleocene non-marine molluscan faunas of western Alberta. *Geol. Surv. Canada, Mem.* 280, 125 pp., 5 figs., 9 pls.
- WARREN, P. S., AND C. R. STELCK, 1955
New Cenomanian ammonites from Alberta. *Res. Coun. Alberta, Rept. No.* 70, pp. 63-75, pls. 4-9.
- WHITFIELD, R. P., 1903
Notice of six new species of Unios from the Laramie group. *Amer. Mus. Nat. Hist., Bull.*, vol. 19, art. 15, pp. 483-487, pls. 38-40.
- 1907
Remarks on and descriptions of new fossil Unionidae from the Laramie clays of Montana. *Amer. Mus. Nat. Hist., Bull.*, vol. 23, art. 26, pp. 623-628, pls. 38-42.
- YEN, T. C., 1951
Fresh-water mollusks of Cretaceous age from Montana and Wyoming. Part 1: a fluviatile fauna from the Kootenai formation near Harlowton, Montana. *U.S. Geol. Survey, Prof. Paper* 233-A, pp. 1-9, pl. 1.

LIBRARY
ROYAL ONTARIO MUSEUM