Recent Discoveries of Cretaceous Marine Vertebrates on the Eastern Margins of the Western Interior Seaway

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1. Introduction

A joint Royal Saskatchewan Museum–Canadian Museum of Nature field project began in 1991 with the goal of examining Late Cretaceous marine deposits to learn more about the evolution of the northern part of the Western Interior Seaway and its vertebrate faunas. The project built on earlier collecting along the Carrot River by Royal Saskatchewan Museum staff in 1959 and again in 1986, but was sparked by discoveries made by Mr. Dickson Hardie on his farm, which borders the river near Arborfield. Fossils discovered by Mr. Hardie, and subsequently donated by him to the RSM, include bones and teeth of fishes and bones of plesiosaurs, turtles, and birds. The diversity and abundance of the fossil material sparked an immediate interest in the Cretaceous deposits in the Carrot River area. In several field seasons since then, our team has expanded its geographical scope to include most of the Pasquia Hills area. This paper describes some of our recent discoveries and discusses future research.

a) Geological Setting

During most of the last 35 million years of the Cretaceous, an epicontinental seaway divided North America, linking the arctic Boreal Sea to the warm Tethyan Sea of southern latitudes. At its maximum, the seaway extended from the newly-formed Rocky Mountains eastward to what is today western Ontario. An overview of the Western Interior Seaway within the context of Cretaceous North America is provided by Russell (1989). In eastern Saskatchewan, alternating transgressive pulses and regressive cycles are recorded in several hundred metres of sediment that were deposited from the Late Albian through most of the Maestrichtian.

Cretaceous strata crop out where cut by rivers along the Manitoba Escarpment in southwestern Manitoba and east-central Saskatchewan. The Escarpment, which is 675 km in length, forms the eastern erosional edge of the Western Interior Basin. Our study area, the Pasquia Hills near the Manitoba border between the Saskatchewan and Red Deer rivers in Saskatchewan, represents the most northwestern of the five uplands of the Manitoba Escarpment. The Escarpment has been the subject of geological study for many years (McInnes, 1908; Ells, 1923; McLearn and Wickenden, 1936; Wickenden, 1945; Beck, 1974). A detailed study and synthesis of these Cretaceous rocks and their Foraminifera by McNeil and Caldwell (1981) led to this research.

To date, our research has concentrated primarily on deposits of the Belle Fourche Member (Cenomanian) of the Ashville Formation and the Favel Formation (Turonian), with some exploration of the Niobrara Formation (Coniacian-Santonian) (Figure 1). Formation descriptions and ages follow McNeil (1984) and McNeil and Caldwell (1981).

2. Previous Vertebrate Paleontological Studies

The chalk badlands of Kansas and adjacent states in the US Midwest have been fertile collecting grounds for marine vertebrate remains for well over a century, but until comparatively recently, the Western Interior Seaway deposits in Canada, and especially those on its eastern margin, received little attention. Whiteaves (1889) described two sharks and two bony fishes from Manitoba Cretaceous deposits. Also mosasaur (Anonymous, 1934) and plesiosaur fossils (Russell 1935) have been described from Manitoba.

Bardack (1968) was the first to systematically collect and describe vertebrate fossils, primarily fish, from Manitoba localities along the Manitoba Escarpment. Russell (1988) compiled published reports of fossil vertebrates from the entire seaway. Case *et al.* (1990) describe selachians from a locality along the Carrot River in Saskatchewan, and Nicholls *et al.* (1990) identify marine turtles from several localities in Manitoba and from a locality along the Carrot River. In the most recently published report on fossil vertebrates from the region, Tokaryk *et al.* (1997) describe new taxa of marine birds from a Cenomanian deposit along the Carrot River.

Russell (1993) discusses the evolution of the vertebrate faunas of the seaway and characterizes them in a temporal series of assemblages defined by flexible intervals of taxonomic change (faunal turnovers), not by lithostratigraphic referent. He refers to these assemblages as North American Marine Vertebrate

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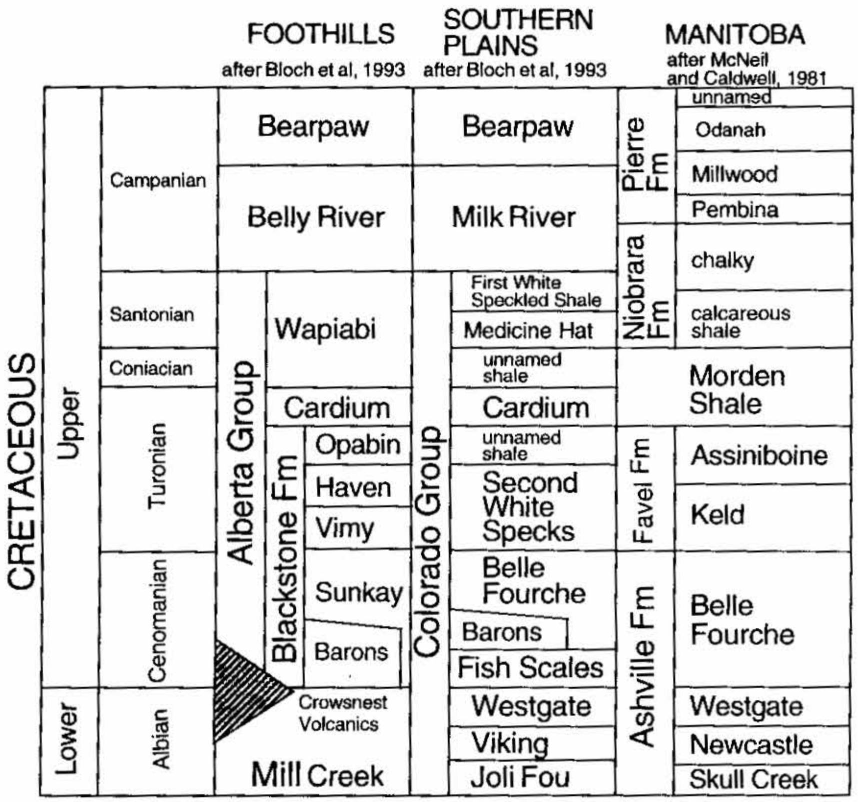

Figure 1 - Stratigraphic nomenclature of Upper Cretaceous strata in the Western Canada Sedimentary Basin (from Schröder-Adams et al., this volume).

"Ages", and includes the Pasquia Hills fauna in his "Niobrara Age". Most of our samples are 5 to 10 million years older than the classic Coniacian-Santonian "Niobrara" fauna, but share an overall similarity.

3. Current Research in the Pasquia Hills

Field work by our team has focused on several localities clustered in the three areas highlighted in Figure 2, with the goal of finding mid-Late Cretaceous vertebrates, and placing them within a stratigraphic and a paleoenvironmental context. In the text, Royal Saskatchewan Museum locality numbers have the "SMNH" prefix.

a) Carrot River Area

SMNH Locality 63E03-0001

Geology and Invertebrate Biostratigraphy

The stratigraphically oldest locality is a 1 to 2 m thick exposure along the Carrot River. It is made up of soft, carbonaceous dark shale characteristic of the Belle Fourche Member of the Ashville Formation (McNeil and Caldwell, 1981). Analysis of lithology, pollen, dinoflagellates, and Foraminifera places this locality in the upper part of the Belle Fourche, with a middle to late Cenomanian age (Figure 1). Vertebrate fossils are found disarticulated in a thin, hard, discontinuous bioclastic layer (Figure 3) capped by a 3 to 5 cm thick bentonite. The layer is very hard and resistant to acid, making preparation of specimens both difficult and time consuming.

This locality contains an assemblage of diverse and well-preserved dinoflagellate cysts and terrestrially-derived palynomorphs. David Jarzen, then of the Canadian Museum of Nature and now with the Florida Museum of Natural History, has identified several dinoflagellates indicated by Williams *et al.* (1993) as Cenomanian marker species, including *Ovoidinium verrucosum* and *Kiokansium williamsii.* Angiosperm pollen taxa are the most abundant and diverse. Cenomanian marker species include *Foveotricolpites robustus, Rousea brenneri,* and *Phimopollenites tectatus* (Jarzen, unpubl. rep., 1992).

Foraminifera recovered from immediately above and below the bioclastic layer are identified in McNeil (1992). The most common taxon is *Verneuilinoides perplexus*, placing the bone bed within the middle Cenomanian foraminiferal *V. perplexus* Zone (Caldwell *et al.* 1978).

Vertebrate Fossils

Reptiles: A number of elements from marine reptiles have been identified, including almost 100 bones of plesiosaurs, representing primarily pliosaurids but also elasmosaurids. Two vertebrae from a small ornithischian dinosaur have also been identified. Two bones of marine turtles were described from this locality by Nicholls *et al.* (1990), including one protostegid. The turtle bones were reported to be Coniacian in age as the deposit was thought at the time of publication to represent the Niobrara Formation.

Birds: Tokaryk *et al.* (1997) describe five new taxa of birds from this locality, the oldest diverse avifauna known from North America. Two of the birds, *Pasquiaornis hardei* and *P. tankei*, are hesperornithiforms; toothed, flightless diving birds that were roughly the size of a loon. Two species of the genus *Ichthyornis* are described, the oldest so far reported. Ichthyornithiforms were small, toothed, tern-like flyers. The fifth bird taxon is a possible enantiornithine. In total, some 200 bird bones have been recovered from the locality.

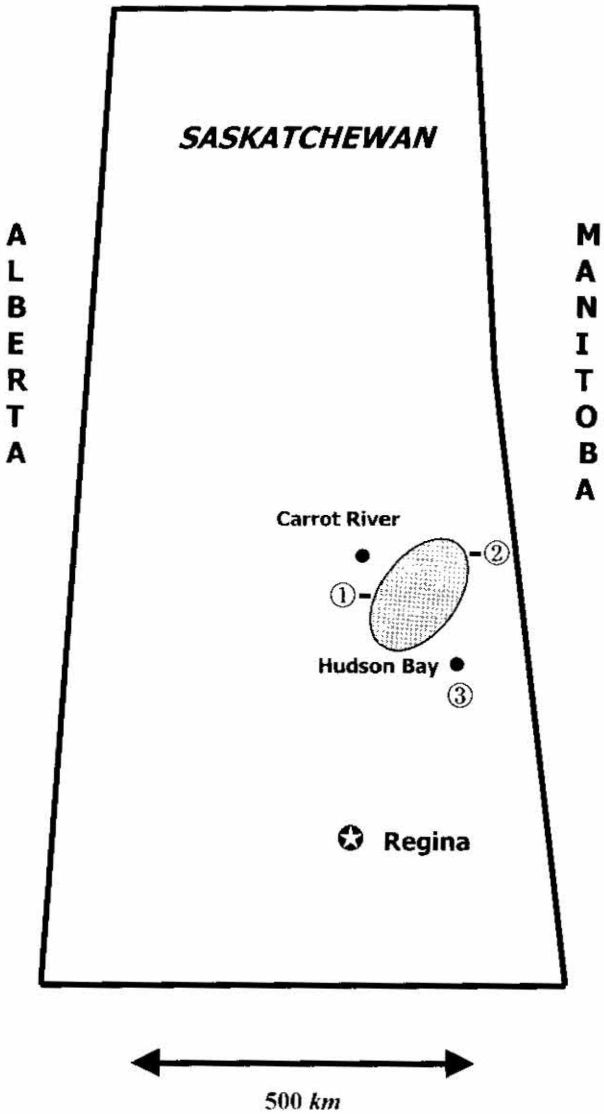

Figure 2 - Fossil vertebrate localities mentioned in the text in the vicinity of the Pasquia Hills. 1) Carrot River localities (Ashville and Favel formations); 2) Bainbridge River localities (Ashville, Favel, Morden, and Niobrara formations); and 3) Etomami River localities (Niobrara and Pierre formations).

Fish: Fish bones and teeth are the most abundant fossils recovered from this locality; teeth are more common than bones. Selachians include sharks of the genus *Hybodus;* at least two species of *Ptychodus, P. decurrens* and *P. occidentalis; Cretoxyrhina mantelli; Cretolamna appendiculata;* the genera *Leptostyrax* and another lamniform, possibly *Protolamna;* and one or more species of the genus *Squalicorax,* including *S. curvatus* and an undescribed species of this genus known from Texas and Kansas (Welton and Farish, 1993). Teleosts include *Protosphyraena, Enchodus,* and an ichthyodectid, probably *Ichthyodectes ctenodon.*

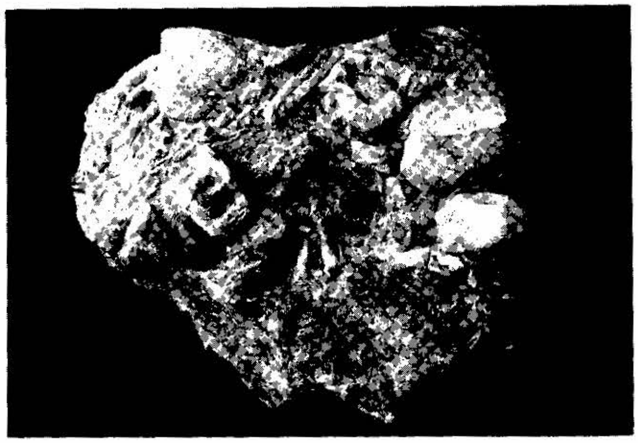

Figure 3 - Sample from the bioclastic layer at SMNH Locality 63E03-0001. Overall dimensions are 12 cm by 10 cm. At top left is an unidentified marine reptile bone; at center left an ichthyodectid vertebra; below it to the right is the black, finely-striated tooth of a bony fish, *Protosphyraena* ***sp.; the 2 cm wide ridged tooth at right center is from a pavement-toothed shark,*** *Ptychodus occidentalis.* ***Numerous other shark teeth are evident, including a grouping at top right of three sharply-angled teeth of*** *Squalicorax* ***sp. surrounding the root and part of the crown of a lamniform shark, possibly of the genus*** *Protolamna.*

SMNH Locality 63E04-0001

Geology and Invertebrate Biostratigraphy

This locality is an 8 m thick exposure dominated by well-layered, white-speckled, calcareous shale. At least six interbeds of bentonite are preserved. The Laurier Limestone, a regional marker described by McNeil and Caldwell (1981), is present in the upper few metres of the outcrop. This unit is composed of two 15 to 20 cm thick limestone beds separated by a bentonite bed 14 cm in thickness. Based on lithology and fossil content, strata at this locality are placed within the Keld Member of the Favel Formation (Figure 1).

Preliminary analysis of the Foraminifera (McNeil, 1992) suggests the age of these rocks to be late Cenomanian? to early Turonian, in the *Clavihedbergella simplex* Subzone of the *Hedbergella loetterlei* Zone (Caldwell *et al.,* 1978). Extensive sampling of molluscs by Christopher Collom of the University of Calgary confirms the abundance of inoceramids, particularly *Mytiloides labiatus.* The only ammonite found, in a concretionary zone above the primary bone-bearing strata, is *Collignoniceras woolgari.* These invertebrates indicate that these strata are early Turonian in age.

Vertebrate Fossils

Only the upper few metres of this locality have been extensively sampled for vertebrates. The well-preserved skeleton of a 6 to 7 m long marine crocodyliform, *Teleorhinus robustus,* was recovered about a metre below the Laurier Limestone. This gavial-like specimen is the most complete and best-preserved known example of its kind. A manuscript by Xiao-Chun Wu and Anthony Russell of the University of Calgary and one of us (SLC) describing the specimen and its relationships to other known crocodyliforms is in preparation. No other marine reptiles have been found at the locality, nor any birds.

Selachian taxa collected at the locality include the sharks *Ptychodus whipplei*, *Cretolamna appendiculata*, *Cretolamna* cf. *C. woodwardi*, *Cretoxyrhina mantelli*, *Odontaspis* sp., *Squalicorax curvatus*, *Squalicorax falcatus*, and an undescribed species of this genus (Welton and Farish, 1993). Teleosts remains are abundant, particularly at roughly the same stratigraphic level as the *Teleorhinus*. Articulated skeletons of three of the giant (4 to 5 m) ichthyodectid *Xiphactinus audax* and several specimens of the 30 to 40 cm herring-like *Apsopelix anglicus* have been found, as well as one *Pachyrhizodus minimus*. Remains of *Enchodus*, *Gillicus*, *Ichthyodectes*, and *Protosphyraena* have also been identified, but much work has yet to be done on scattered, isolated remains found in several "fish hash" zones.

Case *et al.* (1990) reported on selachian teeth found in an "oyster layer" at this locality a number of years ago. We have found similar matrix at the locality in small, loose blocks, but to date have not been able to match them with strata *in situ*. Our search for the source stratum will continue during future field work.

Three new selachian taxa are described by Case *et al.* (1990): two sharks, *Odontaspis saskatchewanensis* and *Synodontaspis lilliae*, and a ray, *Cretomanta canadensis*. These are associated with a mollusc-eating pavement-toothed shark, *Ptychodus* cf. *P. rugosus*, and other sharks including *Cretodus* sp., *Cretoxyrhina mantelli*, *Squalicorax falcatus*, and the ray *Rhinobatos* sp. The oysters were identified by James Haggart of the Geological Survey of Canada (Vancouver) as *Ostrea* sp. cf. *Ostrea congesta* var. *bentonensis* Logan. Whereas Case *et al.* (1990) ascribe a Coniacian age to this fossil assemblage, based at least in part on the erroneous identification of the strata as Niobrara Formation, location of its source stratum may enable us to determine if it is Coniacian or Turonian in age.

b) Bainbridge River Area

SMNH Locality 63E09-0003

Geology and Invertebrate Biostratigraphy

Exploration of localities of Cenomanian age in the Pasquia Hills, using McNeil and Caldwell's (1981) work as a guide, led to the discovery on the Bainbridge River of a second bioclastic "bone bed" (Figure 2), 100 km to the northeast of the Carrot River bone bed (in the vicinity of Outcrop Section 21, McNeil and Caldwell, 1981).

The first samples of the Bainbridge River bioclastic layer were found in the river bed during fieldwork in 1994, and it was not until the following year that we were able to attribute it to its probable source at the base of a 25 m thick exposure.

Many large pieces of this bioclastic material were collected at this locality, but none was found farther upstream. Extensive late summer and spring floods considerably alter these exposures, collapsing cliff faces and eroding banks, and although a concerted effort was made again in 1997, the bone bed has still not been identified *in situ*. However, in 1995 we collected large boulders of bone bed apparently freshly-derived from the source, with soft, black carbonaceous shale adhering to them. Micropaleontological contents of the shale will be compared with those of measured samples taken *in situ* on the cliff face in 1995 and 1997, and may enable us to confirm our tentative placement of the bone bed at or near the base of the exposure.

The bone bed is at least as old as the Carrot River bioclastic layer, but is different in lithology and in some details of its appearance (Figure 4). Both bone beds have large bone and teeth inclusions, generally randomly oriented, and abundant disarticulated bird, plesiosaur, shark, and bony fish remains. The Bainbridge bed is thicker (up to 0.4 m or more), has many phosphatic "pebbles" and coprolites as inclusions, and is characterized by occasional calcite-lined vugs up to several centimetres in each dimension, the result of diagenetic changes to rip-up clasts of bentonite. The Bainbridge bioclastic material breaks down relatively easily when immersed in mild acetic acid (Figure 4).

This bed possibly correlates to the Fish Scales Marker Bed, a unit that is preserved over a large area in the Western Interior. The base of the Fish Scales coincides with the Albian-Cenomanian boundary (Figure 1); this

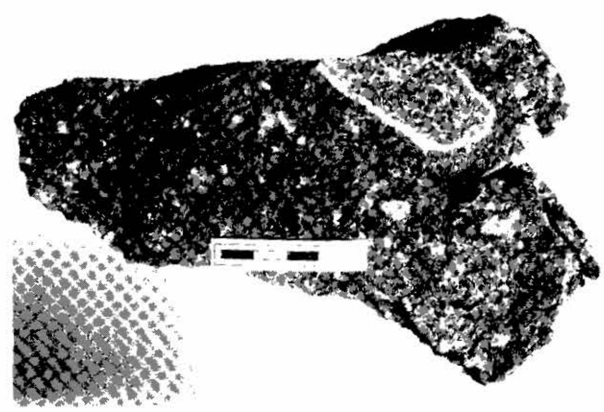

Figure 4 - Bone bed showing phosphatic pebble to immediate right of scale bar, coprolites (most of the semi-ovate white fragments), bone (primarily in black, such as the fish vertebra above center of scale bar and the 2 cm long bird bone at the upper left), and calcite-lined vug at upper right.

boundary is placed at the base of the Belle Fourche Member in the Manitoba Escarpment area (Leckie *et al.*, 1992; McNeil, 1984; McNeil and Caldwell, 1981).

At this locality, some 3 m above the base of the exposure, is a 2 to 4 cm thick layer of storm-tossed oyster shells mixed with a few disarticulated vertebrate remains, possibly the *Ostrea beloiti* beds. Above this layer is a 22 cm thick bentonite, possibly another widespread marker in the west, the "X" bentonite.

Biostratigraphic description of this locality is in progress by C. Collom, who is studying the well-preserved and abundant inoceramids from collections and measurements made in 1995, and by Schröder-Adams *et al.* (preliminary results this volume) who worked with us in the field in 1997. Although, the data sets have not been combined, it is clear that the locality incorporates a significant portion of the Ashville Formation, all of the Favel Formation, and at least part of the Morden Shale (*sensu* McNeil and Caldwell, 1981).

Vertebrate Fossils

Most of our work on the vertebrate fauna from this locality has concentrated on the bone bed; however, in the white-speckled shales of the Favel Formation we have collected the remains, some of which are articulated, of bony fishes such as *Pachyrhizodus, Enchodus, Apsopelix, Ichthyodectes,* and *Xiphactinus.* The oyster layer in the Belle Fourche Member of the Ashville Formation has produced teeth of *Xiphactinus* and the dentary of a small ichthyodectid.

Disaggregation of the bone bed in the laboratory using 5 to 10 percent acetic acid buffered by calcium orthophosphate has yielded tens of thousands of individual bones and teeth. Numerous bird bones have been recovered, including those of hesperornithiforms and ichthyornithiforms, but they have not yet been studied. Plesiosaur bones are present in small quantities, but have not been useful in separating taxa. A few turtle bones have been found, but they have not as yet been studied. Recently teeth and portions of the jaw of two different taxa of lizards were recovered.

Fish bones and teeth are very abundant, and are in an early stage of analysis. Intact cranial elements are rare, but teeth and vertebrae are common. Selachian taxa include *Hybodus, Ptychodus, Odontaspis, Carcharias, Squalicorax curvatus, "Squalicorax sp."* (Welton and Farish, 1993), *Chiloscyllium,* and an unidentified orectolobiform (Figure 5).

Bony fishes include some unusual and potentially very interesting taxa, namely an early eel, an early salmoniform, an acanthopterygian, and several large conical teeth referable to the genus *Elopopsis* (J.D. Stewart, pers. comm., 1997). A pycnodont similar to *Micropycnodon* has been identified from several individual teeth and tooth plates. *Protosphyraena, Ichthyodectes,* and an albulid are also present, as are *Apsopelix* and *Pachyrhizodus*. Three species of

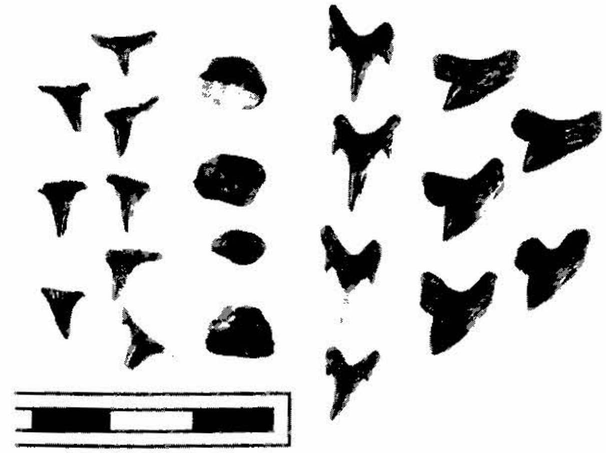

Figure 5 - Shark teeth recovered from bioclastic layer include (L to R) eight teeth of** Hybodus; **four teeth of** Ptychodus; **four odontaspid teeth, cf.** Carcharias; **and five teeth of** Squalicorax. **Scale bar in centimetres.

Enchodus have been identified from the bone bed: *E. gladiolus, E. petrosus, and E. shumardi.* Many well-preserved vertebrae and teeth are yet to be identified.

c) Etomami River

SMNH Localities 63D09-0001 and 63D09-0002

Geology and Invertebrate Biostratigraphy

Two adjacent exposures only a few metres in height (6 and 5 m, respectively) are located on the Etomami River south of Hudson Bay [Outcrop Section numbers 25 (63D09-0001) and 26 (63D09-0002) in McNeil and Caldwell, 1981]. The contact between the Niobrara Formation and the overlying Pierre Formation is readily discernible. Numerous bentonites in the Pierre attest to the high degree of volcanic activity in the Campanian. The upper part of the Niobrara is fairly fissile, with selenite crystals abounding. The lowest parts of the Niobrara, at or below water level, are much less fissile. This unit contains two *Pseudoperna congesta* oyster layers 0.3 m apart.

Vertebrate Fossils

We have done very little collecting in the Pierre Formation at the locality, and record only a few degraded marine reptile bones from its base at the contact with the Niobrara, and a probable plesiosaur tooth in the upper part of the Niobrara at McNeil and Caldwell's (1981) Outcrop Section 25. Small numbers of *Enchodus* and other teleost bones, and one *Xiphactinus* scale were collected in the Pierre at McNeil and Caldwell's (1981) Outcrop Section 26. The upper part of the Niobrara is productive for small, disarticulated vertebrate fossils, especially those of *Enchodus*. Only during a 1995 visit was the water level low enough to expose the lower part of the Niobrara at both localities. The unit produced a number of larger fossil fish specimens that have not yet been identified, and one fairly large lamniform shark tooth from a species as yet undescribed.

4. Discussion

Abundant vertebrate specimens and other geological and paleoenvironmental data have been collected from Cenomanian and Turonian strata in this little-known part of the Western Interior Seaway. Identification of taxa is ongoing and interpretation of the various data is in the preliminary stages. The vertebrate fauna from these Pasquia Hills localities contains many "firsts", "oldests", and interesting combinations not found elsewhere. These sequential faunas have at the same time both regional and cosmopolitan aspects – sharks and bony fishes that ranged from Texas to the Pasquia Hills to Europe, and birds that are not currently known to have occurred anywhere else in the world.

Due to the large samples, particularly from the bioclastic layers, taxa identification is far from complete. Outlined below are some of the subjects that will be addressed as more data become available.

1) **Paleobiogeography of the northeastern part of the seaway:** These localities lie at the edge of the overlap zone between Kauffman's (1984) proposed "Northern Interior Subprovince" and his "Western Interior Endemic Center" biogeographic subdivisions of the seaway. As our work progresses it will be interesting to compare northern and southern faunas from Cenomanian and Turonian localities within the seaway to look for clinal and other patterns, much as Nicholls and Russell (1990) did with Campanian faunas.

2) **Origin of the bioclastic bone beds:** Preliminary evidence suggests that the Cenomanian bone beds were deposited in nearshore shallow water depositional environments. However, more detailed sedimentological, taphonomic, and diagenetic studies are required to determine their origin.

3) **Impact of habitat on fauna:** With generally good bone preservation at various localities in a relatively restricted area, these uplands offer an opportunity to study habitat as a significant variable in faunal studies.

4) **Effects of the 94 my Oceanic Anoxic Event:** Recognition in strata in the study area of the Oceanic Anoxic Event that occurred about 94 million years ago would allow us to address its biotic significance.

5) **Abundance of birds and plesiosaurs:** Further work is required to undertand why Cretaceous marine faunas in our study area are characterized by an abundance of birds and plesiosaurs.

5. Acknowledgments

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