Annual Field Report

2010

RE: Manitoba Heritage Permit A03-10

March 3, 2011

Canadian Fossil Discovery Centre

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2010 Field Season Snapshots:

Abstract

The 2010 Field Season was a triumphant success at the Canadian Fossil Discovery Centre! A total number of 112 days were spent at dig sites within the Pembina Mountain region of the Manitoba Escarpment. Public programming was increased and many new fossil specimens were collected for accessioning into the museum collection. Scientific research into the geology and biostratigraphy of the Pierre Shale was increased due to the addition of a second field vehicle in the CFDC's field program along with spectacular new discoveries made possible only by the slow, tedious nature of scientific field documentation and recovery. We also received visiting researchers from such academic institutions as the Manitoba Geological Survey, the Royal Tyrrell Museum of Palaeontology, the University of Calgary, and international researchers from Western Washington University, USA and Tokyo Gakugei University, in Japan. Local, National, and International media attention helped increased public awareness of the museum as a catalyst for education into Manitoba's fossil heritage, providing for a very successful all around 2010 field season!

Introduction

The Canadian Fossil Discovery Centre (CFDC) held Heritage Permit No. A03-10 in accordance with The Heritage Resources Act of 1987, issued by the Archaeological Assessment Services, Historic Resources Branch of Manitoba Culture, Heritage, Tourism and Sport for the 2010 field season.

All fossil material collected under this permit occurred between May and November of 2010 and was directly supervised by CFDC Vertebrate Paleontologist, Joseph Hatcher. All excavation occurred along the Manitoba Escarpment, specifically within the upland geographic region of Pembina Mountain.

The CFDC maintains a site list of 31 different properties that have produced fossils where field work has been conducted since the inception of the museum in 1972. While many of these sites have not been revisited since the active bentonite mining in the area ended in the mid 1980's, the CFDC did visit 22 of these sites during 2010, along with a few new outcrops. Sites searched and excavated under Heritage Permit No. A03-10 including their site name and legal land description are available in Table 1.

The premises for permit A03-10 was both qualitative and quantitative and met all of the following objectives:

- To continue providing a program of active fossil recovery in the Pembina Mountain area of the Manitoba Escarpment.
- To increase the CFDC collection of marine vertebrate fossils from the Pierre Shale and other geological formations spanning the Cretaceous deposits of Manitoba.
- Continue research and data capture from dig sites and other supplemental geological localities in the area.
- Provide new material for small travelling exhibits, educational institutions, and other museums.

- To increase public awareness and knowledge concerning paleontology and paleontological procedures.

- To use this project to assist in generating revenue for the CFDC over the long term.

- To extract, prepare, preserve and catalogue recovered specimens and to make some of these processes visible to the public during the winter months.

- Increase knowledge and awareness of Manitoba's unique geoheritage and associated Cretaceous marine vertebrate fossils.

Table 1 – CFDC Dig Sites at which field work was conducted during the 2010 field season.

Both public groups and museum staff were responsible for the collection of fossil specimens and their data is currently stored and maintained in the Collections Department of the Canadian Fossil Discovery Centre, 111-B Gilmour Street in the town of Morden, Manitoba, Canada. A back up copy of the collection database is stored off of the CFDC premises in a secure facility at the Town of Morden Community Resource Office within the Civic Centre.

Geological Setting

The Manitoba Escarpment, a physiographic feature that rises above the Red River Valley, extends north-westerly across the southern of Manitoba. Cenozoic glacial activity is responsible for the current topography of Manitoba, especially the escarpment. This escarpment represents the easternmost edge of Cretaceous rocks within Manitoba.

All of the excavation sites during the 2010 field season were located in or directly adjacent to previously mined bentonite quarries where layers of shale are exposed. Collection and excavation were specific to the Boyne Member of the Carlile Formation, and the Gammon Ferruginous, Pembina, and Millwood Members of the Pierre Shale.

Carlile Formation

The Carlile Formation is composed of non-calcareous, carbonaceous shale of the 55 m thick Morden Member, overlain by the 75 m thick calcareous, speckled, chalky shale of the Boyne Member (Bamburak and Nicolas, 2009).

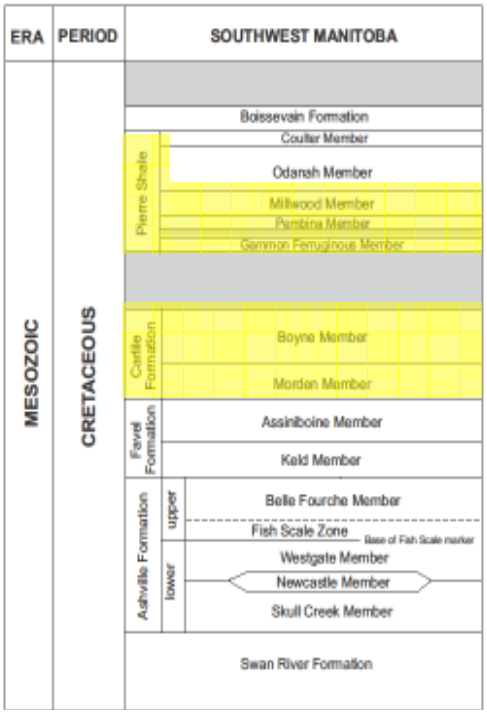

FIGURE 1 - Composite stratigraphic column of the Cretaceous rock sequence along the Manitoba Escarpment highlighting the geological formations and members covered in this report (Bamburak and Nicolas, 2010).

Morden Member

The non-calcareous, black carbonaceous shale of the Morden Member has been historically overlooked by vertebrate paleontologists in the Pembina Mountain region due to earlier documentation that fossils were generally rare in the Morden Shale (McNeil and Caldwell, 1981). However, during the 2010 field season, field observation and recording of multiple exposures throughout Pembina Mountain resulted in the discovery and collection of small vertebrate fossils, the first in the CFDC collection from this geological unit.

The CFDC Field Research Team located exposures of the Morden Shale which can be seen in outcrop around culverts and ditches in the town of Morden, and locations west in outcrops located north and south of MB Hwy 3 between Morden and Thornhill, MB. In some areas, mostly located on the first prairie level west of the town of Morden, the Morden Shale was documented to be unconformably overlain by Cenozoic glacial sediments primarily composed of sands and gravels. In general, the shale is a carbonaceous shale "twin" to that of the Pembina Member of the Pierre Shale, except that the Morden Shale lacks the abundant bentonite beds which are so common in the lower part of the Pembina. The Morden Shale does contain rare, thin (2cm) bentonite seams, which were observed by our team in an outcrop on road 2 North.

In addition to bentonite, McNeil and Caldwell reported that the Morden Shale contains rare, large, ovoid concretions (McNeil and Caldwell, 1981). Samples of these concretions were observed in the Morden Shale *in-situ* at multiple sites during the 2010 field season and some were collected for further geological research. Once cleaned in the CFDC lab, the concretions are composed of pyrite, mainly iron and sulphur, and they are unweathered, indicating that they formed under reducing conditions, and that over time they will oxidize and disassociate into gypsum and jarosite, both or which are also common components of the Morden Member (J. Bamburak, pers. comm.).

Additionally, these concretions were found to house numerous small vertebrate fossils, principally Osteichthyian (fish) fossils, which remain an important object for future scientific study.

Boyne Member

The buff, grey, calcareous shale of the Boyne Member is composed of two units: the lower Calcareous Unit, and the upper Chalky Unit, separated by a resistant siltstone and sandstone sequence informally designated as the "Babcock Beds" at the top of the calcareous unit (Nicolas and Bamburak, 2009).

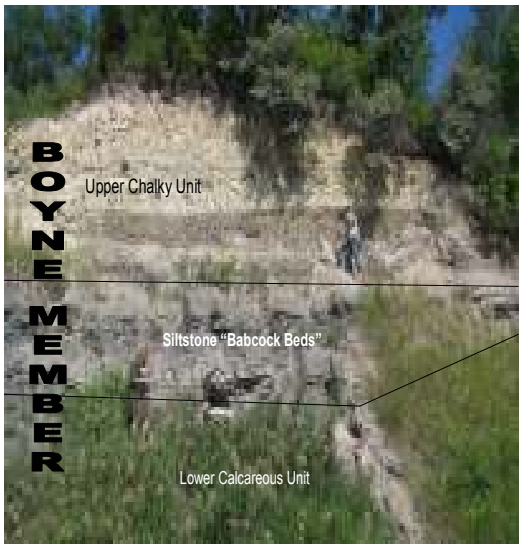

FIGURE 2 – Outcrop exposure in Snow Valley where the lower calcareous unit of the Boyne Member meets the overlying chalky unit at the "Babcock Beds." The siltstone Babcock Beds are the resistant ledge in the middle of photo. Photograph taken by Joseph Hatcher, July 20, 2010.

Outcrop exposures documented by the CFDC Field Team throughout the Pembina Mountain area typically only expose various sections of the upper chalky unit. The lower calcareous unit was only observed in the Snow Valley area, along road cut exposures west of the town of Roseisle, MB where it is capped by the Babcock Beds.

Multiple outcrops of the seemingly monotonous Boyne Member exhibit varied stratigraphic portions of the Member, with little change in the deposition and/or the lithofacies representing this time of the Cretaceous. However, the CFDC Field Team was able to piece together a rough stratigraphic picture of what a nearly complete Boyne Member (Chalky Unit) section would roughly look like, with the most complete exposure outcropped along a road cut in Snow Valley.

Outcrops were observed across a range of 53 kilometres (28.5 nautical miles) from as far south as Pembina Valley Provincial Park, along compass heading 165.26 degrees in Pembina Mountain, to as far north as Snow Valley.

FIGURE 3 – Google Earth Image showing the geographic scope of field research along 53 kilometres of Pembina Mountain conducted by the CFDC within proximity to the town of Morden in 2010. Yellow line indicates Canada/US border.

The Chalky Unit of the Boyne Member is only subtlety diverse and requires intensive field investigation before various sections of the member become discernible from one another. Based on observations and documentation with Snow Valley and again at Pembina Valley Provincial Park, two stratigraphic layers of "coquina shells" occur *in-situ* near the base of the Boyne's upper Chalky Unit. These units could prove to be useful biostratigraphic datum markers for the Boyne Member of the Carlile Formation, and could possibly correlate with similar oyster-shell beds from the Smoky Hill Chalk of the Niobrara Formation of Western Kansas (Everhart and Everhart, 1992).

Additionally, as a note of curiosity, many red ladybugs are often observed on Boyne facies, where they have burrowed in many small holes from the surface of the exposure, and while excavating with field tools, coming across colonies of usually deceased red ladybugs at or near the surface is quite common.

Pierre Shale

Gammon Ferruginous Member

The Gammon Ferruginous Member of the Pierre Shale is composed of non-calcaerous, carbonaceous, hard, and grey to black shale containing many red-weathering siderite concretions (McNeil and Caldwell, 1981). Typically, the Gammon Ferruginous is absent within outcrop exposures in the Pembina Mountain region, producing a geological unconformity between the Boyne Member of the Carlile Formation and the Pembina Member of the Pierre Shale. However, the Gammon Ferruginous Member is known in Manitoba's subsurface where the Member has recently been measured at a maximum thickness of over 56 m in south-western Manitoba, with a strong thinning of the deposits to the east (Bamburak and Nicolas 2010). It was postulated in 1981 by McNeil and Caldwell that subsidence of post-Boyne deposition uplift allowed for the Gammon sediments of the earliest Pierre Sea to make inroads into the bevelled Boyne surfaces, and then subsequently, the Pierre Sea would spread out further across Manitoba and lead to the deposition of the Pembina sediments (McNeil and Caldwell, 1981).

Pembina Member

The basic lithology of the Pembina Member consists of non-calcareous, carbonaceous, black shale with numerous bentonite horizons located in the lower portion of the Member (Bamburak and Janzic, 2007). The sequence of alternating bentonite and carbonaceous shale layers is commonly known as the "Ardmore Bentonite Succession" in equivalent beds on the United States (Bertog et al. 2007). The Pembina Member has an average thickness of 7 metres with a trend to thin out towards the north (Bamburak and Janzic, 2007). The Pembina Member has produced the majority of the fossil collection at the CFDC to date, however it has not been

determined if this represents a particularly high fossiliferous zone or if the high yield of fossil vertebrates is due to a collecting bias from previous bentonite mining activities within the Pembina Member (Nicholls, 1988).

Millwood Member

The Millwood Member conformably overlies the Pembina Member of the Pierre Shale and is exposed in many outcrops and former bentonite mines. Within the upland region of Pembina Mountain, the Millwood Member is an average 18 m thick and consists of grey, non-calcareous shale interbedded with light grey calcareous shale, both of which having a high content of montmorillonite (McNeil and Caldwell, 1981; Bannatyne, 1970).

Banded concretionary layers have been observed near the top of the Millwood section at sites 4, 16, and 26. These concretionary layers provide for the only physical stratigraphic datum point in the Pembina Mountain area outcrops of the otherwise monotonous-looking shale of the Millwood Member. Research published in 2007 announced the first occurrence of a single fossil decapod specimen from a concretion in the Millwood Member of Manitoba (Feldmann et al, 2007). A future study which looks closer into any possible decapod assemblages in the Millwood concretionary layers could prove very useful for establishing a stratigraphic datum within the Millwood Member.

Paleoenvironment

The Late Cretaceous Period was a time when the climate was regionally warmer and more tropical than we experience today. Warmer temperatures resulted in the rise of eustatic sea levels flooding lowlands of larger land masses. The Western Interior Seaway (WIS) was one of the epicontinental seas spanning from what is now the Arctic Ocean to the Gulf of Mexico with an inlet from Hudson Bay during the Cretaceous Period. The maximum extent of the flooding would have occurred during the Campanian Stage of the Late Cretaceous Period, approximately 83 million years ago.

The maximum extent of the WIS at this time would have been approximately 1,000 kilometres from the eastern margin of the Rocky Mountain Front to the western foothills to the Appalachian Mountains located in the east (Carpenter, 2006). A maximum water depth of approximately 50 fathoms would have enabled the water currents and deposition cycles to become represented by the highly fossiliferous Pierre Shale today.

Recent models of the WIS are based on azimuth orientation data of long bones to produce taphonomic data for the sea floor (Carpenter, 2006, Hatcher et al, 2008) and the surface wind conditions determined from ash fall patterns of the bentonite layers within the Pembina Member (Carpenter, 2006). Deposition of the Pierre Shale was sourced from terrestrial sediments to the

west (Jones and Blatt, 1984) which also occurred during a change in paleomagnetic polarity, with the general accepted polarity being that of 33R, when the Earth's magnetism was drawing towards the South Pole (Mitchell, 2007; Hicks et al., 1999).

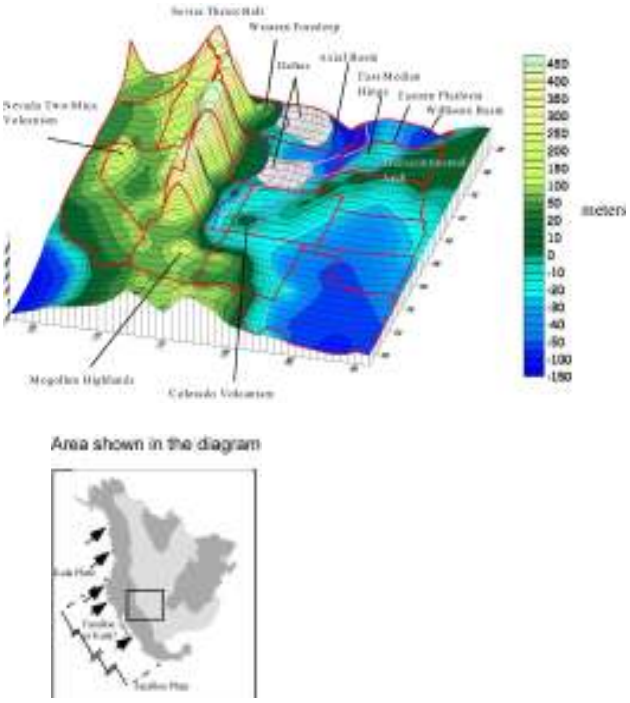

Figure 4 - 3-dimensional reconstruction of the western interior seaway during the Baculites obtusus ammonite range zone. Colors indicate approximate elevations during this time. Blue is below sea level, green is above sea level. The darkest blue indicates the areas of deepest water. Red lines are modern state boundaries for reference (Bertog, *in-press*). The Pembina Mountain region of the Manitoba Escarpment would be immediately north of the Williston Basin in this figure.

Incidentally, throughout the Campanian Stage of the Cretaceous Period, the WIS in North America experienced a prolonged regression referred to as the Claggett Cyclothem and the presence of the mineral jarosite within many of the fossil-rich shale layers is further support for extreme oxidation within the paleoenvironment (Adelman, 2007). Thus, it has been suggested that the Pembina Member of the Pierre Shale is representative of a somewhat sheltered area adjacent to the WIS, along the banks of an estuary or sub-tidal lagoon (Hatcher et al, 2008; Adelman, 2007; Nicholls, 1988).

Based on the carbonaceous and non-calcareous shales of the Pembina Member, it is generally assumed that the bottom of the sea floor was laden with organic debris (Bamburak and Janzic, 2007). Since the organic carbon is amorphous type II, it was most likely derived from marine plankton (Carpenter, 2006).

Research Goals and Strategy

Research for the 2010 field season was propelled forward by the addition of a second field vehicle which enabled a research team consisting of paleontologists, museum staff, volunteers and research interns comprising approximately 95% of time spent in the field at designated museum sites.

Public participants also assisted museum staff with research and excavation at public sites. This provided new fossil material for the CFDC while also providing an opportunity for educating the public on Manitoba's prehistoric heritage.

The museum research program started out the season focused primarily

on the continued geologic correlation of the multiple bentonite layers within the Pembina Member of the Pierre Shale based on palynomorphs preserved within the bentonite. While this study did in fact continue in 2010, the discovery of large vertebrate fossils in the unique Gammon Ferruginous Member of the Pierre Shale and the Member's stratigraphic relationships to the underlying Boyne Member of the Carlile Formation and the overlying Pembina Member of the Pierre Shale ended up consuming the vast majority of field research time during the 2010 Field Season.

The CFDC research also on Gammon Ferruginous Member within the upland region of Pembina Mountain has turned out to be an excellent regional stratigraphic marker for fossil hunting. Since most of the Pembina bentonite and shale layers were previously mined away from many of the sites on which the CFDC currently excavated, it can be difficult if not impossible to geologically orient oneself during the search for specific vertebrate fossils within specific Cretaceous shale horizons.

However the recent, although limited, discoveries of the Gammon Ferruginous Member of the Pierre Shale provides for a stratigraphic marker from which we can work backwards geologically. As such, we were able to determine that one of the CFDC plesiosaur specimens excavated in 2008 (P.08.01.04) comes from the first carbonaceous shale horizon of the Pembina Member, based on the underlying Gammon Ferruginous Member and the overlying 9 cm H1 (Horizon #1) bentonite layer. By using the Gammon Ferruginous Member as a unique datum point when in the field, the search for Pierre Shale vertebrate fossil-bearing horizons becomes more productive.

There are few facilities, like the CFDC, worldwide with extensive unique collections focused on one subject matter allowing for virtually unlimited research.

Public programming has also been a component of the CFDC field season for more than a decade comprising both additional searching and excavating hours along with the education of southern Manitoba's prehistory.

Specific dig sties were chosen for public digs based on proximity to Morden, school bus access, abundance of fossils and their general preservation. Trained summer employees in the related fields of geology, paleontology, zoology, and education supervised components of the public digs. All specimens that were to be accessioned into the CFDC collection were directed and documentation was facilitated by the Assistant Curator, Curator, and experienced Field Technicians.

Field Season Statistics

During the 2010 Field Season, the CFDC hosted visiting academic

researchers from the Manitoba Geological Survey, the Royal Tyrrell Museum of Palaeontology, the University of Calgary, and international researchers from Western Washington University, USA and Tokyo Gakugei University, in Japan.

The CFDC obtained a second field vehicle prior to the start of the 2010 Field Season, and a new approach was taken to paleontological field work at the CFDC. In all previous years, having only one vehicle limited the research potential because the principal researchers were limited to visiting the same dig sites that the public programs attended, which restricted research potential to a few select areas. However, with the addition of a second vehicle in 2010, the CFDC summer Field Technicians were trained and primarily responsible for the public programming, and the CFDC paleontologists, research interns, and volunteers were then able to use the second vehicle to travel to other various research sites, resulting in the discovery new sedimentary rock outcrops in the area, and new fossil specimens discovered and excavated.

Wildlife

The Manitoba woodtick, *Dermacentor variablis,* is a common, small (~4 mm) insect which inhabits most of the wooded areas within the Pembina Mountain region of the Manitoba Escarpment. Their annual season began in April of this year, and overall their numbers seemed to be up from previous years. I personally removed a counted 299 total wood ticks from myself throughout the season, and charted their annual life cycle in Figure 4. Wood ticks are a constant companion during field work in Manitoba, and 2010 was no exception.

FIGURE 5 – Graph indicating the life cycle of *Dermacantor variablis,* the Manitoba wood tick, as encountered during the 2010 Field Season.

The CFDC Field Research Team spent 112 days in the field totalling 640 field hours throughout the 2010 Field Season, compared with only 68 days totalling 316 field hours the previous year (2009). This increase in total number of field days directly influenced the higher rate of fossil discovery, which was a direct result of the CFDC acquiring a second field vehicle in 2010.

The addition of the second field vehicle increased the total number of days in the field, total number of hours in the field, research output, and total number of fossils collected and accessioned into the CFDC collection.

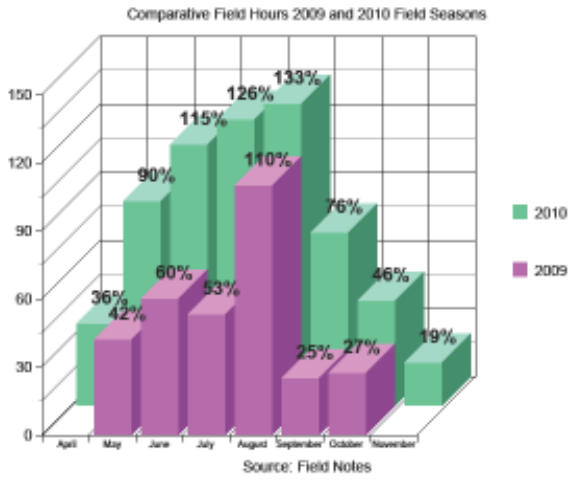

FIGURE 6 – Comparative bar graph showing the increase in field hours and research output between 2009 and 2010 as a direct result of the CFDC obtaining a second field vehicle for research.

A total of 31 specimens were accessioned into the CFDC collection from the 2009 field season, while the 2010 field season has already accessioned 36 specimens and counting, not to mention additional collection of the large plaster jackets containing the *Xiphactinus* and *Clidastes* specimens (F.09.03.13 and M.09.01.13, respectively) which are part of the 2009 collection.

Sites

F.2010.01.00 – *Osteichthyes*

This specimen was discovered in a road cut outcrop of shale belonging to the Morden Member of the Carlile Formation. It is not yet identified beyond the Class level of *Osteichthyes*, but the specimen consists of a tiny fish jaw with teeth, the first such fossil discovered by the CFDC from the Morden Shale.

VZ.2010.01.00 – *Gallus gallus*

This specimen consists of a complete furculum which was accessioned for purposes of comparative anatomy with Hesperornithiform fossil material in the CFDC collection.

Site #1

This property is that of a former bentonite test pit from the early 1970's from which the first fossils in the CFDC collection were discovered! The site has since been rehabilitated and most of the limited exposure consists of Millwood Member shale, littered with abundant glacial erratics. The CFDC has not re-visited the site in almost forty years until 2010, when a tip from one of the local landowners hinted at fossils still located there. The CFDC made a few short visits to the property to meet with the landowner and to investigate the geology of the site.

Prospecting did not reveal any new fossils, in part due to the abundant glacial erratics on the surface making it

more difficult to observe fossils on the Millwood buttes. Most of the few site visits to this property in 2010 were part of an initial field investigation into re-opening the site of P.72.03.01, the largest short-necked plesiosaur in the CFDC collection to date. However, no fossil specimens were collected from this site in 2010.

Site #2

This property is only accessible through a rugged bush-wacking one mile hike from Site #3 and as such, only a few site visits were made during the 2010 Field Season. Field crews spent time searching for fossils and examining the stratigraphy of the exposures but time constraints and other commitments limited what the crew could accomplish.

While no fossils were collected from this site in 2010, there are many of the correct Carlile and Pembina exposures on the property and more time should be spent prospecting at this site in future field seasons.

Site #3

This property is the same property where the first mosasaur discovery in Canada occurred 76 years ago (Graham 2009). Today, the close proximity of this site to the town of Morden and the open shale pit provide for a great site to take many public and school dig programs. Many exciting discoveries have been made by children and families from this site in recent years.

B.2010.01.03 – *Hesperornis* sp.

This rare specimen consists of one fairly complete and fairly well-preserved sacrum, or pelvis, of the diving bird *Hesperornis.* Such pelvic material of this taxon is a rare find in the Pembina Mountain region, and this particular specimen may prove to be the most complete such fossil of this kind yet accessioned into the CFDC collection. The specimen will be a valuable addition to the CFDC Aves collection!

F.2010.01.03 – *Xiphactinus audax*

This specimen consists of one large well preserved but incomplete vertebral centrum belonging to the giant bulldog tarpon-like fish of the Cretaceous, *Xiphactinus.* While this taxon was previously documented in this area, it does remain fairly rare and geographical information about this specimen will be useful in the CFDC collection for other researchers.

Site #4

This site is a former bentonite mine property where most of the Pembina Member of the Pierre Shale has been stripped or mined away. However, the lower shale horizons of the Pembina Member are in place, and the open expanse of the shale pit permits a large number of people, which makes this site good for large school and public dig programs. However, the current exposed horizon is near its base and it would most likely increase fossil recovery to scrape away the surface shale and first Pembina bentonite horizon to expose the first and untouched layer of Pembina shale for future field seasons.

B.2010.01.04 – *Hesperornis* sp.

This specimen was discovered during the Morden Corn and Apple Festival in August 2010 by a family of public dig participants during the CFDC programs that weekend. The specimen consists of one well preserved and complete femur, which was discovered directly associated with a more poorly preserved mosasaur skeleton within the first (oldest) black shale horizon of the Pembina Member.

Site #5

The Fossil Crew made a few visits to this site in 2010, but on all occasions no fossils were discovered or collected.

Site #6

While this site was active on MB Heritage Permit A03-10, no site visits were made by the CFDC during the 2010 Field Season due to time restraints and other significant discoveries requiring attention at other sites.

Site #7

This site was only visited twice during the 2010 Field Season. The CFDC Fossil Crew prospected along Pembina Member exposures in a large ditch but due to muddy conditions and limited exposure, was unsuccessful in locating fossils on either site visit; however the CFDC did obtain stratigraphic data from a small ditch which displayed a geologic unconformity between the Boyne Member of the Carlile Formation and the Pembina Member of the Pierre Shale. The Gammon Ferruginous Member was absent from this outcrop.

Site #8

While this site was active on MB Heritage Permit A03-10, no site visits were made by the CFDC during the 2010 Field Season due to time restraints and other significant discoveries requiring attention at other sites.

Site #9

Only one visit was made to this site, near the end of the 2010 Field Season. The landowner had discovered some fossils eroding from a cliff along Deadhorse Creek and invited the CFDC to come see it and excavate it. The specimen comes from the upper shale layers of the Ardmore bentonite succession in the Pembina Member of the Pierre Shale. This would be a good site for future examination of an *in-situ* Pembina exposure where mining activities have not disturbed the geology.

B.2010.01.09 – *Hesperornis* sp.

The specimen consists of a complete femur and complete tibiotarsus and possible patella, all well preserved and discovered semi-articulated. Despite vigorous excavation for more of the fossil skeleton, only the well preserved leg elements and one vertebra was recovered.

Site #10

While this site was active on Heritage Permit A03-10, the CFDC made only one visit to the site early in the season. Our single site visit included the discovery of a distal mosasaur jaw bone and some rib fragments eroding out of a Pembina Member bentonite succession outcrop. The specimen was documented, but the land title changed hands and the CFDC was not successful in getting a hold of the new landowner for permission to access the land. As such, the fossil remains *in-situ,* awaiting future excavation once permission to enter and excavate is granted by the new landowner.

Site #11

This site was formerly an active bentonite mine which today exhibits a roadside outcrop of primarily the lower Pembina Member alternating bentonite/shale layers. This site was only visited twice during the 2010 field season, and no fossil specimens were discovered or collected.

Site #13

This site saw a Field Season as it never before has, with unprecedented fossil discoveries and geological units not previously documented in this area.

Large quarry excavation took place in the east bank of the ditch to recover specimens discovered in 2009, and the CFDC encountered two fossiliferous horizons in addition to the one we set out to find. Fossil recovery from this site reached a new all time high this year. The vast majority of days in the field were spent at this site during the 2010 field season, resulting in the excavations of a large *Xiphactinus* fish skeleton along with an associated *Clidastes* mosasaur specimen which was initially discovered in 2009 although the main excavation occurred in 2010. The fossils attracted media attention and site visits from the Discovery Channel's *Daily Planet* show, Winnipeg news stations CTV, Global and CBC along with newspaper reporters from the Winnipeg Free Press, and the Morden Times. The resulting media stories influenced visits to the site by the mayor of Morden Mr. Doug Wilson, the mayor of Winkler Mr. Martin Harder, Member of Parliament for Portage-Lisgar Ms. Candace Hoeppner, and officers from the Royal Canadian Mounted Police who were interested in providing patrols for added site security.

Due to the vast amount of new information obtained during summer excavation at this site, a separate and more detailed account of this site is explained in "Appendix A" at the end of this report.

F.09.03.13 – *Xiphactinus* sp.

Xiphactinus skull in CFDC laboratory

This specimen was discovered late in 2009, and the first fossils recovered from this specimen occurred in that year, however the main excavation of this specimen occurred throughout the 2010 Field Season. Combined in the same geographic site and the same stratigraphic layer as an associated small mosasaur specimen (M.09.01.13 – below), the 2010 excavation produced a total of ten additional plaster jackets containing the bulk of the disarticulated skull and at least some vertebrae and possible fin and rib elements. Only two of the ten plaster jackets have been opened to date, and due to the very dense nature of the matrix and fragility of fish fossils, the preparation of this scientifically significant specimen is slow and tedious. More of the specimen likely remains *in-situ* at the site for continued excavation in 2011.

M.09.01.13 – *Clidastes* sp.

The small mosasaur which is associated with the giant *Xiphactinus* fish specimen mentioned above belongs to the smaller and regionally rarer taxon, *Clidastes.* While also initially discovered in 2009, the main excavation of this specimen occurred with the above fish

specimen (F.09.03.13) in 2010. This mosasaur appears to be a bit more articulated in the site, and in 2010 the CFDC Fossil Crew removed plaster jackets containing the skull, cervical vertebrae, scapula, coracoid, and some ribs. The majority of the specimen appears to have curved back into the hillside, and awaits continued excavation of the in 2011.

B.2010.01.13 – *Ichthyornis* sp.

The specimen consists on only one well preserved distal tarsometatarsus, but it is only the third documented *Ichthyornis* discovery in Manitoba, ever. The previous two fossils belonging to this taxon from Manitoba were discovered in 1977 from the Pembina Member of the Pierre Shale. While B.2010.01.13 is certainly the first occurrence of this taxon from the Gammon Ferruginous Member of Manitoba, it could also eventually prove to be the first occurrence of this taxon in the Gammon Ferruginous Member worldwide.

B.2010.02.13 – *Hesperornis* sp.

This specimen consists on one nearly complete tibiotarsus which was recovered from the Upper Gammon Ferruginous Member of the Pierre Shale, the first such vertebrate fossil in the CFDC collection from the Upper Gammon. Knowledge of this specimen within its overall stratigraphic framework provides researchers a new datum point for the evolution and distribution of this taxon.

B.2010.03.13 – *Hesperornis* sp.

The specimen consists of one solitary vertebra, well preserved. It was excavated from the lowermost micro-vertebrate layer within the Middle unit of the Gammon Ferruginous Member.

B.2010.04.13 – *Hesperornis* sp.

This specimen consists of an incomplete but well preserved femur, collected from the West Side of the ditch within the Pembina Member of the Pierre Shale. This specimen is not part of the main quarry excavation which occurred in the east bank.

B.2010.05.13 – *Hesperornis* sp.

This specimen consists of a single complete and well preserved phalange of the flightless Cretaceous bird, *Hesperornis.* The specimen was collected from the Middle Unit of the

Gammon Ferruginous Member of the Pierre Shale.

F.2010.01.13 – *Cimolichthyes nepaholica*

This specimen consists of a complete and well-preserved jaw with different rows of teeth. It was collected from the micro-vertebrate layer within the lowermost Middle Unit of the Gammon Ferruginous Member of the Pierre Shale, east bank of the ditch.

F.2010.02.13 – *Gillicus* sp.

This specimen was collected from the Upper Chalky Unit of the Boyne Member of the Carlile Formation, east bank of the ditch, in exposure beneath the Gammon Ferruginous Member. It will add to our new examination of fossil taxa within the Boyne Member for paleoecological reconstructions of the Boyne Sea.

F.2010.03.13 – Class Osteichthyes

This specimen consists of a small fish jaw with teeth, collected from the upper chalky unit of the Boyne Member of the Carlile Formation, from above the highest Boyne bentonite layer, within the turbulent deposition near the Carlile/Pierre Transition.

P.2010.01.13 – *Styxosaurus snowii*

This specimen consists of only one cervical vertebra, collected from the micro-vertebrate layer at the lowermost Middle Unit of the Gammon Ferruginous Member of the Pierre Shale. This taxon is rare in the Cretaceous deposits of Manitoba and provides exciting insight into the local paleoecology during the deposition of the Gammon sediments.

U.2010.01.13 – Ichnofossils

These specimens are currently unidentified ichnofossils from a specific layer within the Upper Unit of the Gammon Ferruginous Member of the Pierre Shale. The fossils were dissolved out of their shale matrix in the CFDC lab and are most likely the remains of in-filled decapod burrows or rhizoliths, although a positive identification has not yet been made for these specimens.

U.2010.02.13 –Invertebrate Fossil

This specimen was collected from the Middle Unit of the Gammon Ferruginous Member in the Pierre Shale. Segmented stems point to the possibility

that this specimen could be a crinoid, although a positive identification has yet to be made for this specimen. The specimen could have a potentially large impact on our understanding of the paleoecology of the Gammon Ferruginous Member of the Pierre Shale in the future.

Site #14

The CFDC Fossil Crew made a few early season visits to this site which exhibits primarily outcrops of the Pembina and Millwood Members of the Pierre Shale. However, no fossil specimens were discovered or collected from this site during the 2010 Field Season.

Site #15

This historically productive site remained productive again in 2010. The site of a former bentonite mine, Pembina and Millwood sediments make up the outcrop in this locality.

B.2010.01.15 – *Hesperornis* sp.

This specimen consists of one well preserved tarsometatarsus fragment collected from the Millwood Member of the Pierre Shale.

F.2010.01.15 – *Xiphactinus audax*

This specimen consists of large jaw fragments with teeth belonging to the giant Cretaceous fish, *Xiphactinus.* This specimen was collected from loose Pembina Member sediments which did not appear *in-situ.* Due to its darker color, it is possible that this specimen originated in the Millwood Member of the Pierre Shale although it was physically collected from loose Pembina sediments.

F.2010.02.15 – *Pachyrhizodus* sp.

This specimen consists of a premaxilla with teeth collected from the Pembina Member of the Pierre Shale.

I.2010.01.15 – Invertebrates

This specimen was collected from the Millwood Member of the Pierre Shale. It consists of shell fragments belonging to a bivalve from the Millwood Sea.

M.2010.01.15 – Family Mosasauridae

This specimen consists of one large well-preserved mosasaur tooth collected from the Millwood Member of the Pierre Shale.

M.2010.02.15 – Family Mosasauridae

This specimen consists of one mosasaur tooth, collected from the Pembina Member of the Pierre Shale.

Site #16

The CFDC Field Teams visited this site a few times early in the 2010 Field Season. The site was a former bentonite mine but today most of the exposure is that of the upper Millwood Member crossing into the Odanah Member of the Pierre Shale. Nonetheless, at least one specimen was collected from the Pembina Member by the Field Team.

M.2010.01.16 – Family Mosasauridae

This specimen consists of three associated, non-articulated caudal vertebrae of a small mosasaur.

Site #18

This site was a former bentonite mine which today exhibits a machine-induced mixing of geology between the Pembina and Millwood Members of the Pierre Shale. While much of the exposed Pembina sediments are no longer *in-situ,* the Millwood sediments appear to be natural. This site was only visited a few times during the 2010 Field Season, resulting in one accessioned specimen.

F.2010.01.18 – Family Ichthyodectidae

This specimen consists of one large "fang" tooth protruding from an incomplete premaxilla. It was collected from the Millwood Member of the Pierre Shale.

Site #19

While this site was active on MB Heritage Permit A03-10, only one attempted site visit occurred. The Fossil Crew encountered 'No Trespassing' signs everywhere and limited accessibility so no actual sites visits took place during the 2010 Field Season.

Site #20

The CFDC Field Crews made only a few visits to this site during the 2010 Field Season with various public dig programs. However, perhaps to do limited exposure, no fossil specimens were collected from Site #20 during the season.

Site #22

While this site was included on MB Heritage Permit A03-10, the CFDC made no formal trips to this site during the 2010 Field Season. However, a CFDC volunteer made a site visit resulting in a one outstanding fossil which was accessioned into the collection this year.

S.2010.01.22 – Class Chondrichthyes

This specimen consists of one fossil shark tooth collected from the Boyne Member of the Carlile Formation.

Site #23

B.2010.01.23 – *Hesperornis* sp.

This specimen consists of one incomplete tibiotarsus collected from the Millwood Member of the Pierre Shale. According to one guest researcher who visited the CFDC during the field season, this could be a new species of *Hesperornis* but future studies will need to be done before it can be said for sure.

B.2010.02.23 – *Hesperornis* sp.

This specimen consists of two phalanges collected from the Millwood Member of the Pierre Shale.

B.2010.03.23 – *Baptornis* sp.

This specimen was collected from the Millwood Member of the Pierre Shale. It consists of only one incomplete femur, however the rarity of this taxon within the Pembina Mountain region warrants its collection and associated field data scientifically significant.

F.2010.01.23 – Family Pachyrhizodontidae

This specimen consists of one tooth collected from the Pembina Member of the Pierre Shale.

Site #26

The CFDC Fossil Crew made a few early season visits to this site which exhibits primarily outcrops of the Millwood and Odanah Members of the Pierre Shale. However, no fossil specimens were discovered or collected from this site during the 2010 Field Season.

Site #27

While this site was active on MB Heritage Permit A03-10, no site visits were made by the CFDC during the 2010 Field Season.

Site #28

While this site was active on MB Heritage Permit A03-10, no site visits were made by the CFDC during the 2010 Field Season.

Site #30

This site borders the CFDC Property and served as a very fossiliferous location to take many of the 1 and 2 day dig programs to search for fossils during the 2010 Field Season.

B.2010.01.30 – *Hesperornis* sp.

This specimen consists of a well-preserved phalange collected from the Millwood Member of the Pierre Shale.

M.2010.01.30 – *Tylosaurus pembinensis*

This specimen consists of a single large well-preserved tooth collected from the Pembina Member of the Pierre Shale.

M.2010.02.30 – Family Mosasauridae

This specimen, a large caudal vertebra, was collected by one of the CFDC summer students from the Pembina Member of the Pierre Shale.

S.2010.01.30 – *Squalicorax* sp.

This fossil shark tooth was discovered by the CFDC Curator and collected from the Pembina Member of the Pierre Shale.

Site #31

This site is new to the CFDC site list and consists largely of road-cut outcrop exposure spanning the entirety of the Boyne Member of the Carlile Formation and across the Gammon Ferruginous Member and into the Pembina Member of the Pierre Shale. The CFDC Field Team made three research visits to this site during the 2010 Field Season, adding new geological datum points and discovering new fossils from the Boyne Member of the Carlile Formation.

Q.2010.01.31 – *Tusoteuthis longa*

This specimen consists of an incomplete gladius section from the Cretaceous squid, *Tusoteuthis*. This particular specimen was collected from the lower part of the Upper Chalky Unit of the Boyne Member of the Carlile Formation, in the stratigraphic vicinity of the coquina beds, which are also located lower in the unit. This is the first squid fossil from the Boyne Member ever accessioned into the CFDC collection.

S.2010.01.31 – *Cretoxyrhina* sp.

This specimen consists of one very well-preserved shark tooth collected from the Upper Chalky Unit of the Boyne Member of the Carlile Formation.

S.2010.02.31 – *Cretoxyrhina* sp.

This second specimen consists of one very well-preserved shark tooth collected from the Upper Chalky Unit of the Boyne Member of the Carlile Formation.

Recommendations

The public paleontology programs provided by the CFDC are unique within the province, providing education to people of all ages. The continuation of these programs is important not only to the museum and its research but also to the public. These programs should all continue in 2011 and continue to grow and evolve throughout the new decade.

Collaborative research efforts with researchers from other institutions should continue at the CFDC in 2011. This helps to promote the advancement of science along with interest of our fossil heritage within the scientific community.

As the CFDC grows physically,

so should its role as the leading vertebrate paleontological institution within the province. The CFDC is not merely a stagnant museum with stale exhibits; it is a living, breathing institution of higher science. I therefore recommend increasing the range and scope of the CFDC's field work and funding to include all vertebrate fossil-bearing strata within the province. While some of the strata is located in the traditional excavation areas of the Morden and Miami area along the Manitoba escarpment, the entire escarpment itself has the potential for vertebrate fossils to appear anywhere... from Pembina Mountain, to Riding Mountain, to Duck Mountain. Our data sets are so far quite regional in scope, and there is much to be discovered in *all* areas of the Escarpment.

A recent increase in geological field work and research has led to new and exciting data sets which can be applied to the larger geologic context of the vertebrate fossils housed at the CFDC. Continuation of this geological framework is needed in 2011 and into the future. As new specimens are discovered and field research continues at an exponential rate, solid geologic data will be essential to the long term growth of the research and scientific respectability at the CFDC.

One key recommendation is the continued manual excavation of vertebrate fossils from the Gammon Ferruginous Member of the Pierre Shale. This fossils and the geological unit are so unique that the site warrants serious consideration as a Provincial Geoheritage Site. Only through the careful excavation of the site by selective manpower can the field data be adequately obtained and fossils safely removed while also preserving the site for future researchers.

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Occasional waterfall over the Boyne bentonite below main *Xiphactinus* Quarry, September 2, 2010.

APPENDIX "A"

The Ditch, a geological odyssey

The main excavation site during the 2010 Field Season took place at Site #13, in the RM of Stanley. The discovery late in the 2009 Field Season of large fish and smaller mosasaur fossils led to a new excavation in the east bank of the drainage ditch at the start of the 2010 Field Season.

Excavation began with the mechanical removal of overburden from above the fossil layer. The CFDC hired Harder Backhoe Services in Morden, MB to come out to the site, and remove the overburden while the CFDC Curator and Assistant Curator remained on-site to provide direction. The decision was made to cease backhoe excavation approximately four feet above the main fossil layer, so that the backhoe did not disturb the main fossil layer.

Over the course of the next month, CFDC staff, public dig participants, and volunteers removed the four feet of densely packed shale by hand, wielding large pick-axes and shovels in order to expose the fossil layer from above. During this time of tedious intensive overburden removal, the CFDC staff was able to make many observations in the shale at this site, most notably that the shale was much harder than any shale which the current CFDC staff had ever excavated in. Through time, the principal investigators observed and made note of many more subtle variations from the normal Pierre Shale that we were accustomed to working in, particularly in regard to the reddish-brown siderite concretions deposited throughout the shale.

As the CFDC began to excavate the *Xiphactinus* and the mosasaur specimens, more and more observations were made and recorded within the site in regards to the difference in shale. As background research continued, we came into the grand realization that the fossils, and the quarry as a whole, could only be the Gammon Ferruginous Member of the Pierre Shale. This is highly significant for many reasons.

Initial geological investigations into the Cretaceous Manitoba escarpment described the Gammon Ferruginous Member as the basal member of the Pierre Shale (McNeil and Caldwell, 1981).

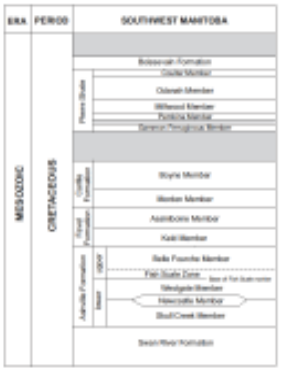


FIGURE A – Composite stratigraphic column of the Cretaceous rock sequence along the Manitoba Escarpment. (Bamburak and Nicolas, 2010)

As of 1980, the member had only been observed in outcrop on the north flank of Riding Mountain and the member was reportedly absent from the entire Pembina Mountain region of the escarpment. In 1996, the member was first observed in the Pembina Hills by the Manitoba Geological Survey (Bamburak 1996; Bamburak and Nicolas 2010).

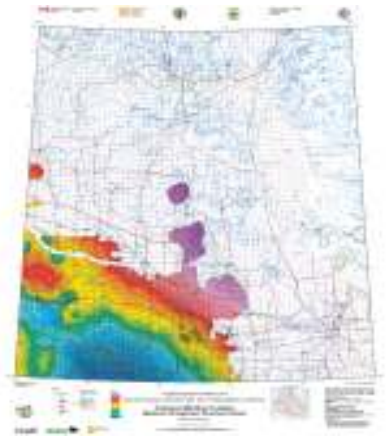


FIGURE B – Subsurface structure contour map of the Gammon Ferruginous Member of the Pierre Shale in Manitoba and Saskatchewan.

TGI Williston Basin Working Group. 2008. Cretaceous Milk River Formation (Gammon Ferruginous): structure contour; Manitoba Science, Technology, Energy and Mines, Manitoba Geological Survey, Stratigraphic Map SM2008-KMR-S, scale 1:1, 000, 000, URL http://www.gov.mb.ca/stem/mrd/geo/willistontgi/mapfiles/pdfs/004_cret_milk_river_fm_str.pdf [October 2010].

Since that time, the Gammon Ferruginous Member has only been casually observed in very limited exposures throughout the Pembina Mountain region. Typically the member is absent in the Pembina Hills, with a geological unconformity existing between the Boyne Member of the Carlile Formation and the Pembina Member of the Pierre Shale. However, in some very limited areas, small deposits of the Gammon Ferruginous Member have been measured and recorded in seemingly random distribution, in deposits typically less than 30 cm thick. More recently, gas and mineral exploration within the province by the Industrial Minerals Branch of the Manitoba Geological Survey has recorded and mapped the Gammon Ferruginous Member throughout the subsurface of south-western Manitoba.

At the site of the CFDC's 2010 main fossil excavation, the Gammon Ferruginous Member had been previously thought to be entirely absent, with the more typical Boyne/Pembina unconformity present at this and the adjacent outcrops. However, as the CFDC Fossil Crew chiselled away the overburden from the fossils, without realizing it at first, exposed what is today

the thickest single deposit of the Gammon Ferruginous Member in Pembina Mountain at over 3 stratigraphic meters (Bamburak and Nicolas, 2010). Throughout the remainder of the field season, this quarry kept the CFDC research team quite busy. Since paleontological fossil excavation involves many man hours of painstaking field labour, many subtleties of this mysterious and poorly understood geological unit came to light through careful field documentation and research while the fossils were being exposed, mapped, and excavated. Through our research we have learned about a whole chapter of the Cretaceous Western Interior Seaway that covered Manitoba, and I will do my best to summarize below what we have learned to date about the paleoenvironment.

We begin our journey near the south end of the site, where rock exposure of the upper chalky unit from the Boyne Member of the Carlile Formation is outcropped with calcareous, white-speckled shale and alternating orange-stained bentonite layers.

FIGURE - C View of the south end of the site, exhibiting the calcareous shales and orange bentonite layers from the Boyne Member of the Carlile Formation.

During the deposition of the Boyne, the Pacific tectonic plate was sub-ducting beneath the North American plate, causing the bulging Rocky Mountain uplift with frequent and violent volcanic ash clouds blanketing the Boyne Sea. Sedimentation rates would have been slow and fossil recovery from the Boyne teaches us that some fish, squid, and bivalve clams inhabited the Boyne Sea, but it appears to have been ruled by the "Ginsu Shark", *Cretoxyrhina,* whose fossilized teeth are among the most common discovered in the Boyne to date. The presence of these, the largest sharks of the Cretaceous Period, along with squid may be suggestive that the Boyne was a deeper sea that the mosasaurs and plesiosaurs did not yet rule.

As we travel north through the exposure, we gradually climb towards the last days of the Boyne Sea. The uppermost Boyne bentonite layer was measured at 27 cm thick. When wet, the bentonite is slippery and otherwise not very remarkable, however when dry, it still feels similar to volcanic ash. Above this uppermost bentonite layer, the Boyne is capped by 272 cm of marlstone, claystone, and bentonite turbulently distributed throughout the calcareous shale. This could indicate that a change occurring in the paleoclimate and/or paleogeography due to plate tectonics along the Pacific coast and/or the 33R polar paleomagnetic reversal (Haggert et al., 2009; Mitchell, 2007). In either case, sediment deposition became increasing more turbulent near the final days of the Boyne Sea.

Then something happened. Something large-scale changed the sedimentation source. The regressive Clagget Cyclothem of the Western Interior Seaway began with new iron-rich sediments making the first deposits of the Pierre Sea. The geological contact between the Carlile Formation and the Pierre Shale is sharp, and occurs along a selenite crystal layer at the site. The new Pierre Sea began to make small inroads into low lying areas of the

previous Boyne Sea, and the first ferruginous deposits of the Pierre Shale came to rest upon the Boyne (McNeil and Caldwell, 1981). The Gammon Ferruginous Member in Manitoba was best described by McNeil and Caldwell from outcrops on the north flank of Riding Mountain in 1981 (McNeil and Caldwell, 1981). They even referred to informal lower, middle, and upper units of the Gammon Ferruginous Member, although no further explanation was provided as to what distinguishes one unit from another (McNeil and Caldwell, 1981). However, excavation at the CFDC *Xiphactinus* Quarry revealed three unique lithologies that we took to calling the lower, middle, and upper Gammon Ferruginous units. The Lower Gammon Ferruginous Member measures 38 cm thick and consists of dense, gray, non-calcareous, carbonaceous shale with high turbidity exhibited by various types of bentonites. It is within the Lower Gammon Ferruginous that the *Xiphactinus* specimen (F.09.03.13) and the *Clidastes* specimen (M.09.01.13) were excavated. Were these two taxa fighting? Was one scavenging the other? Or were they each separate mortalities that were turbulently deposited in the same place? The exciting mystery begins! In the Lower Gammon we see a change in paleoenvironment from that of the preceding Boyne Sea, and we also see an influx of large marine life, a small mosasaur and large fish.

Only 3 cm above the fossils is another change in lithology to very hard, black, waxy carbonaceous shale with abundant red siderite concretions. Overall the unit measures 115 cm thick. At its base is an 11 cm thick fossiliferous zone which our staff referred to as the Microvertebrate Assemblage. This layer contains numerous fossil remains of multiple taxa, mostly tiny, possibly undescribed, fish along with large genera such as individual *Styxosaurus* vertebrae, mosasaur fossils, and many which remain unidentified at this time. The Microvertebrate Assemblage occurs just on top of the contact between the Lower and Middle units of the Gammon Ferruginous Member. It is key to our lesson on the Gammon. At the top of the Lower Gammon, we excavated large taxa such a *Clidastes* mosasaur and a *Xiphactinus* fish. These fierce predators ruled the Lower Gammon. Then something happened outside of the Sea which would alter the sediment deposition again… possibly raging surface storms, hurricanes traveling north along the Western Interior Seaway, Rocky Mountain uplift, etc., and the result was a change in marine habitat and paleofauna. From the large taxa of the Lower Gammon to the mostly tiny fish and invertebrates of the basal Middle Gammon. A small14 cm section of sedimentary rock in the site captures this magnificent change in Earth's geologic history!

Above the Microvertebrate Assemblage, the remainder of the Middle Gammon did not produce any fossils. The uppermost 4 cm of the Middle Gammon unit consists of loosely packed, ferruginous sandstone. This sandstone bed may eventually correlate to the Groat Sandstone Bed from the Gammon Ferruginous Member of South Dakota and Wyoming (Bishop, 1986); although at this time much additional research funding would be required to geochemically test this hypothesis. The source of the sandstone in the site remains currently unknown, but it could suggest that deposition was occurring in a marine near-shore environment, moving possibly into brackish conditions in the overlying unit. The 4 cm Red Sandstone bed in the CFDC *Xiphactinus* Quarry marks the top of the Middle Gammon Unit, which is subsequently overlain by the 167 cm thick Upper Gammon Unit.

The Upper Gammon Unit consists of grey, flaky bentonitic non-calcareous to calcareous shale with reddish-brown siderite concretions throughout. Lithologically it is

very similar to the Millwood Member of the Pierre Shale, except that the Upper Gammon Unit contains abundant reddish-brown (ferruginous) concretions where as the Millwood lacks them. Twenty cm above the base of the Upper Gammon, a yellow ichnofossil layer contains thousands of tiny invertebrate trace fossils, possibly rhizoliths or decapod burrows, each of which would indicate brackish water conditions nearer to the shore. Fossil decapods have been documented from the Gammon Ferruginous Member of the Pierre Shale in South Dakota, with a detailed stratigraphic record of fossil crabs, shrimps, burrows and even fecal coprolites (Bishop 1977). Whether or not the ichnofossil layer preserved in the Upper unit of the Gammon Ferruginous at our site in Manitoba can correlate to the decapod assemblage in the Gammon Ferruginous outcrops in South Dakota remains to be solved. The ichnofossil layer is then overlain by an additional 39 cm of shale, from which a well preserved tibiotarsus fossil from the flightless diving bird *Hesperornis* was collected (CFDC specimen B.2010.02.13). Above this section, two small horizontal bentonite layers were discovered approaching the top of the Gammon Ferruginous Member as a whole, volcanic precursor rumblings to what would later transpire during the future deposition of the Pembina.

Finally, as we begin to hike out of the site, we once again transcend time where the Gammon Ferruginous Member meets the overlying Pembina Member of the Pierre Shale. Four shale horizons alternating with four bentonite horizons make up the extent of the basal Pembina Member lithofacies at the site.

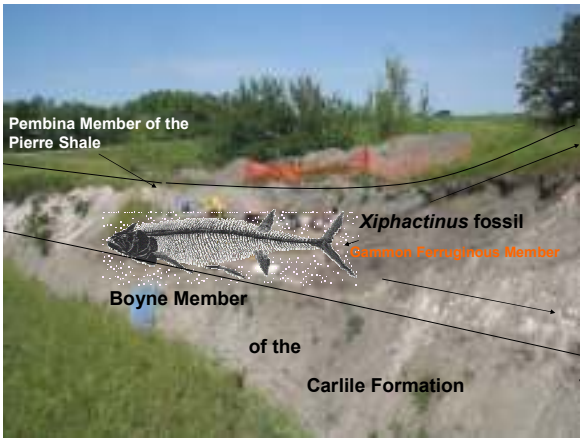
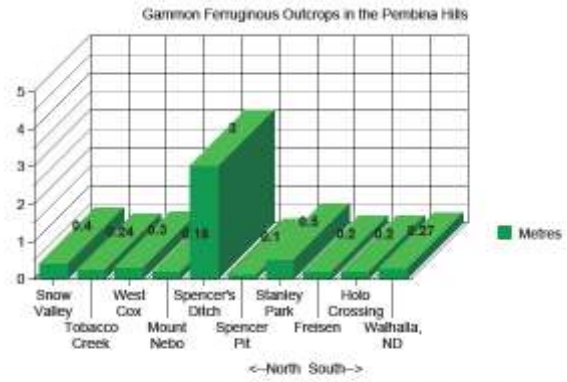


FIGURE D – View of 2010 *Xiphactinus* Quarry displaying the underlying Boyne Member of the Carlile Formation, the Gammon Ferruginous Member of the Pierre Shale is sandwiched in the middle of the quarry, while the Pembina Member of the Pierre Shale caps the sequence. The *Xiphactinus* and *Clidastes* specimens (CFDC F.09.03.13 and M.09.01.13, respectively) were excavated from just above the geological contact point between the Carlile Formation and the Pierre Shale (Boyne/Gammon contact).

In summary, the site represents a geological unit which is rare and often absent within the Pembina Mountain region of the Manitoba Escarpment. The sedimentary rock layers at the site cross over one geological formational boundary, three geological member boundaries, and three smaller sub-units within the Gammon Ferruginous Member of the Pierre Shale. The fossils excavated from the site tell a story of change through time, one layer preserving large taxa such as the giant Cretaceous fish *Xiphactinus,* and the next layer preserving mostly small fish fossils, but with the inclusion of larger marine reptile fossils as well. The uppermost layers of the site preserve ichnofossils which represent a new paleoenvironment for the Pembina Hills of southern Manitoba during this small and unique window into the Cretaceous. The Red Sandstone layer and the ichnofossil layer combine to indicate near to shore conditions during deposition of the Upper Gammon Ferruginous Unit, which changes

our picture of the paleogeography of the Manitoba arm of the Western Interior Seaway in Cretaceous North America.

The site also exhibits the single thickest deposit of the Gammon Ferruginous Member yet known within exposure in the Pembina Mountain region (Bamburak and Nicolas, 2010). Research undertaken by the Manitoba Geological Survey has also looked into the geochemistry of the Gammon Ferruginous Member with attention on the presence of Rare Earth Elements (REE) and associated oil and gas potential. Samples from the *Xiphactinus* Quarry produced the highest anomalous values for REE in the study, with additional high concentrations of Th, U, and P relative to all other Cretaceous shales with the MGS chemostratigraphic database! (Bamburak and Nicolas, 2010).



Source: Bamburak, J.D. and M.P.B. Nicolas. 2010. Gammon Ferruginous Member of the Cretaceous Pierre Shale in southwestern Manitoba: distribution and mineral potential (parts of NTS 62F, G, J, K, N, O, 63C); in Report of Activities 2010, Manitoba Inno

With the gas and oil industrial mineral potential of the Gammon Ferruginous Member, there is the possibility of future economic mining and/or oil well drilling within the Gammon Ferruginous Member of the Pierre Shale. If such mining were to ever commence, a clear and present danger would exist to the unique vertebrate fossil history of this geological horizon and I would recommend that such mines should require a paleontological impact assessment prior to, and throughout, excavation and exposure of the Member.

Xiphactinus Kill Zone

Excavated from specifically within the turbulent sediments of the lower unit of the Gammon Ferruginous Member of the Pierre Shale, the two large vertebrate specimens consist of one small mosasaur of the genus *Clidastes,* and the large Cretaceous fish *Xiphactinus* (CFDC specimens M.09.01.13 and F.09.03.13, respectively). The *Clidastes* specimen was discovered partially articulated, with a skull including toothed jaws, some cervical vertebrae, ribs, and scapulocoracoid. The skeleton curved back towards the remaining hillside and likely still remains *in-situ.* Continued excavation in 2011 will likely produce more of this specimen's axial skeleton. The *Xiphactinus* specimen was excavated from the same layer, although discovered disarticulated. Most elements are associated with the disarticulated skull, with vertebral centra and vertebral processes, fins and rib elements also present. The specimen is encrusted in gypsum crystals and selenite, making fossil preparation slow and tedious, but at the same time resulting in outstanding preservation of the fossils. Plaster jackets opened in the CFDC fossil prep lab thus far have been carefully cleaned and some possible pathologies exist on many of the skull elements of F.09.03.13. The laboratory discovery of a well-preserved *Squalicorax* shark tooth in the matrix reveals the presence of this taxon also at the site, but was it as a scavenger or predator of the *Xiphactinus?* The scars and holes encountered on fossil skull elements in the prep lab so far could prove to be bite mark pathologies from a shark like *Squalicorax,* and if so, then what role did the *Clidastes* play in the drama that unfolded at this site during the first days of the Pierre Sea, over 80 million years ago? While the discovery of a *Clidastes* and a *Xiphactinus* within a rare, relatively unknown

sedimentary rock unit is exciting, the additional evidence of *Squalicorax* being present at the site adds depth and complexity to this magnificent paleontological story. Continued excavation in 2011 of the *Clidastes* and a diligent search for more of the *Xiphactinus* along with further evidence of the *Squalicorax* will help CFDC paleontologists solve this incredible paleontological detective story. Similar stories have been preserved in rocks from the Western Interior Seaway from further south (Everhart, 2004; Shimada and Everhart, 2004). However, to date there is no such occurrence in the scientific literature of anything quite like the "*Xiphactinus* Kill Zone" Quarry preserving a *Clidastes/Xiphactinus/Squalicorax* encounter within a unique and rare geological horizon. As the fossils continue to be cleaned in the CFDC fossil prep lab and future field seasons devoted to the continued research and excavation of these specimens from this site, a more complete picture of this incredible story will come to light and CFDC researchers will publish the results in an elite, peer-reviewed scientific journal in the near future.

Annual Field Report

2010

RE: Manitoba Heritage Permit A02-10

March 3, 2011

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Submitted by: Joseph Hatcher

Assistant Curator

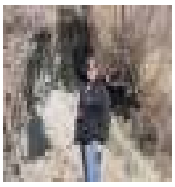
Canadian Fossil Discovery Centre

Submission Date: March 3, 2011

Snapshots of Discovery

Manitoba Heritage Permit A02-10








"Dedicated to excellence in fossil preservation, research and learning experiences."

Introduction

The Canadian Fossil Discovery Centre (CFDC) held Heritage Permit No. A02-10 in accordance with The Heritage Resources Act of 1987, issued by the Archaeological Assessment Services, Historic Resources Branch of Manitoba Culture, Heritage, Tourism and Sport for the 2010 field season.

All fossil material collected under this permit occurred during only two individual field excursions in April and August of 2010. Sites visited on Heritage Permit A02-10 are as follows:

April 2010 – The CFDC Curator and Assistant Curator visited outcrops of the Favel Formation on the banks of the Wilson River, south of Manitoba Highway #5, and other outcrops of the Favel Formation near the town of Keld, Manitoba.

August 2010 – A small research team consisting of the CFDC Curator, Assistant Curator, and two international paleontology student researchers from Japan and the United States again visited the Wilson River outcrops of the Favel Formation south of Highway #5, in addition to outcrops of the Cretaceous Ashville Formation along the Wilson River near the town of Ashville, Manitoba; outcrops (although few) of the Millwood Member of the Pierre Shale along Highway #478 in the Assiniboine River Valley south of the town of Millwood, Manitoba; an outcrop exposing the Keld and Assiniboine Members of the Favel Formation and the overlying Morden Member of the Carlile Formation at Skane's Crossing on the Ochre River, the Turtle River outcrop of the Jurassic Reston Formation, and the Jurassic Melita Formation near St. Rose du Lac, Manitoba.

The premises for permit A02-10 was both qualitative and quantitative and met all of the following objectives:

- To increase the CFDC collection of marine vertebrate fossils from the Pierre Shale and other geological formations spanning the Cretaceous deposits of Manitoba.
- Continue research and data capture from dig sites and other supplemental geological localities along the Manitoba Escarpment.
- To increase public awareness and knowledge concerning paleontology and paleontological procedures.
- To extract, prepare, preserve and catalogue recovered specimens and to make some of these processes visible to the public during the winter months.
- Increase knowledge and awareness of Manitoba's Cretaceous marine vertebrates.

Geological Setting

The Manitoba Escarpment, a physiographic feature that rises above the Red River Valley, extends north-westerly across the southern portion of Manitoba (see Figure 1). Cenozoic

glacial activity is responsible for the current topography of Manitoba, especially the escarpment. This escarpment represents the easternmost edge of Cretaceous rocks within Manitoba, extending all the way from the Canada/US border to the Pasquia Hills in Saskatchewan.

Figure 1 – Topography map of Manitoba, with the green highlighted section representing the extent of Cretaceous fossiliferous rocks within the Province spanning from the Canada/US border north-westerly to the Pasquia Hills in Saskatchewan.

All of the field work conducted under Heritage Permit A02-10 was done in the Jurassic Reston and Melita Formations, the Bell Fourche Member of the Cretaceous Ashville Formation, the Keld and Assiniboine Members of the Cretaceous Favel Formation, the Morden Member of the Cretaceous Carlile Formation, and the Millwood Member of the Pierre Shale (See Figure 2).

Reston Formation

The Jurassic Reston Formation consists of interbedded calcareous shale and limestone (Groom 2006). Very few outcrops of any Jurassic formations are exposed at the surface in Manitoba, and the Reston Formation is only known from small outcrops exposed along the banks of the Turtle River, approximately one mile south of the town of St. Rose du Lac, Manitoba.

No vertebrate fossils were discovered during the single short outing to this outcrop; however invertebrate bivalve fossils were discovered and collected with geological samples of Reston Formation limestone.

Melita Formation

The Jurassic Melita Formation is composed of calcareous shale and sandstone (Groom 2006) located at the surface only in former brick quarries within the Rural Municipality of Ste. Rose. Much of the oil production in Manitoba is restricted to the Jurassic sandstones of the Melita Formation (Fox and Martiniuk 1997), since its discovery in Melita Formation sandstones near St. Lazare, MB in 1993.

The CFDC made one short field excursion to the Melita sandstone; no vertebrate or invertebrate fossils were discovered or collected, although geological sandstone samples were collected.

Ashville Formation

The Cretaceous Ashville Formation is composed of non-calcareous, dark grey to black carbonaceous shale (McNeil and Caldwell, 1981). The formation is further divided into four discernible members, the second most numerous (only to the Pierre Shale) of any other

Cretaceous formation in Manitoba. In stratigraphic order, these members are the Skull Creek Member, the Newcastle Member, the Westgate Member, and the Belle Fourche Member (See Figure 2). Of these, only the Belle Fourche Member was visited on a single occasion by the CFDC in August 2010 in exposures along the Wilson River near the village of Ashville, Manitoba.

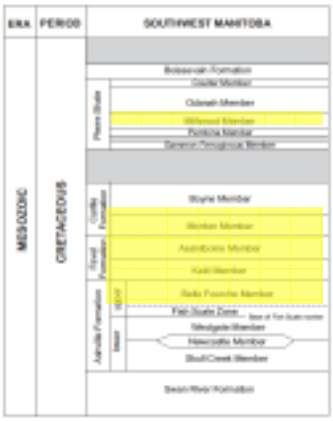


Figure 2 - Composite stratigraphic column of the Cretaceous rock sequence along the Manitoba Escarpment (Bamburak and Nicolas, 2010). Highlighted section indicates where field work was conducted in the stratigraphic column of the Cretaceous rocks in Manitoba on Heritage Permit A02-10.

Belle Fourche Member

The Belle Fourche Member of the Ashville Formation is composed of grey to black carbonaceous shale (McNeil and Caldwell, 1981). The outcrops visited by the CFDC along the Wilson River near the village of Ashville, Manitoba exhibited black carbonaceous shale littered with metamorphic glacial till washed onto the banks of the river. Neither of the established geological datums of the "Fish Scale Marker" or the "X" Bentonite was observed, but it is believed that this section of outcrop represents the upper part of the Bell Fourche Member based on its geographic proximity to the overlying Keld Member of the Favel Formation along the same river to the south. No vertebrate fossils were collected from the Ashville Formation, although geological samples of the black carbonaceous shale were collected for reference.

Favel Formation

The Cretaceous Favel Formation is perhaps the most prominent geological formation exposed in the Manitoba Escarpment, with exposures of fossiliferous white-speckled shale interbedded with argillaceous limestone and calcarenite from as far south as Road 20 North in the Pembina Mountain area, to the Assiniboine River valley south of the Riding Mountain area, and as far north as the Pasquia Hills in Saskatchewan (McNeil and Caldwell, 1981; Cumbaa et al, 2006; Wu et al., 2001).

Keld Member

The basal member of the Favel Formation is the 17 metre thick olive-grey, calcareous, white-speckled shale with abundant bentonite seams and thin beds of argillaceous limestone in the uppermost 5 metres (McNeil and Caldwell, 1981). The CFDC visited

outcrops of the Keld Member along the banks of the Wilson River south of Manitoba Highway #5, and outcrops along the Ochre River at "Skane's Crossing." The member is capped by a distinctive lithology known as the "Laurier Limestone Beds" which is composed of a 5 to 15 cm thick argillaceous limestone named for the town of Laurier, Manitoba.

Visits to these outcrops by the CFDC did result in the discovery and collection of both vertebrate and invertebrate fossil specimens. Most of the representative collection consists of invertebrate clams (*Inoceramus)*, and at least one dis-articulated fish skeleton (*Enchodus* sp.). Geological samples of the Laurier Limestone Beds also contain occasional fish scales and other seemingly random vertebrate fossil occurrences throughout the layer.

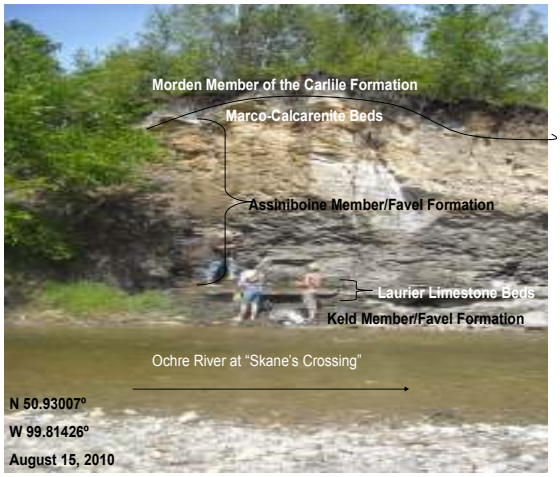


Figure 3 – Outcrop along the Ochre River at "Skane's Crossing" exhibiting the Keld and Assiniboine Members of the Favel Formation, and the overlying Morden Member of the Carlile Formation. People in the photograph from left to right: Joseph Hatcher, Keiichi Aotsuka, Katya Slater-Szirom. Photograph taken by Anita-Maria Janzic, August 15, 2010.

Assiniboine Member

Overlying the Keld Member is the Assiniboine Member of the Favel Formation. The 16 metre thick Assiniboine Member is a sequence of grey calcareous, white-speckled shale with thin interbeds of bentonite and calcarenite (McNeil and Caldwell, 1981). The uppermost metre of the Assiniboine Member consists of a yellowish-brown, fossiliferous calcarenite which is traceable over long geographic distances of the Manitoba Escarpment, thus making it a useful stratigraphic datum point in the Manitoba Cretaceous sequence.

Known formally as the "Marco-Calcarenite," this unit's southernmost known exposure lies within a small roadside ditch on the south side of Road 20 North in the Rural Municipality of Thompson between the towns of Morden and Miami, Manitoba. This geographic location makes this exposure of the Marco-Calcarenite the easternmost exposure of Cretaceous rocks in all of Manitoba (J. Bamburak, pers. comm., 2010).

The CFDC recorded the stratigraphy of the Assiniboine Member at Skane's Crossing on the Ochre River and collected representative geological samples of the Marco-Calcarenite. These samples contain numerous invertebrate fossils of bivalve clams, worm tubes, belemoids and various fish fragments. The Marco-Calcarenite is of Middle

Turonian age (McNeil and Caldwell, 1981), making it a very useful datum in the overall Cretaceous sequence within the Manitoba Escarpment.

Carlile Formation

The Carlile Formation is composed of the non-calcareous, carbonaceous shale of the 55 metre thick Morden Member, overlain by the 75 m thick calcareous, speckled, chalky shale of the Boyne Member (Bamburak and Nicolas, 2009).

Morden Member

The grey to black, non-calcareous, carbonaceous shale of the Morden Member is the basal member of the Carlile Formation. A geological "twin" of the Ashville Formation, the Morden Member was encountered only briefly during field work on Heritage Permit A02-10 at creek bank exposures off of the Vermillion River to the north of Riding Mountain, and another small exposure at the top of the sequence exposed at "Skane's Crossing" on the Ochre River. No fossils were discovered or collected from these two outcrops; likewise, no geological samples were collected from these outcrops in 2010. However, the CFDC has documented knowledge of these exposures should they be required for any future research.

Pierre Shale

The Pierre Shale represents a succession of five members, commonly exposed in the Riding Mountain and Pembina Mountain regions of the Manitoba Escarpment. Of these, only the Millwood Member was briefly investigated on Heritage Permit A02-10.

Millwood Member

The Millwood Member conformably overlies the Pembina Member of the Pierre Shale and is exposed in many outcrops lacking vegetation. The Millwood Member is an average 18 metres thick, and consists of grey, non-calcareous shale interbedded with light grey calcareous shale, both of which having a high content of montmorillonite (McNeil and Caldwell, 1981; Bannatyne, 1970). Banded concretionary layers have been observed near the top of the Millwood section at sites in the Pembina Mountain region.

The original type locality for the Millwood Member was established by Joseph Tyrrell of the Geological Survey of Canada for outcrops near the railway spur line being graded at the town of Millwood, Manitoba (Tyrrell 1890). However, the town of Millwood was later by-passed by the Manitoba and North Western Railway (Mulligan and Ryder, 1985) and the type locality outcrops of the Millwood Member along the graded spur line were subsequently overgrown. When the outcrop was next studied by McNeil and Caldwell (1981) in the late 1970's, the outcrops at the Millwood type locality were completely gone. Therefore, McNeil and Caldwell established a neostratotype locality for the Millwood Member in road-cuts along Highway #478 in the Assiniboine River Valley, 8 km south of Millwood,

Manitoba (McNeil and Caldwell 1981, page 68).

Field work by the CFDC in 2010 resulted in a trip to visit the neostratotype locality of McNeil and Caldwell (1981) to record and use as the datum for all Millwood exposures regularly encountered by the CFDC in the Pembina Mountains. However, upon arrival, it was observed and noted that McNeil and Caldwell's neostratotype locality has also since been overgrown and little geological work has been conducted on this member since 1981. Therefore, a neostratotype needs to be formally described in the scientific literature! While the CFDC made note of this fact, no fossil specimens were discovered or collected from the overgrown exposures, and only one small geological sample was collected.

Research Goals and Strategy

The primary purpose of research under Heritage Permit A02-10 was to increase the geological and paleontological knowledge of the Cretaceous sequence of the Manitoba Escarpment, and to collect small representative samples of fossils from geological units not located within the CFDC's principal study area in the Pembina Mountain region. Due to limited funding, weather conditions, vehicle repairs, and other obligations of the other permit (Heritage Permit A03-10), time allotted to this project was brief and actual time on the ground was even less. In spite of those challenges, the CFDC did accomplish the primary mission of obtaining a better understanding of the other Cretaceous rock units of the Manitoba Escarpment, and new, richer, research plans are underway as a direct result of this initial investigation beyond the Pembina Hills.

Thoughts & Recommendations

The CFDC's principal study area lies within the Pembina Mountain region of the Manitoba Escarpment, historically specific to the Pierre Shale due to the abundance of vertebrate fossil discoveries made by bentonite mining activities within the Pembina Member between the 1930's and late 1980's. Today, bentonite mining operations have been shut down for twenty years and many old quarries have been rehabilitated and are abundant in vegetation, resulting in a dramatic decrease in total numbers of vertebrate fossil specimens being discovered annually since 1990. While the principal study area still remains within the Pembina Mountain region, launching new field research initiatives beyond the principal study can prove critical to our overall understanding of Manitoba during the Cretaceous Period.

The Manitoba Escarpment spans six (6) geological formations of Cretaceous age, spanning thirteen (13) members, and at least two (2) units (See Figure 2). Every bit of it has fossil producing potential. One such example

is the recent discovery of a large and rare marine crocodile (Fort Dauphin Museum specimen MD-1055-1) from the Keld Member of the Favel Formation near Dauphin, Manitoba (Hatcher and Janzic, 2010; Wu et al, 2001). By conducting supplemental investigations into these other geological formations, we can gain a more complete understanding of Manitoba during the Cretaceous Period and thus begin to document specific "search windows" within these various formations for vertebrate fossil abundance.

Establishing datum points to correlate outcrops across geographic distance of the Manitoba Escarpment could also prove very useful in the long term for identifying areas where fossils are more likely to occur, and at the same time diversify the existing CFDC vertebrate fossil collection, the largest of its kind in Canada, with an even more thorough and unique collection. I recommend project-based investigations to the overall Manitoba Escarpment in future years, as permitted by time, funding, weather, etc.

Acknowledgements

I would like to thank Anita-Maria Janzic of the Canadian Fossil Discovery Centre in Manitoba, Keiichi Aotsuka of Tokyo Gakugei University in Japan, and Katya Slater-Szirom of Western Washington University in the United States for their assistance with field work on Heritage Permit A02-10.

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Sunset on April 22, 2010, Manitoba Highway #5 bridge over the Wilson River; view looking west.