HISTORY OF THE WANNAGAN CREEK EXPEDITIONS

1970 – 1996

Bruce R. Erickson

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Frontispiece: Aerial view of Wannagan Creek Quarry 1970s in late Paleocene strata of western North Dakota. Looking south; working surface of quarry (center); spoil piles (left center; Camp (foreground); Sentinel Butte Formation (horizon).

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Fitzpatrick Curator of Paleontology

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CONTENTS

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Prologue

Before sunrise at Wannagan Creek Quarry, Cookie is preparing breakfast for the 12 members of the field crew. Early morning and before dusk are the most productive times for digging fossils, mostly because of the 100 degree midday heat. By afternoon, Siesta is part of the routine, and became modus operandi for the 27 field seasons of the Wannagan Creek Expeditions to the badlands of western North Dakota.

Prior to beginning what was to become a major research project for the paleontology department of the Science Museum of Minnesota, exploratory reconnaissance was conducted to evaluate the potential for excavation at the location where a concentration of fossil crocodile bones had been previously found. In 1970 relatively little was known about the vertebrate paleontology of the Late Paleocene deposits in this area. Encouraged by this fact and our recent findings in Montana, a plan was proposed upon return to the museum. The necessary special land use permits were applied for and funding for the project was sought. Recruiting a field crew for a three month hitch, for the 1971 field season, took a bit longer than anticipated. However; by the following season, 1972, more than enough participants were available.

The Badlands of western North Dakota are made up of late Paleocene clastics (poorly consolidated sedimentary rocks) of the non-marine Bullion Creek (Tongue River) and overlying Somber Sentinel Butte formations of the Fort Union Group. These two formations are separated by a prominent lignite bed (The HT lignite: Royse, 1972) which shows in the distant buttes in figure 1.

In 1971 a quarry site was established in the Bullion Creek Formation, on National Grasslands, Section 18, Tp. 141 N, R. 102 W, Billings County, North Dakota (Figure 29). Topographically the quarry lies about 20 meters (66 feet) below the lignite bed at the base of the Sentinel Butte Formation. It is situated on a low wedge-shaped ridge formed by the confluence of two coulees which trend in a northwest direction. The immediate area is an uneven, grassy table of washes and erosion surfaces with re-entrant slopes.

Field work here was conducted annually from 1970 to 1996 and carried out during June, July, August, and occasionally into October weather allowing. Collecting activities at the quarry site, as well as in the coeval deposits of the surrounding badlands, were done through authorization of local ranchers and our Academic Disturbing Permit issued by the US Forest Service, US Department of Agriculture.

Expenses were funded by museum departmental budgets, grants from various agencies as well as by individuals. Many aspects of the Wannagan Creek expeditions were made possible by the sustained and generous support of the Philip W. Fitzpatrick Research Fund.

Results of the Wannagan Creek Expeditions can be summarized as having expanded our knowledge of the area and the paleontological collections of the museum by some 8,000 specimens, including over 30 new taxa. Numerous scientific publications have been produced by a number of authors in various scientific journals which contain a wealth of information about the paleontology and paleo-environment of the late Paleocene of the western interior of North America. It was not until 1999 that the name

"Fossil Lake Wannagan" was officially published (Erickson, 1999). A major exhibit on Wannagan Creek, "After the Dinosaurs", was produced along with a traveling exhibit on the results of the expeditions. What follows is an annotated history of the Wannagan Creek Expeditions in general chronological order of site development and related discoveries 1970 - 1996, as recorded in my field notes and from discussions with former crew members. Wannagan Creek is a natural drainage feature in the area and the source of the name for the site.

FIGURE 1. Early stages in development of quarry showing the pale Bullion Creek Formation and the overlying Somber Sentinel Butte Formation. Those formations are separated by a prominent lignitic bed as seen in the four buttes north of the quarry.

HISTORY OF THE WANNAGAN CREEK EXPEDITIONS: 1970 - 1996

The project at Wannagan Creek began in May 1970 as a reconnaissance mission to investigate the source of some fossil bone fragments that were brought to the museum for identification in 1969. The sample of about 40 broken pieces of bone was contained in a shoe box along with a hand-written label: "Found on the Cecil Adams Ranch, Billings County, North Dakota". Examination of the sample revealed evidence of crocodiles, in the form of occipital condyle bones, that indicated no less than six individuals were represented. Six, because an individual skull has but one occipital condyle. This concentration of crocodiles was of great interest for several reasons, not the least of which was my special interest in fossil crocodilians. A second, and more compelling reason, was the general feeling among paleontologists, that North Dakota was not especially productive of vertebrate fossils -- recall this was 1969, and was an area to travel through on ones way to the "rich" fossil fields and dinosaur beds farther west.

A field trip to the area, where the bone fragments came from, was combined with a brief return visit to the John Trumbo Ranch near Jordan, Montana, where we previously (1959 - 1964) collected our Triceratops skeleton. After completing some final survey work in Montana early in May, I traveled back to the Adams Ranch near Sentinel Butte, North Dakota where I made the acquaintance of Cecil (Swede) and Jean Adams, as well as Cecil's sister, Mrs. Scheldrup, who originally brought the shoe box with its contents to Minnesota.

My field notes for September 1970 lists a field party of four individuals: L. Hallgren, S. Hawkins,

T. O'Brien, and B.R. Erickson. Our initial search eventually brought us to an erosional wash at the base of a low butte. While prospecting the wash it was realized that the surface was strewn with bone fragments. This needed investigation, and the ground surface was soon plotted as a grid. Some 25 bags of surface bone scrap were filled and 11 small plaster field jackets were made for the more complete specimens. One jacket (F29 - 70) contained a small nearly complete crocodilian skull (Skull 1 - Loc. G 10 Fig. 2). This site became the location of Wannagan Creek Quarry which was established in June 1971. It's name derives from Wannagan Creek, a major natural feature in this area.

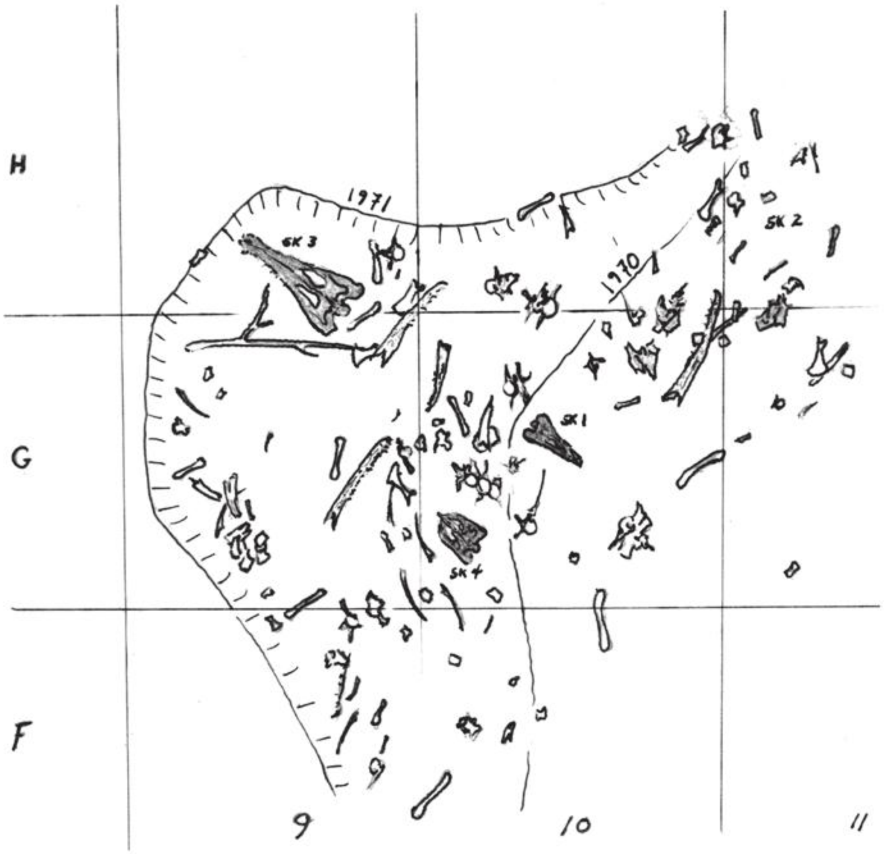


FIGURE 2. Field sketch of map section G, H / 9, 10 showing locations of 4 skulls located in 1970 and 1971. Skull 1, Loc. G – 10 is first skull collected; skull 2 (fragmentary) Loc. H – 11; skull 3, Loc. G – H, 9 designated holotype of *Leidyosuchus formidabilis*; skull 4, Loc. G – 10 small skull missing tip of rostrum.

Field time was interrupted for the writer, during this first season of 1970, due to my previous commitment as delegate to the 2nd Gondwana Symposium on Continental Drift; in South Africa. Field activities at Wannagan Creek were resumed after the South African meetings with a second trip to the North Dakota site during September. Two additional crocodile skulls, one fragmentary, as well as numerous other specimens were recovered during this time and confirmed our decision to establish a major excavation at this site. The first materials representing champsosaurs, turtles, and mammals were also among the fossils located. Arrangements were made with the U.S. Forest Service for continued development of the site. Preparations for the following seasons involved finding a water point (location for good water) not too distant from camp, to fill our 150 gal. water trailer. The greatest demand for water, with a quarry operation, is making many plaster and burlap field jackets to collect skeletal materials. My field notes show that 31 additional jackets (F 12 - 70 to F 42 - 70) were made. These were shipped to the museum at the end of the season. A final field notation…."snowed, night of Sept. 24 - cold!"

1971

The 1971 season began with a somewhat larger crew than that of the previous season. Quarry work in early June resulted in considerable down time, because of the usually wet weather, which translates into "MUD". Thereafter, field seasons were planned to begin as late in June as practical.

Photographer/preparator Robert Spading joined the crew specifically to document the excavation and assist with mapping the site and surrounding area. Lacking GPS capabilities in 1971, all mapping was completed with plane table, alidade and stadia rod. The site was eventually checked by GPS method and needed no changes. Figure 2 is a sketch map showing only the relative locations of specimens recovered in 1970 and 1971. The discovery of 4 crocodile skulls in this area here again reaffirmed the importance of this site. Skull 1 Loc. G-10 was the first skull collected. Skull 2 Loc. H-10 is incomplete. Skull 3 Loc. H-9 was designated the holotype of *Leidyosuchus formidabilis.* Skull 4 Loc. G-10 was missing the end of its rostrum. Areas beyond the limits of the quarry excavation, where important specimens were recovered, were also carefully documented at this early time. Most of these sites, some as far as one mile from the main quarry, were indispensable for paleoenvironmental analysis. Additional Special Land Use Permits were required for some of these locations, and were readily issued by the Forest Service for continued study and collecting.

1972

Removal of the unconsolidated shale and sandstone overburden at the new quarry site was the prime objective of the 1972 season. In places the underlying productive layers were covered by several meters of such sediments and local rancher excavator Larry Custer was hired to remove the overburden as work of collecting went on. The overburden removed by "Bobcat" was routinely stockpiled for future reclamation of the site; however, probe, brush, shovel, and wheel barrow remained the essential tools for excavating fossil specimens.

During these early stages of quarry development, the general area, as far as two miles out from the quarry, was intensively and extensively prospected. It soon became apparent that representative taxa occurred in certain locations of characteristic lithologies. For example, the choristoderan champsosaur was found in places of predominantly subaqueous, gray shale containing many fish remains. These places, also, were apparently preferred by the piscivorous champsosaur because of the lack of large crocodiles.

The number and kinds of turtles were unknown at this time; however, their fossils were abundantly represented throughout the sediments of the quarry and beyond. Turtle remains ranged from isolated elements

FIGURE 3. Typical preservation of a turtle shell. The shell of *Protochelydra* shown here is a complete, partly disarticulated carapace. Scale equals 15 cm.

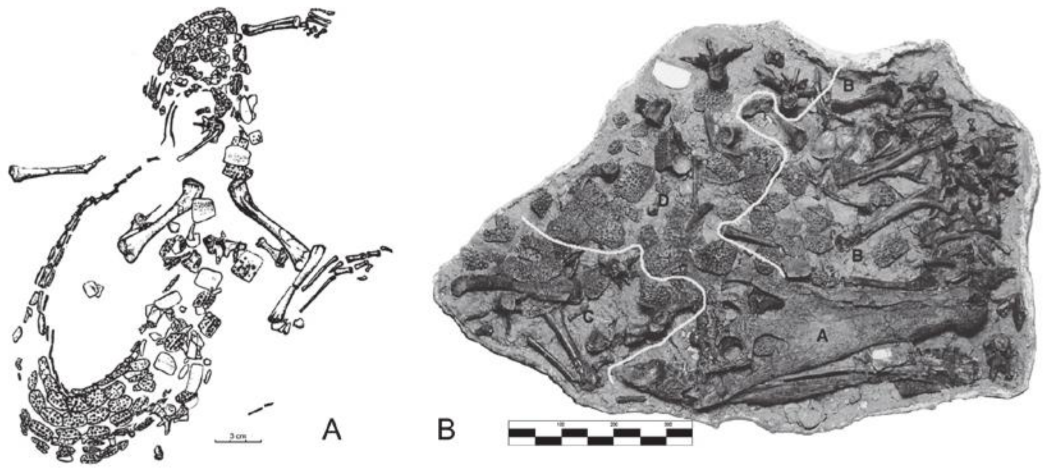


FIGURE 4. Preservation of crocodilian skeletons *in situ*. **A**, articulated partial skeleton of *Wannaganosuchus;* **B**, a single individual of *Borealosuchus* in field jacket as found with skull, mandible, and most of its postcranial elements associated.

to intact shells and skulls. Shells were typically preserved as indicated in Figure 3 with shell elements partly joined together.

Preservation of crocodilian material ranged from articulated specimens such as shown in Figure 4A, to closely associated, isolated elements preserved in either the gray shales or the lignitic shales as in Figure 4B. As with turtle bones, crocodile remains were scattered throughout the deposits. Those preserved under conditions of least distress are undistorted (Figure 5A). Those from the compacted lignitic shales were often taphonomically modified like the humerus in Figure 5B.

FIGURE 5. Right humerus of *Borealosuchus* (*=Leidyosuchus) formidabilis.* **A**, specimen from upper level preserved in undistorted condition; **B**, specimen from lower level (lignitic layer) taphonomically modified by fracturing.

At the close of the 1972 season we initiated the practice of treating the camp area and all access trails with the required nitrogen fertilizer and a 4-seed-mixture of grassland plants to stabilize the site until the next season. This practice was followed through the final field season at Wannagan in 1996. By the end of the 1972 field season we shipped 65 field jackets in 12 wooden crates back to the museum for winter preparation and study.

During the season, visitors spent time at the site observing and/or assisting with digging. Visitors included SMM staff, board members, and local cowboys, some of whom had found fossil bones on their land. Occasional visits from museum board member George Weed brought friends to view his favorite project. His groups often consisted of business associates and students sponsored by Mr. Weed's enthusiasm and support of the project. Robert Spading, who finally became a member of the paleontology staff, and I presented talks and film programs to Weed's groups at the site, at the Rough Riders Hotel in Medora and elsewhere. This became a regular event for a few early seasons.

1973

As the quarry continued to expand with many more fossils added to the collections it became apparent that our excavation was part of an ancient floodplain lake. Early digging, at the edge of the original eroisional outwash, where the first vertebrate remains were found, turned out to be near the north perimeter of the lignitic margin within the Quarry (map coordinates G/H - 9/10). Indication of a lake basin at this location was a layer of laminated, calcareous silt (marl) containing many bivalves and gastropods of the families *Hydrobidae*, *Viviparidae,* and *Pleurocoridae.* This layer was overlain by thick bottom sediments of lignitic shale with abundant plant remains and some compressed bones. Above this layer is a buff-gray shale exposed on the surface as in Figures 1 and 2. Here were many well-preserved turtles as well as the three crocodilian skulls collected in 1970, that told us we were investigating a place with well-established populations of old and young turtles and crocodilians. This sequence of layers represented continuous sedimentation and the first indication of a shoreline environment. As with turtles so also with crocodilians, their remains were well represented, yet the number and kind were unknown.

Field research at Wannagan was once again interrupted during July and August when I was in Australia to attend the 3rd Gondwana Symposium on "Continental Drift" and to investigate the habits and environments of the two living species of crocodiles in Queensland….*Crocodylus porosus* "salty" and the smaller *Crocodylus johnstoni* "freshey". The latter was of most interest because it today inhabits backwaters and billabongs not unlike those of the North Dakota's Wannagan Creek area during the Late Paleocene. More on Australian crocs later! Field work at Wannagan Creek Quarry was resumed by Erickson, Spading, and O'Brien in September and October, 1973.

1974

The season began June 18 with a crew of nine: T. O'Brien, R. Spading, P. Ganzel, C. Faraci (Cookie), M. O'Brien, B. Chuchel, R. Mjos, T. McCutcheon, and B.R. Erickson. Later in the season the crew was increased by four: L. Hallgren, K. Sander, N. Sander, L. Erickson.

Field activities began with locating another source for drinking water close to camp. This was done and the Armstrong ranch nearby was to be used as our water point for several seasons. Arrangements were also made with our friend Custer to do excavating again. His first task was to dig a deep drainage trench from the lowest end of our developing quarry to a small coulee just west of camp. It was also necessary that we build a foot bridge over the 8 foot wide drainage trench as it necessarily divided the camp. With the not so infrequent rains the trench was deepened several times during following seasons.

Custer's second task for this season was to remove a large section of overburden along the north side of the quarry. Here a thick sand facies with pronounced features was recognized as beach deposits of sand cusps. An increase in the number of small mammal bones and teeth was soon apparent in these shoreline sediments. Away from the immediate beach a thin edge (pinchout) of an underlying lignitic layer was eventually interpreted as wave base (Figure 6). Bed 1, below this lignitic zone, produced burrows of decapods and trails of oligochaetes. Other crustacean burrows were encountered in the beach sands, also indicated in Figure 6. Overlying Bed 1 are beds 2 and 3 referred to as "lower" and "upper"

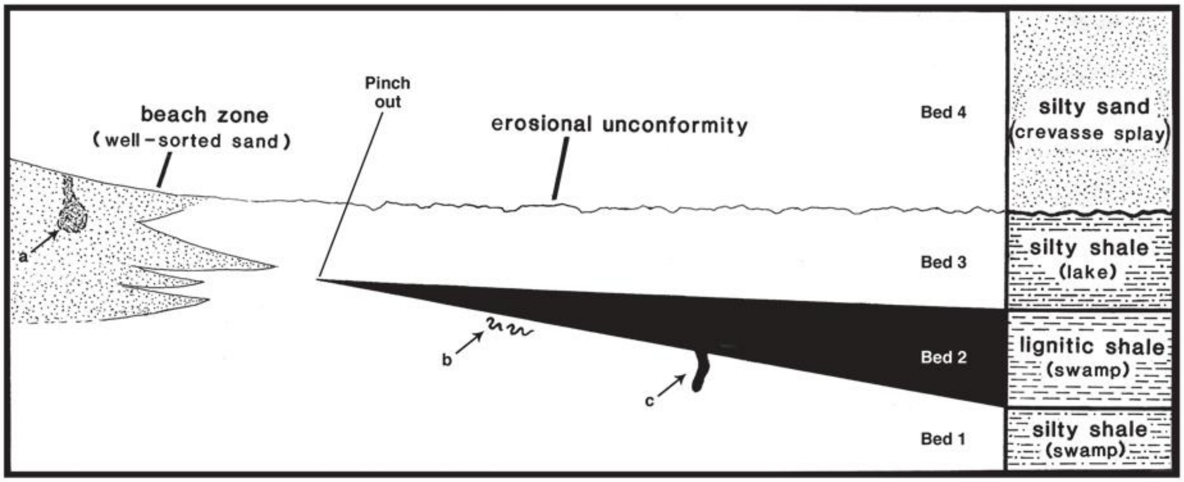


FIGURE 6. Graphic section of quarry. Bed 1, marl bottom deposits; Bed 2, lignitic shale; Bed 3, silty shale deposits; Bed 4, overlying crevasse splay of sand and mud. Locations of ichnofossils indicated by arrows; **a**, arthropod burrow; **b**, oligochaete worm trail; **c**, decapod burrow.

levels respectively to indicate different lithofaces. All of the specimens collected from the quarry deposits carry a field number as well as the designation “lower” or “upper” level to indicate where they were found. Specimens collected beyond the limits of the quarry are located by other designations such as “Saddle” or “New Site” that refers to a specific stratigraphic position. The fossil producing layers have a dip of about 2 degrees to the NE.

Season by season the mammal collections grew and often added taxa previously unknown from this site; however, it is unlikely that all the mammals that inhabited the Wannagan Creek area will become known totally, because of their small size and fragmentary nature. The 1974 field season yielded 234 field jackets as well as an abundance of small specimens collected in vials. With discovery of shoreline and shallow water deposits, a greater focus for the next season was planned for this area of the quarry, which represented a lacustrine beach environment with great potential for special fossils.

Visitors to the site included National Park Officials, J. Lancaster and R. Thompson, and *Golden Valley Press* staff. On August 8 at 7:00 PM the crew listened to the resignation speech of President Richard M. Nixon on the camp radio.

During previous seasons most collecting focused on the north section of the quarry. Meanwhile, the northeastern part of the site required removal of some 2-3 meter thickness of overburden -- possibly in the next two seasons.

1975

An immediate concern for the 1975 season was locating a replacement excavator because Custer was not available. R. Gunkel, a local rancher, familiar with our work was given the job for this season. A section of shoreline between quarry coordinates A-3 and D-5, a distance of about 8 meters, was the first task for Gunkel’s Bobcat. Excavation exposed two crocodile skeletons representing individuals that had been stranded, probably as cadavers, at quarry coordinates H-5 NS w-4/5. Slow water currents altered these specimens by separating the skull from the postcranial skeleton. The skull in H-3, for example, was moved into a position along the shoreline where it became a barrier for development of a prominent sand cusp. The skull in E-4/5 was moved by water currents as well, away from its postcranial skeleton, and its mandible was subsequently detached and moved forward of the skull. The eddy pools created down current of the sand cusps created by these skulls became a lucrative source for many small fossils (Figure 7).

A further note on these shoreline features relates to the noted pinchout margin of the lignitic zone, which is a meter or two laterally from the shoreline. Measured from what is considered shoreline sediments, the pinchout of the lignitic bed (Figure 6) is proposed as wave base, suggesting that wave length on the lake was considerable, as was the fetch (continuous area of water over which the wind blows in one direction).The size of Fossil Lake Wannagan can only be guessed at; however, the above indicates that it was evidently large. Fish, such as over one meter long amiids, in the assemblage also indicate a fairly large body of water. This was our impression of lake size at this time.

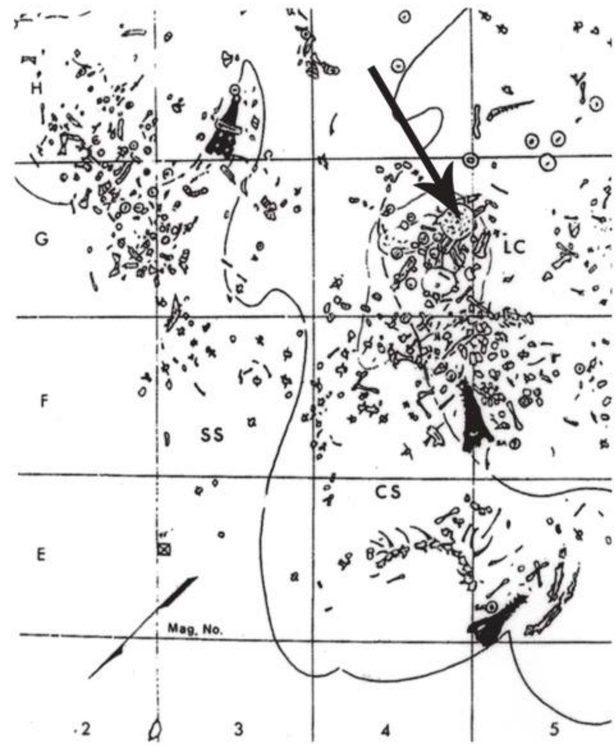


FIGURE 7. Map section of quarry at D-H /2-5 showing beach cusps of shoreline and associated crocodile skulls (silhouettes); **Abbreviations: ss**, sandstone; **cs**, clay shale; **lc**, lignitic shale; arrow indicates concentration of small mammal bones.

Concentrated work in the sandy, silty lignitic facies of the beach shallows, and in the thick deposits of matted leaves and sticks, indicated water levels during non-flood and flood times. Above highwater level, were located six or more curious, circular rings of sand, that were each two meters in diameter. Their spacing at first proposed the former location of tree stumps. Upon further investigation, we found no evidence of wood (tree stumps) as one would expect in an environment of dense tree growth.

Another notion about the origin of these beach rings relates to the expected location of the nests of crocodilians. Crocodilians today are “hole nesters”, and “mound builders”. One Australian form even builds its nest on a mat of floating vegetation. It is uncertain which is the most primitive behavior. Crocodilians use available ground cover of brush, sand, shellsand, or mud to construct their nests. Nests are often dome-shaped and located near water, in a beach situation with the egg chamber always necessarily located above “highwater”. A den may be located nearby as an underground tunnel or in a pool (gator hole). For the purpose of clarification nests and the den entrance of the present-day American crocodile, *Crocodylus acutus,* and a nest and gator hole established by the American alligator are shown in Figure 8 - A,B,C,D. It seems unlikely that any of these strutures would be recognizable as fossil traces even if they were present in and around Fossil Lake Wannagan. However areas outside of the main quarry especially in paleochannel deposits that lacked evidence of heavy bioturbation, as does the beach area, did produce trace fossils as tracks of crocodiles that had been preserved as footprints and belly drags. Convincing evidence of a nest was not found; however the remains of hatchling size individuals were present and strongly argues for a local nesting area. The question of the beach rings remains unanswered.

Among the few complete small skeletons found is that of a possible Scapherpetontid salamander (skull length 10 mm). Its occurrence in quiet water (map location N - 17) indicates its aquatic tendencies and explains its more or less intact condition. It was collected in 12 small blocks of matrix during 1975 - 1976 to insure its total recovery (Figure 23).

On occasion, early morning at Wannagan would find cattle making modern tracks everywhere in the quarry. We soon learned that exposed or partially excavated bones had to be protected -- not an unusual experience for paleontologists digging on ranch lands. An over-turned wheel barrow makes a fine protective cover for an exposed fossil.

I recall another morning when a local rancher rode into camp while out looking for strays. In a small coulee below camp he found one of his calves with a badly sprained foot. Remembering our use of plaster and burlap to jacket fossil bones, he asked if we could make a cast for the calf's foot if he brought the calf in. Cliff soon rode into camp again with the calf over his saddle. So, without a great amount of fuss, the cast was made for the calf's foot. I understand that the calf eventually rejoined the herd.

FIGURE 8. Nesting evidence of living crocodilians. **A**, entrance to den of the American crocodile on creek off Florida Bay; **B**, nest of shell sand of the American crocodile, Florida Bay; **C**, nest of vegetation of the American alligator, Baruch Plantation, Charleston County, South Carolina; **D**, gator hole of American alligator, Baruch Plantation, So. Carolina.

A most welcomed visitor to our camp was my long time friend, Dr. Ray Lemley, veteran collector of fossil mammals of the White River Badlands in Nebraska and South Dakota. Lemley wanted to view the action at Wannagan and joined us in collecting fossil reptiles At home in Rapid City, South Dakota, he was a surgeon and rancher but wished to be addressed as a vertebrate paleontologist because of his many years of collecting, not only in the Big Badlands, but in South America, India, Europe, and Australia. Incidentally, it was Ray Lemley who first showed me how to use dynamite in the process of recovering fossil skeletons in the Badlands.

During his stays at Wannagan Camp, once in 1973 and again in 1975, he assisted with the recovery of many specimens. On one memorable occasion, early on, a crew member uncovering a specimen stated, “It’s only another skull!” Lemley reacted with, “H…, I thought discovery of any crocodile skull was something to celebrate”. At the time he did not realize that this was croc skull number 25 of our final tally of over 100 crocodile specimens. At any rate his point was well-taken.

On the morning of his departure from camp in 1975, Lemley packed his sleeping bag along with his other gear into a large plastic bag and set it outside of his tent. During after breakfast cleanup, our cook, thinking that the plastic bag was just more trash, promptly dumped it into the trash pit, which was located below the camp area, and he went off to other duties. After a long search, the missing bag was located and all, especially Lemley, had a big laugh and another cup of coffee.

Other visitors to our site this season included seven Forest Service personnel from the Billings, Medora, and Washington D.C. offices to inspect our excavation and talk about the nature of our research. News from the museum was also “good”…our grant proposal for the next two years was funded.

Other than rains, insect and snake encounters, and quarry accidents, the season was mostly uneventful. One severe case of sun exposure and heat exhaustion did, however, hospitalize a crew member in Dickinson for several days. Upon returning to camp, he and the entire crew ridgedly held to a mid-day siesta.

Heat exhaustion and heat stroke are two very serious conditions that may result from prolonged exposure to the sun! Any fossil collector should be aware of emergency treatment for each!

By late August an additional 173 field jackets were crated for shipment to St. Paul. The typical inventory of supplies and equipment left in the field, at the Adams Ranch, for next season’s use included the following materials:

Plaster (600 lbs)	Tarp 8x12 (2)	Cot w/covers (15)
Burlap (good supply)	Shellac (10 gal.)	Folding Chair (6)
Alcohol (6 gal.)	Linseed Oil (1 gal.)	Folding table (2)
Penta (3 qts.)	Canvas Preservative (5 gal.)	Stove (1)
Lumber (for crates)	Water Can 5 gal. (6)	Gas Can 5 gal. (4)
Nails (3 boxes)	Gelatin capsules (500)	Wooden Stakes (1 crate)
Tent, 9x9 wall (6)	Tent, Kitchen 9x18 (1)	Tent repair kits (2)
Shovel, 2 (10)	Shovel 2 square (2)	Banding tool (1)
Probes and brushes (many)	Hand tools (1 box)	Wheel barrow (3)
Water trailer, 150 gal. (1)	Outhouse (1)	

The field crew of 1975 is shown in figure 9.

1976

As the excavation steadily yielded various specimens, trace fossils were also accumulating. Most abundant were coprolites identified as those of crocodilians because of their characteristic form, great numbers and likeness to the feces of living crocodiles (Hallgren 1987; Sawyer, 1998). Crocodilian feces are most often deposited in water at the place where feeding occurs. Fossil Lake Wannagan with its large population of crocodiles, was the source of the majority of coprolites. Burrows of oligochaete worms and decapods were also present, especially in shallow water sediments near the shore and in the beach sands as indicated in Figure 6. It was not until 2002, during post quarry survey work in the area, that crocodile and invertebrate foot tracks mentioned earlier were discovered in coeval mudflats near the quarry site (Erickson, 2005). The deposits that produced these trackways had not been subjected to the extensive bioturbation, as in the quarry deposits, and therefore were preserved much as they were originally made. As for coprolites, 764 specimens, by actual count, are now catalogued in the museum's collections.

FIGURE 9. Wannagan Creek field crew of 1975. Left to right standing: Tom O'Brien chief preparator, Mike O'Brien student, Bruce Chuchel student, Charles Faraci cook, Bruce Erickson paleontologist, James Guyer student, Robert Spading photographer/preparator, Curt Hudak geologist, Robert Melchior paleobotanist, Kneeling: Tim McCutchen student, Peter Ganzel preparator.

A major improvement to the quarry operations was installation of a work station. This was a prefabricated 8' x 16' shack, similar to a ranch line shack. Its purpose was to house a microscope table, a large wall map, upon which daily progress in the quarry could be plotted, as well as a dry place to do photo and microfossil preparation (Figure 10, A, B). Two bunks were also added. Our line shack served well for 20 seasons. Today it serves as a tool shed on the Olstad Ranch. A further descriptive note on the line shack: the upper half of each side of the shack was covered with canvas that could be rolled up during hot days. As noted, cattle would occasionally invade our camp --- usually at night and it was not unexpected to be awakened early in the morning by a steer rubbing it's back on a corner of the shack. Cattle would chew holes in the canvas, especially during times when the shack was unoccupied between field seasons. We replaced the corrugated roof only one time because of storm damage and the chewed canvas when needed. Two tents were lost to storms this season.

Discovery of an alligator was a highlight of the 1976 season. A complete skeleton found at quarry location (M - 15) established its coexistance with the crocodile *Borealosuchus (=Leidyosuchus).* The occurrence of this second crocodilian taxon at Lake Wannagan was not unexpected knowing the record of five or six crocodilian taxa that occupied Lake Messel during the Eocene in Germany. Among those several crocs the Messel alligator, *Allognathosuchus,* probably filled a roll similar to that of *Wannaganosuchus* in Lake Wannagan. They may have indeed represented congeneric taxa.

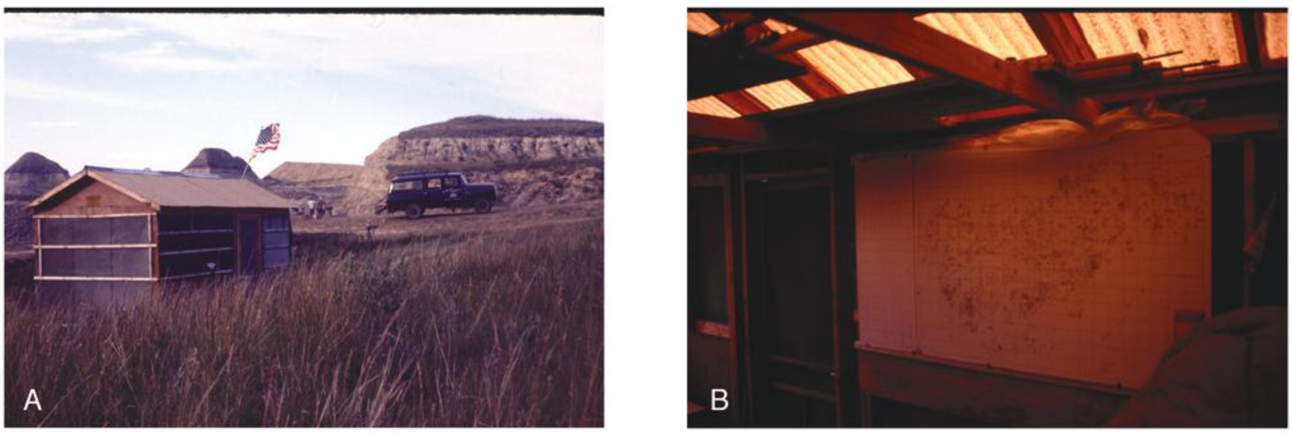


FIGURE 10. **A**, line shack at Wannagan Creek Quarry site; **B**, inside view of wall map of quarry.

Mammals collected this year included a rare skeleton of the primate relative *Plesiadapis.* It is especially significant because its skull is mostly intact, however partly crushed, and one of a few *Plesiadapis* skulls known from North America. The first new species of fossil plant *Oreopanax dakotensis* was named and described from Wannagan Creek Quarry (Melchior, 1976).

1977

In 1977 the museum appointed Dr.Wendell A. Mordy to the position of museum president. He soon expressed interest in the ongoing research in North Dakota and provided various supportive measures such as an immediate assist to the work at the Wannagan Creek project which came through negotiations with Burlington Northern R.R. to insure trasportation of large numbers of excavated specimens from the site to the museum. The loan of a semi-trailer, set out at the quarry site, early in the season, could be loaded with crated fossils throughout the season. Near the close of field operations at the site, the BN dispatcher, in this case in Glendive, Montana, was contacted, and a semi-tractor was sent to pick up and haul the loaded trailer to Glendive where it was trans-loaded onto a railroad flat-car for delivery to St. Paul. This was a pattern repeated for several years, not only at Wannagan Creek Quarry, but at our Wyoming dinosaur quarry as well. Each year some 60,000 pounds of jacketed fossils were carried, from these sites, to the

Science Museum in St. Paul.

Field work during 1977 was divided somewhat evenly between the two excavations that were conducted concurrently. This was carried out with 8 to 10 crew members at each site. Long days in the quarry created the need for diversion other than what was available in the local towns. This may have been devoted to looking at Jupiter's moons through Bruce Chuckle's 10 inch reflector telescope, even when the best viewing was in the wee hours of the morning. Set against the evening's long shadows of the badlands and the nightly cries of coyotes, tales of the "Abominable Sage Man" were eagerly anticipated, especially by younger visitors in camp. Most stories were long, yet forgettable; however, certain crew members became accomplished story-tellers and the routine was established.

Visitors to help dig included: members of the Adams Ranch family, Carolyn Benepe and Jean Madsen (SMM Volunteers), Ray Lingk (rancher), Ken Sander (SMM artist), and D. Harrison and R. Ronder (Forest Rangers).

Lectures on different topics and film presentations were given often by B.R. Erickson and R. Spading to USDA sponsored YCC groups at the site, in Medora and elsewhere. This too became a normal part of field operations each season as an "Education Day" for YCC students who were helping the Forest Service eradicate leafy spurge in the grasslands.

By this eighth season, it was obvious that the rate of recovery of new occurrences had dropped off considerably. Long considered for exploration, a deep coulee in section seven to the north, seemed a logical place to expand our search for additional taxa. Several rock layers here could be correlated closely with those of the quarry area, therefore, with a new permit from the Forest Service, investigation of this "New Site", as it was designated, was begun. It differed mainly in having fewer crocodilian elements, but a relatively greater number of champsosaur bones.

The New Site provides a somewhat different picture of the paleoenvironment than does the lake basin of the quarry. Intensive propecting of this area indicates that in general fewer individuals were present and as noted earlier, skeletal remains are more intact with a fair amount of bone articulations including some complete turtles and champsosaurs. Figure 4 A, B are examples of more intact specimens.

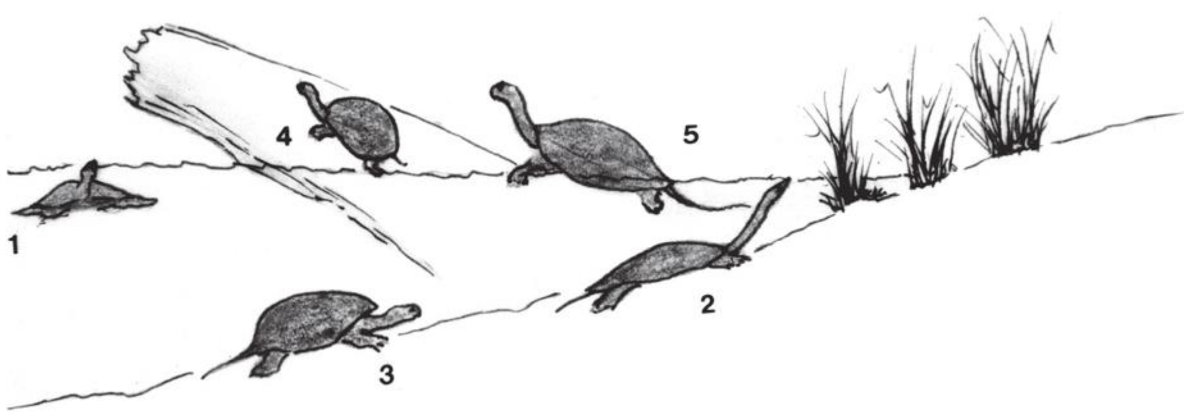


FIGURE 11. Graphic illustration of niche separation Wannagan Creek turtle population: **1**, *Plastomenus;* **2**, *Aspideretes;* **3**, *Protochelydra;* **4**, Emydids; **5**, Polycryptodira.

The assemblage of turtles at this time was already impressive and documented at least five distinct taxa within the lake deposits of the quarry although not in equal numbers. Two forms were more abundant in backwater sediments such as those of the "New Site". Figure 11 attempts to indicate partitioning of the five different Testudines found in Fossil Lake Wannagan. A common condition of the shells of turtles is the occurrence of perforating fractures. Shell punctures, when found in association with crocodiles, are strong evidence of the chelonivorous habits of the crocodiles (Figure 12). One of the most important turtle fossils discovered is that of *Protochelydra zangerli* (Erickson, 1973). This proved to represent a new genus and species and was named in honor of Rainer Zangerl, an authority on turtles, who was curator of fossil reptiles at the Field Museum in Chicago. The carapace of *Protochelydra* is rather high domed compared to the other Wannagan turtles and may be the reason why fewer crocodile tooth tracks are found. The puncture wounds (perforating fractures) that do occur are mostly in the posterior region which has the lowest profile of the shell and is the quickest grab for the jaws of the crocodile, as the turtle retreats. Turtles exhibit the greatest number of puncture wounds due to their broad flat shells. Numerous types of gnaw marks were also found on many different bones of different taxa. Figure 13 A, B presents examples of scavenging tooth marks from small mammals like *Plesiadapis* and multituberculates. As most of the mammals at Wannagan possessed "incisor tusks" and other cutting teeth (Figure 14), it would be difficult to identify the form responsible for doing much of the gnawing.

A detailed assessment of the Wannagan Creek area biotope was important in the decision to visit Grube Messel and other early Tertiary locations in Germany. By February 1977 arrangements had been made with Senckenberg Museum, Frankfurt-an-Main; The Hessisches Landes Museum, Darmstadt; and Staatlichen Museum fur Natarkunde, Stuttgart; to visit their collections and to collect fossils at Grube Messel. While at the Senckenburg Museum I presented a lecture on the work at Wannagan Creek Quarry and Grube Messel. Messel provided an excellent general analogue to Wannagan Creek whereby comparison between many similar taxa and environmental conditions could be made. The occurrence of "stomach stones" for example, brings up a question. Stomach stones or *magensteinen* that are ingested by living crocodiles to provide ballast for hydrostatic control in water, are found with the crocodiles at Messel as well as the crocodiles of des Geiseltales, another similar deposit in Germany. Where are the stomach stones of the Wannagan Creek crocodiles? None were found, and one wonders what may have been used as a substitute by the North Dakota crocodiles. One possible explanation is that separate vertebrae of dead animals, as well as other bony substitutes may have been utilized. However, unlike the usual "stony" stomach

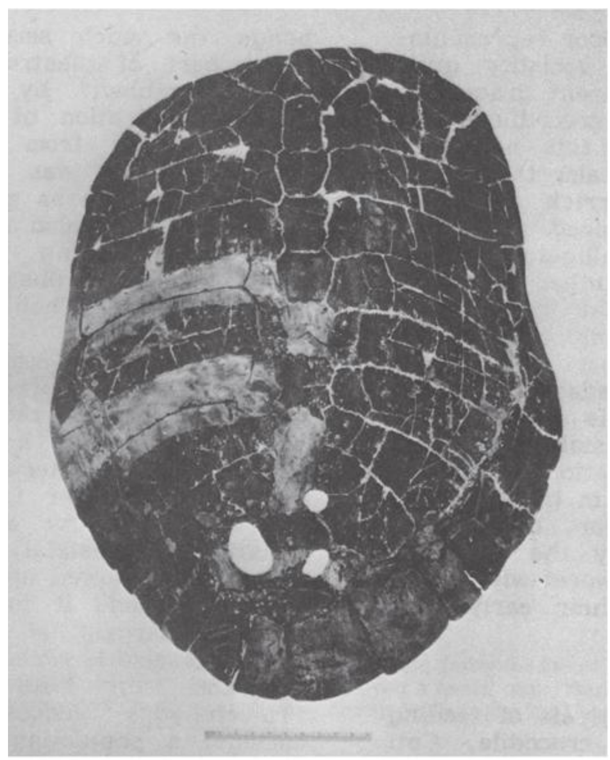
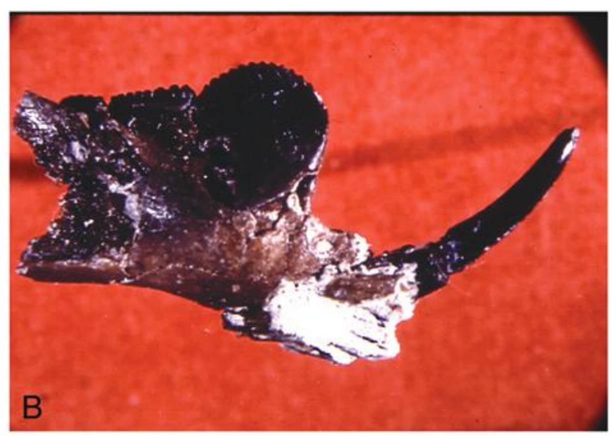


FIGURE 12. Carapace of *Protochelydra zangerli* with perforating fractures attributed to an encounter with a crocodile. Scale bar equals 10 cm.

stones, ingested bones gradually dissolve in the highly acidic conditions of the crocodiles stomach and would not last long before needing replacement. This may partly explain the paucity of vertebrae and small bones required to equip the 100 plus crocodile skeletons found at the site in North Dakota.

FIGURE 13. Evidence of scavenging by small mammals. **A**, metatarsal of crocodile with tooth marks; **B**, bone with either or both tooth and claw marks.

FIGURE 14. Mandibular teeth of Wannagan Creek mammals; **A**, left mandible of *Plesiadapis* with teeth in place including the incisor tusk; **B**, left mandible of multituberculate with teeth in place including shering tooth and incisor tusk.



1978 - 1979

Early meetings in 1979 with Forest Service ranger Berkhardt and archaeologist Radson were held to enlist our help in determining the potential paleontological importance of certain locations scheduled for development by oil companies in the Black Tail area some miles east of the Wannagan Creek site. This was a mutually productive quest as it provided us an opportunity to collect specimens, such as an unusual champsosaur skeleton that may represent a species distinct from the larger *Champsosaurus gigas*. Paleoenvironmental information was also acquired. Soon after the survey of oil sites in the Black

Tail area, SMM research associate, T. Sawyer, arrived at camp. His visit was preparatory to examining the quarry fauna before we finalized our second scheduled trip to the Paris Basin to look at Paleocene crocodiles and champsosaurs from Cernay and Berru in France.

FIGURE 15. Trester's "crop duster" used for our aerial reconnaissance over the Wannagan Creek badlands.

FIGURE 16. Aerial view of Wannagan Creek Quarry looking south over the working face of the excavation. Also seen are field vehicles, BN semi trailer, kitchen tent and access road. Plaster field jackets are also visible in the quarry. Photo by R. Spading 1979.

With resumption of work at Wannagan local rancher H. Olstad and his D-4 bulldozer was put to service removing large amounts of overburden at quarry coordinates L/M-9 and N-11. In this area of the quarry there were many more deeply embedded fossils than we could recover in one day. Therefore, a few evening sessions were organized to map and collect specimens by lantern light. It isn't often that fossil crocodiles are found in such great concentration as they were here. With the large number of specimens, it was now feasible to make a rough judgement concerning the population. Statistics of living crocodile populations that have been studied, for example, shows that most individuals are females and the very few unusually large individuals are males. Of the fifty complete and partly complete adult skulls in this collection, only three are exceptionally large. These are regarded as old males. If this evaluation is correct, the Wannagan Creek assemblage is not very different in this respect from living populations of the American and Nile crocodiles wherein only a few of the average-size specimens represent males.

Our first aerial survey of the overall area was also accomplished, with the assistance of local pilot B. Trester. As a veteran crop-duster, Trester's low-altitude skills with his short-wing, piper cub (Figure 15) were not only needed for our purpose of filming and photographing the distinctive "Blue Beds" and abandoned channels (paleochannels), but afforded us remarkable sightings of nesting golden eagles on badland pinnacles. Lithologically the "Blue Beds" which also represent lacustrian deposits, are distinct from the lake deposits of Wannagan Creek quarry silty shales and did yield some fine specimens. A few grassy tables in the area were suitable for repeated landings and takeoffs. This was not a problem for the versatile, small airplane. Figure 16 is an aerial view of Wannagan Creek Quarry. Note the BN semi-trailer set out for loading fossils. By the time to break camp, 107 crated field jackets had been loaded into this trailer for shipment this season. Jane Brody, *NYTimes*, visited to write an article on our field project at Wannagan Creek which was published in *NYTimes* September 1979.

Early 1980's

A visit to the Paris Natural History Museum in 1980 was made to study the French champsosaur, *Simoedosaurus,* as well as to present a lecture on Wannagan Creek research at the Sorbonne.

A fine specimen, consisting of a complete skeleton of *Simoedosaurus* was recently discovered in western North Dakota and described as the new species, *S. dakotensis,* (Erickson, 1987). This new specimen has implications for the origin of *Simoedosaurus* as it is the only described skeleton from North America from deposits somewhat older than those at Cernay and Berru in the Paris Basin.

So far a single species of champsosaur, *Champsosaurus gigas,* (Erickson, 1972) is the only taxon recognized in the deposits at Wannagan Creek, however, among the abundant remains of champsosaurs, there is evidence of a possible second species, other than *Simoedosaurus* -- to be discussed later.

Among the fossils collected in France at this time were numerous coprolites to be studied by research associate T. Sawyer. Coprolites are fossilized feces, in this case from champsosaurs, to be compared with those of Wannagan Creek specimens. Identification of reptilian coprolites is usually based on morphology (Sawyer, 1981). Crocodile coprolites have a characteristic morphology with bending and concave terminations (Milan and Hedegaard, 2010; B.E. pers. observ). Distinctions between those of crocodiles and champsosaurs are conjectural (Sawyer, 1981). They are the most abundant ichnofossils from Wannagan Creek. Figure 17 compares various coprolites from Wannagan and Europe.

FIGURE 17. Various crocodile and champsosaur coprolites from Wannagan Creek Quarry, Berru and Cernay, Paris Basin sites. The largest 4 specimens are putative crocodile coprolites.

During some winter months R.Spading and I began what was to become an on-going study of the American Alligator, *Alligator mississippiensis* in the southeastern coastal states of North and South Carolina, Georgia, and Florida. During the winter, our work on the living North American crocodilians lasted over a period of about 8 years. Early in this period (1980 - 1982), I was resident at Belle Baruch Research Station (Hobcaw Barony) near Georgetown, South Carolina. Here was a large undisturbed population of American gators that was most of the time accessible for study in terms of their behavior and habitat. A great amount of data gathered here was directly applicable to Wannagan Creek.

In 1982 I had occasion to visit the Charleston Museum where I met curator, Al Sanders. The Charleston Museum at this time was beginning a collection of fragmentary vertebrate fossils from the Late Paleocene Williamsburg Formation which included crocodile and turtle remains. This material is in part coeval with the Wannagan fauna, of the western interior and offered a chance to compare different subtropical environments of a freshwater flood-basin and a coastal plain estuary system.

Meanwhile back at the ranch, the Wannagan Creek site once again had witnessed near loss of our camp to severe winds and rain. Flattened tents required patching and mending before resumption of quarry work. “Cookie” (C. Faraci), became the camp’s best “sail maker” as shown in Figure 18.

Mapping became the main task as shoreline features were being exposed. A sketch map (Figure 7), from my field notes of July 1980, records this section of the excavation with its sand cusps and three partly buried skeletons of *Borealosuchus* (skulls in silhouette). Each skeleton is mostly complete, but many of the separated elements were not visible during mapping. Other specimens found here include numerous mammal bones, turtle fragments, and coprolites. Periodic flooding of this area is indicated by the upward fining of sediments and a number of small sand domes. Bottom conditions at the pinchout margin (wave base) of the lignite (Figure 6) were relatively free of vertebrate remains. Water depth at this point was estimated to have been about one meter where carcasses floated and drifted toward the shore. The greatest concentrations of bones occurred either along the shoreline or in deeper water deposit where the bottom had thick accumulations of mud and plant debris to hold remains. Long bones were occasionally found *in situ* standing upright. This suggests that one end of the bone contained a pocket of air which gave it buoyancy and allowed it to float vertically. When it contacted the soft muddy substrate it settled in a vertical orientation.

FIGURE 18. Charles Faraci at camp patching tent canvas after a recent storm.

Eighty separate skulls of *Borealosuchus,* in various states of articulation, were recorded eventually among the vertebrate materials of Fossil Lake Wannagan. Another 20 plus skulls were identified on the basis of incomplete fragmentary crania. Of the intact skulls only 16 were oriented lying flat, with the dorsal surface of the skull facing upward; 25 skulls were found with the palate facing upward; 4 skulls were resting on one lateral side, deeply imbedded in the sediments. These orientations were determined by the mobility of the sediments, bottom currents, and by skull buoyancy. Only about 6 skulls were located with an articulated mandible, yet most skulls had associated mandibles, or fragmented mandibles. Taphonomically, the most unusual occurrence of skulls is the group of three that are stacked one upon another at quarry coordinates M, N - 1, 2 (Figure 19). Their association with a submerged log was likely caused by water current. These three skulls were incorporated into one field jacket F66-83. The field number indicates that it is the 66th field jacket removed in 1983; “F” indicates the Wannagan Creek site.

Among the many taphonomic aspects of Fossil Lake Wannagan, bone modification was common as will be discussed later under the paleopathologic conditions that were found. Disassociation of skeletal parts was also a conspicuous feature of the bones especially when plotted on a map.

Between 1981 -- 1983 both the North Dakota site and the Wyoming dinosaur site were worked intensively and extensively. Discovery of the skeletons of *Diplodocus* and *Camptosaurus* at Poison Creek Quarry, Wyoming, required additional hands which meant reduction of the crew in North Dakota for the next two seasons. Quarry operations in North Dakota continued, however, with deepening of the drainage ditch and concentrated efforts in the lignitic deposits.

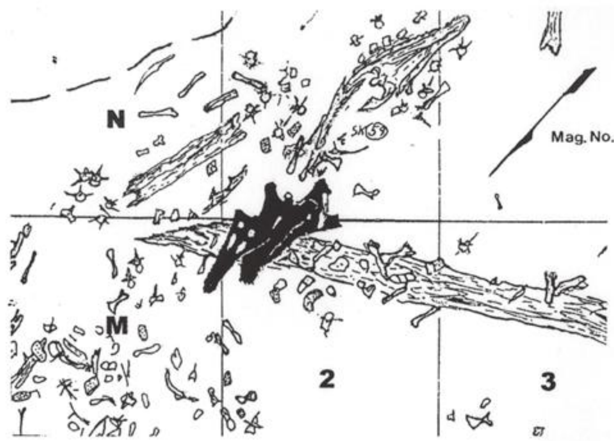


FIGURE 19. Map section of quarry at M,N/1,2,3 with three crocodile skulls *in situ* (silhouettes) stacked upon one another lying over a bottom log.

The Forest Service expressed interest in an "Education Day" at the Wannagan Creek site whereby our excavation could provide a special "day-a-month" for the YCC (Youth Conservation Corps) members to assist and learn some field techniques and methods of paleontology. This arrangement allowed the student group time away from their routine duties of eradicating leafy spurge from the grasslands. Our program with the YCC worked well for several seasons.

A second project with the USDA involved assembling an exhibit of the Wannagan Creek flora and fauna at the Forest Service main office in Dickinson, North Dakota. After completion by our crew this exhibit remained in place for several years and provided Forest Service personnel (as well as many visitors to the USFS Office) with information on research in the area other than that related to petroleum geology.

A list of visitors to the excavation included: crocodile researchers Graham Webb, New South Wales, Australia; and J. Lange. Curt Hadland, SMM biologist, set up a lab to collect and prepare recent birds and small mammals for SMM's biology collections.

1984

With the opening of the quarry in 1984, two skulls, numbers 57 and 60 were soon discovered near the three stacked skulls previously noted. Each of these skulls was buried or sandwiched in a thick cover of the broad fossil leaves of lily and sycamore. Members of the North Dakota Paleontological Society assisted our paleobotany crew with the recovery of many fine examples of fossil plants from these carbonaceous shales.

The list of other visitors to the site included: Prof. Bud Holland, Univ. of ND; Mike Brauer, NDPS; and new crew members: Dave Engberg, SMM; Nan Pickett, Univ. of WI; Mike Leite, Univ. of WY; Chris Heinz, Ken Zentzis, LeRoy Pomraning, some of whom joined the crew to continue the work at Poison Creek dinosaur quarry in Wyoming. After we broke Wannagan Creek camp late in July we moved the outfit to the Arno Ranch

FIGURE 20. SMM president James Peterson during visit to the Wannagan Creek site to dig for fossils in 1985.

in Wyoming, where our second quarry was located. A day or two was required for the crew to become acclimated from digging croc bones to dinosaur bones. The field crew also learned the term "Dry Thunder Shower", in local usage indicating a rainstorm which does not deposit enough water to hold the dust down. It does sometimes produce high winds and we did lose one tent as I recall which was replaced the following season.

1985

In 1985 a new 150 gallon "water mule" replaced the two beat up water trailers we had used for some time. As usual, road repairs had to be made and one small bridge to our North Dakota site was repaired by adding a few wooden planks to its top. This was a time when oil exploration in the area had just begun, and the roads and trails were not yet designed for heavy truck traffic.

Late in June, SMM president James Peterson arrived at the site to participate in some field research (Figure 20). After spending the first night when the temperature was 39.5 F. degrees, he much appreciated the loan of a sleeping bag from crew member Dick Benson, who fortunately had a spare with him. As with other special visitors, the president was treated to an original experience….the now "famous", at least in some quarters, "Wannagan Sling". At times while sitting out some very inclement weather for several days, it was inevitable that the Wannagan Sling was invented. The improvised recipe from our larder: Tang (hot), 2 measures of Brandy, and Maraschino cherry juice.

During mid-season, at the request of the Forest Service once again, we investigated several potential oil lease sites for their paleontological importance. Three site S, Teneco Oil drilling pads in the Black Tail Coulee area, Billings County, all were found to have high paleontological importance. One of these sites, in fact yielded a fine skeleton of an unusual champsosaur. Ranger Barry Berkhardt of the Dickinson office assisted with its recovery. Other Oil drilling pads, Billings County, south of Medora were found also to have high paleontological value. Our recommendations (impact statements) were filed with the Forest Service. Such investigations are not always welcomed by the oil site developers, especially when we might recommend preservation of the site for scientific purposes rather than for petroleum.

The 1985 field season was also one of a very heavy grasshopper invasion. On several occassions, crop dusters sprayed Malathion over the area and by the end of August there were no surviving hoppers. We also were informed at the time by the rangers that the chemical spray was harmless to people; however, it was stated that if our vehicles were sprayed, they should be washed to prevent the paint from deteriorating.

Near the end of the 1985 season, paleobotanist R. Melchior, (who had been associated with the Wannagan Creek project for some time) and I participated in a field conference on Dauphin Island, Alabama. The symposium "Peat Accumulating Environments", hosted by the University of Alabama, afforded us an opportunity to examine a modern analogue of Wannagan Creek. Discussions with numerous botanists were applicable to the work in North Dakota and several days were spent in the forbidding gator infested swamplands bordering Mobile Bay to acquire some first-hand knowledge about this classic croc environment. Much of this time in Alabama was given to making comparisons with the present-day Australian crocodiles, especially in light of the several different species being compared. This all focused back on the Wannagan Creek population of crocodilians in their special habitat.

1986 - 1990

Our new "Academic Disturbing Permit" which was an extended land use permit, covered more of section 7 and section 18 in Billings County, for an additional 960 acres of grassland and badlands. This now allowed us to remove many specimens that had been discovered by our prospecting efforts during earlier field seasons.

To the north and some miles east is present-day Lake Sakakawea where our search continued. Along its north shore, near Tioga, the familiar "Blue Beds" showed up with their abundant gastropods and bivalves. Collecting in these beds as well as above and below them was interesting, but lacked the variety of vertebrate taxa encountered in the Wannagan Creek area. Remnants of a forest was indicated by numerous tree stumps and trunk sections of what were believed to belong to either *Taxodium* (Cypress) or *Metasequoia* (Dawn Redwood), which are found abundantly represented in the Sentinel Butte Formation which is younger than the Wannagan Creek site. Associated with the deposits near Lake Sakakawea were isolated fragments of champsosaurs and scarce remains of the large Paleocene mammal *Titanoides,* which had not yet been recorded at the Wannagan Creek area.

To assist in interpreting the stratigraphy closer to our site, two different-sized augers were borrowed from the Soil Conservation Service in Beach, North Dakota. Bore holes made in the floodplain sediments at the quarry and well beyond the quarry verified the extent and thickness of the various flat-lying layers of The Bullion Creek Formation. Many abrupt biofacies and lithofacies changes were found to be essential for our correlations, especially from one butte to another. The 1986 field season concluded after removal and shipment of many field jackets.

FIGURE 21. Examples of bone pathologies from Wannagan Creek Quarry. **A**, smooth periosteopathy of crocodile pubis; **B**, spondyloarthopathy of crocodile metatarsal/phalanx; **C**, oblique fracture with secondary osteomyelitis of crocodile tibia; **D**, oblique fracture of small mammal bone; **E**, periosteopathy of crocodile vertebra in ventral view; **F**, malformation of crocodile chevron.

In 1987 and 1988 examination of the pathological conditions found in both recent and fossil crocodilian specimens was undertaken to assist with the interpretation of such conditions in the Wannagan Creek forms. Collections of several museums in South Carolina, Georgia, and Florida were visited as well as privately held collections. Many relevant specimens were examined. All of the pathologies that regularly occur in the North Dakota fossils were recognized in Recent specimens in these collections. This points out the unchanged nature of disease through time, at least in some reptiles. Six distinct pathologic structural varieties were found among some 75 examples of crocodile bones in the North Dakota assemblage. Some are shown in Figure 21A - F. Examples are reported here in order of their frequency of occurrence: *periosteopathy* (disruption of superficial bone, secondary to trauma); *fractures;spondyloarthropathy* (inflammatory joint disorders); *osteomyelitis* (infection and bone destruction); *exostoses* (abnormal bony projection); *congenital malformations* (also see Sawyer and Erickson, 1998).

Observations of encounters between living crocodilians demonstrates the causes of some abnormalities, especially those involving traumatic etiology such as wounds, and explains the prevalence of periosteopathy and fractures.

Turtle pathologies show up as well, mostly as perforating fractures of the shell. As previously mentioned, shell punctures are attributed to the chelonivorous habits of crocodilians because of the close association of the two reptiles and the match found between tooth and puncture patterns. It should be noted also that present-day crocodilians frequently seize turtles but often fail to crush them and leave only tooth marks (personal observations). An unusual occurrence among the turtle remains is a partial plastron of *Protochelydra zangerli* with pits on both visceral and external surfaces possibly caused by feeding dermestids (Fig. 22). Close inspection of these pits reveals mandibular marks of dermestid beetles (Fig. 22 B, C). According to Britt et al. (2008) extant dermestids feed on lipid laden bone tissue and leave minute scratches from their apical teeth such as those shown in Figure 22 (arrows).

1989

Lake Wannagan, and its backwaters, were large enough to allow niche separation (partitioning) of its turtle population. Living turtles require certain environmental factors of temperature, water depth, cover, and food sources for spacial separation. It is evident that these conditions were present at Wannagan accounting for turtle spacial distribution in the lake as well as in backwaters. By 1989 Wannagan turtle finds exceeded the number of elements expected. Semi-articulated and many complete shells as well as intact skulls brought the number of individuals to well over several hundred specimens. *Protochelydra* is the most populous of the Testudines with over 200 specimens by itself. The remains consist of complete shells, skulls, mandibles, and large numbers of separate elements of adults and sub-adults.

Two soft-shelled trionychoids, *Aspideretes* and *Plastomenus* are distributed throughout the area. The latter is less abundant and was found mostly in paleochannel deposits. Complete shells of various sizes including those of hatchlings are among the remains. These have not been studied in detail, but it is likely that several species are present. Largest of the Wannagan turtles are polycryptodires with shells measuring about 50 cm across. Emydids, which are rare in the Paleocene, are represented by at least 6 individuals in various stages of completeness. These are small forms with shells some 11-12 cm across. They are found mostly in deposits at the “New Site” in section 7, and in carbonaceous shale facies of Lake Wannagan. In this flood basin environment turtles were found with equal frequency in both lacustrine and paludal sediments.

Among evidence of amphibians a few anuran bones and trunk vertebrae of the salamanders

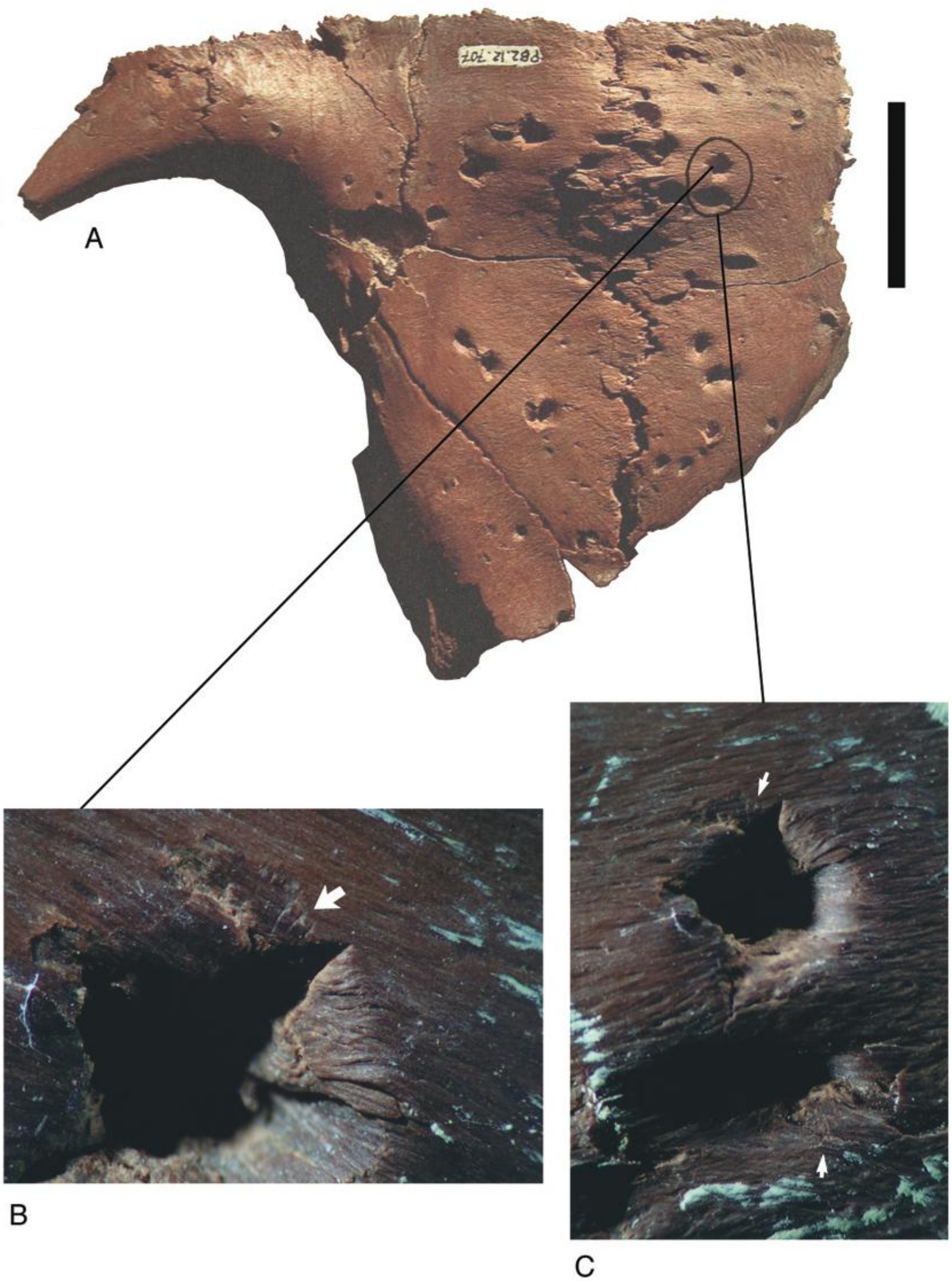


FIGURE 22. **A**, articulated left and right hyoplastra and left xiphiplastron of *Protochelydra zangerli* showing pitting from bone dermestids scale bar equals 3 cm; **B** and **C**, enlargements of pits on right visceral surface of hypoplastron (circled) in **A**, Dermestid mandibular marks inidicated by arrows, pit openings approximately 2 x 2 mm and 2 x 5 mm.

FIGURE 23. One of 12 small blocks of matrix containing the skeleton of a salamander. The blocks were separated from one another when they were collected at quarry location N – 17 in 1976. Arrow indicates the skull associated with hyobranchial elements and vertebrae of one individual.

FIGURE 24. Articulated cervical and dorsal vertebrae of large champsosaur *in situ*. Typical of specimens collected from backwater paleochannel sediments of section 7.

Piceoerpeton P76.28.237 and P76.28.238 (Naylor and Krause, 1981) a series of 9 articulated vertebrae P95.17.1 and a skeleton with skull and mandible (Figure 23) make up the salamander materials found.

Figure 24 is a partly articulated, adult skeleton of *Champsosaurus gigas* that is characteristic of vertebrate remains found in backwater sediments of section 7, but not typical of those from the lake deposits. Its main significance here is its relatively large size and its state of articulation. Individual elements that occur in the lacustrine sediments of Lake Wannagan represent mostly small disarticulated specimens with vertebral lengths of about 1- 2 cm. Individuals from backwaters and from interfluve deposits are mostly adults having vertebrae with overall lengths of 2.5 - 3.5 centimeters. Unlike crocodilians, we know nothing of reproduction in the champsosaurs, yet it is likely that they too nested on dry land. The more insular locations such as small hummocks, within the backwaters, were evidently places for nesting; however, young individuals are most abundant away from these potential nesting locations, perhaps for their own protection from adults. In this behavior they may have resembled that of male crocodilians that may prey on their own young. It is also of note that long bones (humeri and femora) of adult champsosaurs show modest morphological variations, which suggest either taxonomic difference, or that the stouter, more robust long bones belong to females that traveled overland, especially during nesting times, and were more ambulatory than the males whose long bones were best adapted for swimming. Vertebral lengths evidentaly are not diagnostic of possible distinctions between males and females.

An estimated 200 mammal specimens had been collected by now; however, many had not been found on the surface as they were unexposed in the matrix surrounding larger fossils that had already been jacketed. Many of these specimens were teeth or other small isolated elements. Mammalian teeth were concentrated along shoreline facies, especially where they had been deposited by slow water currents in small eddy pools. One group of 22 specimens, including mandibular halves, fragmented limb parts, and teeth, is suggestive of material that may have accumulated beneath the favorite perch of some "Paleocene raptor" as indicated by the arrow in Figure 7. Largest of the Wannagan Creek mammals is *Titanoides,* that is known from only a few specimens outside of the quarry limits. A somewhat smaller, large dog-sized Condylarth is *Phenacodus* which occurs in the lake deposits as well as elsewhere as separate teeth and limb fragments. *Phenacodus* was a wide-spread genus and occurs in the late Paleocene deposits in southeastern states.

1990 - 1991

The field seasons of 1990 and 1991 were once again mostly devoted to quarry operations at our dinosaur site in Johnson County, Wyoming, where major portions of two sauropod skeletons were being removed.

In the Wannagan Creek area, the presence of near by present-day anthills on outcrops of the Sentinel Butte Formation required investigation. As we have found elsewhere, some of these modern ant mounds were a lucrative source of small fossil mammal teeth and bones. They were mined intensely for any possible quarry taxa. The ants that construct these mounds routinely utilize small objects, such as small pebbles, fossil wood particles, and certain-size mammal teeth about 2 - 4 mm in diameter, to roof their dome-like colonies. Prospecting the "roof" for small fossils is simple and requires one person to pick specimens from the roof and a second person to keep the ants at bay. Ant stings and bites on one's arms and legs are unpleasant to say the least. Collecting this way is usually rewarding; however, in this case, not part of the Wannagan Creek assemblage.

Ants may retrieve suitable-size objects from considerable distances. This fact is important to the collector for locality data about small mammals. To determine just how far the ants will travel to collect materials, involves the simple technique of making several concentric rings of colored, 2 - 4 mm-sized beads, at measured distances, around the ant mound. Each ring contains only one color bead. As the different colors of beads show up on the anthill, the distance traveled by the ants to collect can be recorded.

After collecting material from anthills, the crew left for Wyoming. Paleobotanist R. Melchior and an assistant remained at the Wannagan site for some time, to collect more plant fossils and complete our inventory before departing the site late in August 1990.

Despite unusually wet conditions at the North Dakota quarry, the 6 person field crew of 1991, under Tom O'Brien, collected some 19 field jackets and some fine alligator materials in the Winter Creek area near the main quarry. This was a relatively short season, June 13 - August 8, mostly due to weather conditions; yet, as with all other seasons, productive.

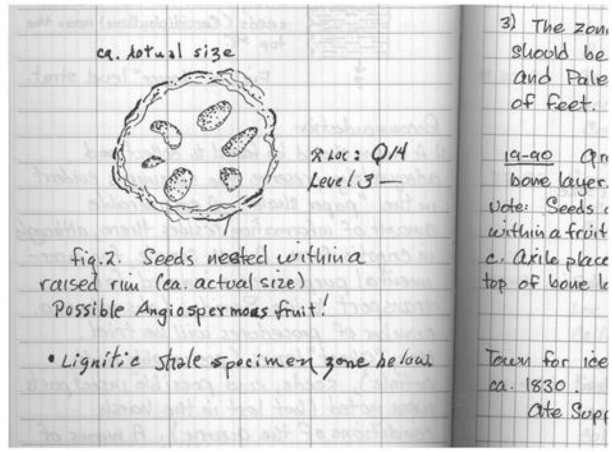


FIGURE 25. Field sketch of plant remains (angiospermous fruit) *in situ* – too fragile to remove from site.

Every season megafloral materials were added to the collections from all levels of the site. Most productive was level 2. Upon stripping overburden at quarry coordinates H-1 towards M-2, ghost leaves with cuticle as well as several kinds of seeds divulged the presence of angiospermous fruit showing c.axial placentation. Figure 25 from the field notes explains this interesting occurrence. Associated, thinly-bedded, fissile sediments furnished many fine seed specimens for the collections. Some of the largest leaves, for example those of *Platanus,* with leaves over 25 cm across are recorded in field notes and on the quarry map. Coalified tree branches and logs, that were once afloat in Lake Wannagan also appear on the map. Logs stranded in shallow water became barriers and traps for skeletal parts and other debris that was moved by bottom currents. In one case, the three stacked crocodile skulls mentioned earlier (field jacket number F66 - 83), piled up against a submerged log at quarry location M/N - ½. This chance event resulted from the wave swash which moved the skulls along the shoreline. Much of the forest upper story over the area was provided by large trees such as *Metasequoia* (Dawn Redwood), *Taxodium* (Cypress), and *Platanus* (Sycamore) that also contributed substantially to the development of the lignitic layer (level 2). By 1991, 1356 field jackets had been transported to the museum from the site. About 50 of these jackets contained scores of plant parts, some of which are shown in Figure 26. As discussed earlier the invertebrate fossils found at Wannagan Creek are known from actual specimens (body fossils) as well as from various kinds of traces (ichnofossils) namely burrows and trails. Among the few insect remains in evidence are an odonate wing, a probable damselfly wing, pupa, and beetle elytra. Evidence of the work of bark beetles was found on some tree remnants. A short trackway of a new species of arthropod is that of *Kouphichnium pentapodus* (Figure 27) which was collected during post-quarry prospecting in the "New Site" area. The only trace of vertebrate other than coprolite evidence, is the trackway of a crocodile - *Borealosuchipus hanksi* (Erickson, 2005) also from the "New Site" area. Shallow water sediments and mudflats were the most productive of these trace fossils in places of little bioturbation. It is also of note that

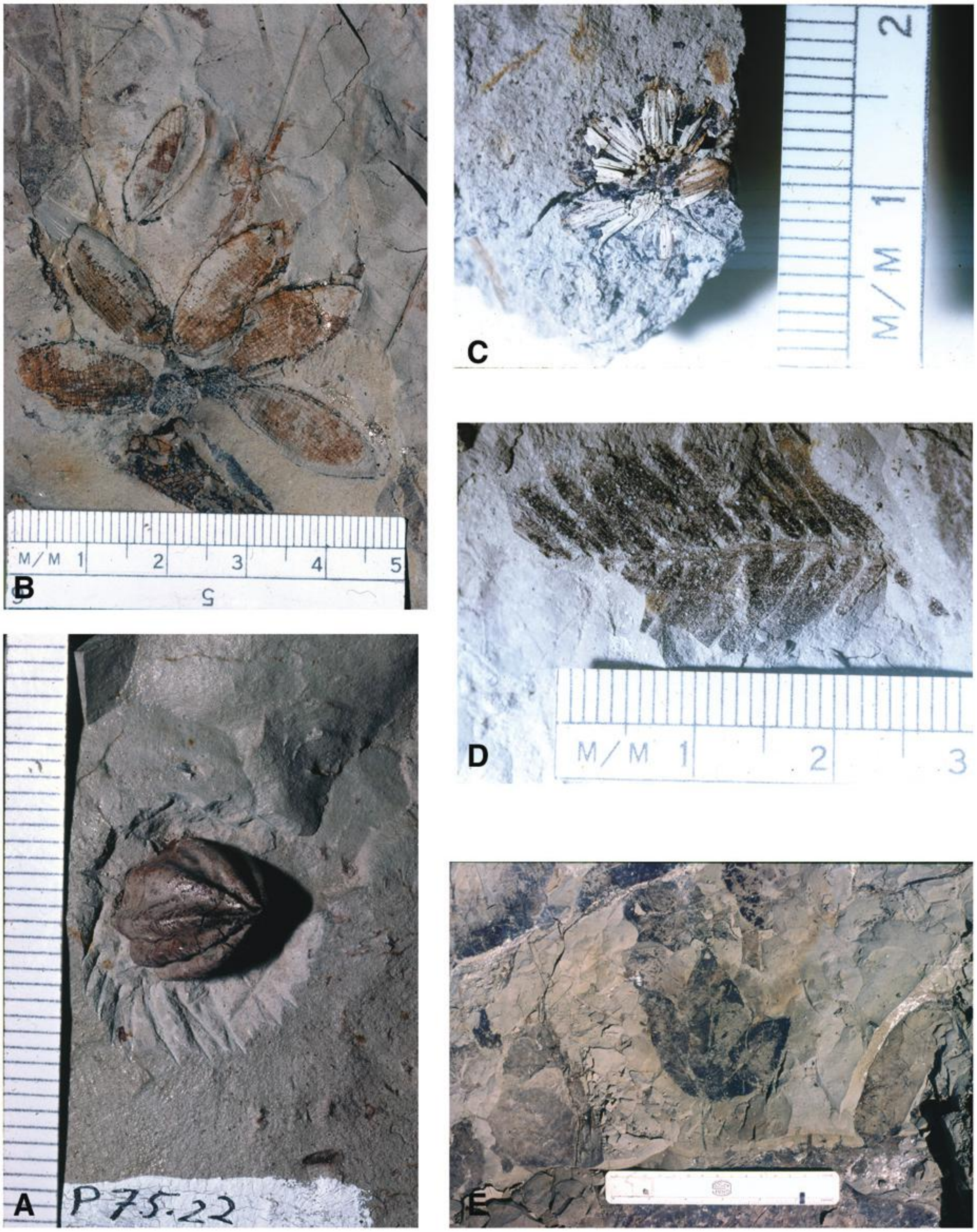


FIGURE 26. Plant remains of Wannagan Creek Quarry *in situ*. **A**, seed (nut) of undetermined taxon; **B**, seed cluster of *Cercidiphyllum* (Katsura tree); **C**, *Sparganium;* **D**, leaf of *Metasequoia;* **E**, leaf of *Platanus* (Plane tree).

nearly all of the ichnofossils recovered were eventually recognized as new taxa (previously unknown taxa).

1991 - 1993

1991-1993 work at Wannagan was paced to accommodate all of the activities at the quarry yet to be accomplished under our new 5-year permit. Our crew was held to ten individuals. During 1991 and the following season 1992, we did some road repairs that allowed us access to the site. This task always required filling of outwashes and occasional bridge work on the single dirt (mud) track. By mid-season of 1993 most of the roads, used to transport oil from local wells, were usable without 4-wheel drive - at least when they were somewhat maintained by the oil companies.

Scaling-down of quarry operations began in 1993 by removal of the debris that usually accumulates at a quarry site. Remnants of wooden structures, old burlap and plaster, non-serviceable equipment such as an old gas refrigerator and field stove along with irreparable tentage, all required hauling. This year three tents were lost to storms and were added to the list.

Early in the season, time was allowed for participation in the paleontological symposium, held at nearby Bowman, North Dakota to honor Marshal Lambert, curator of the Carter County Museum in Ekalaka, Montana. Lambert, for many years, collected vertebrate fossils in Montana related to our work at Wannagan Creek.

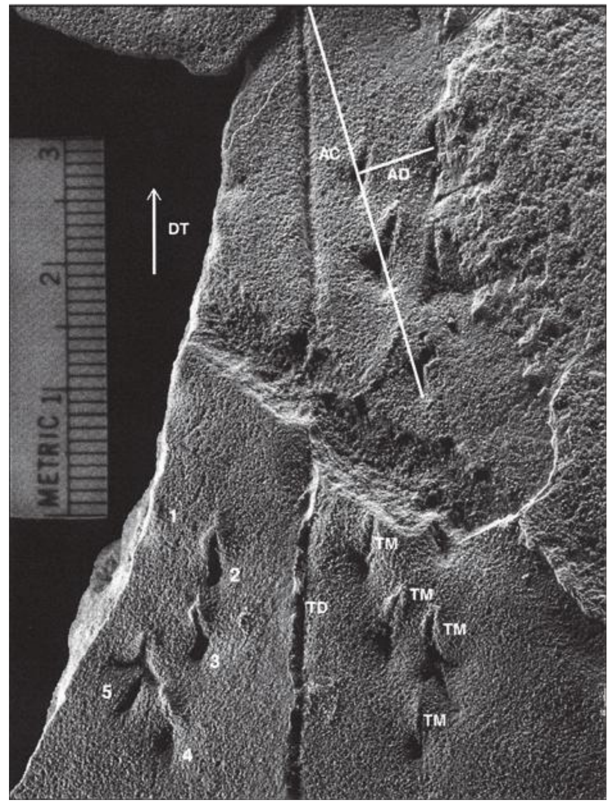


FIGURE 27. Photographic enlargement of trackway of arthropod *Kouphichnium pentapodus* n.sp. 1-5 foot imprints; **TM**, tic marks; **AC**, angle of convergence upon midline; **AD**, angle of divergence from midline; **TD**, tail drag mark; **DT**, direction of travel.

By August we had established many new records for the area, including collections of microfossils. Thirty-six field jackets documented the work at quarry locations, P, R, S -- 14, 15, 16 respectively. The concentrated collecting here allowed final mapping of this area of the quarry. Composition of the vertebrate fauna was well established at this point in our excavations. Conditions at Wannagan were not suitable for preservation of many of the smaller forms and the probability of their preservation was predictable in spite of their abundance. About 30 lizard fragments were found along with three skull bones of snake. Bird remains were scarce and mostly small with the exception of a humerus of *Presbyornis* (Benson, 1999). Outside the quarry, but nearby, were found petrified peat deposits, that represented a forest floor with tree stumps belonging to the genera *Taxodium* or *Trochodendron.* This deposit did not correlate with those in our study area, but specimens were collected nevertheless for their paleontological significance.

1994 - 1995

A side trip to Jordan, Montana and the Garfield County Museum was made to examine materials from some local deposits of the early Paleocene Tullock Fm. to compare with Late Paleocene materials from North Dakota. These older materials provided another look at the whole of the Paleocene of the region.

At Wannagan, backfilling of the east end of the quarry was in full swing. Ranger N. Bishop was on hand to advise on details. Much of the work of backfilling was done by local rancher H. Olstad with his cat and grader. Using materials which had been stock-piled over the years, reclamation of the site required sloping the backfilled surface, seeding with four specified grasses, and applying nitrogen fertilizer as in all previous seasons. The seed mixture consisted of: White yarrow, white sage, blue flax, and prairie coneflower, with one of the following: oats or barley or flax as a cover crop. Seeding was done after September 15. Extensive landscaping was completed as well, by Olstad in exchange for our paleontology department's old1964 International 4x4 field truck, which served us for many years at many locations in the States, Canada, and Mexico. In addition, the line shack that we erected in 1976 was given to Olstad, which he set up as a tool shed on his ranch south of Sentinel Butte.

Between 1991 and 1995, abandoned channel features were examined to determine if any may have belonged to feeder streams flowing into Lake Wannagan. Most of the paleochannels were discontinuous and could not be directly correlated with the time of Fossil Lake Wannagan. However, because of the number of these fragmented channels and the flood basin environment it is likely that the lake received input from some of these channels. Channel deposits contained fossil wood, but lacked many bone fragments.

1996

After 27 field seasons, it was with a certain reluctance that I closed Wannagan Creek Quarry. Extensive prospecting was resumed, however, in the area and especially in the "New Site" area north of the principal excavation site. This was done under an amended authorization permit that carried us into 2002. Paleoenvironmental information and numerous specimens were added to the existing assemblage including trackways of two new ichno taxa -- the crocodile, *Borealosuchipus hanksi,* and the arthropod, *Kouphichnium pentapodus.* Another important addition to the collections was the multituberculate *Catopsalis.*

Epilogue

I had interests in the fossil reptiles of North Dakota long before the discovery of "Wannagan Creek" in 1970. Earlier seasons in the badlands of Montana and Alberta during the 1960's, set the stage for inspection of the under-prospected badlands of western North Dakota where the Paleocene rocks differ from those of Alberta and Montana. Parts of western North Dakota are characterized by rugged badlands made up of flat-lying, sedimentary strata of the Late Paleocene Fort Union Group -- Bullion Creek (Tongue River) and Sentinel Butte formations. These beds contain a barely known wealth of vertebrate fossils. My initial quest here was for the "once thought-to-be" uncommon Late Paleocene champsosaur. Numerous finds across western North Dakota to the Missouri River in central North Dakota, cleared up this impression about their rarity with our discovery of many specimens.

Our early collections were made in the vicinity of Huff on the Missouri near Lake Oahe south of Mandan by use of McKenna boxes which were floated on the slow currents of the river. A McKenna box is a simple wooden box, with screen ends and bottom. A string of such boxes, loaded with selected matrix, will yield a concentration of small bones and teeth, that provide a representative sample of the taxa that are present in the area. Numerous bones of champsosaurs turned up at various locations with this method.

While engaged in this work, I became acquainted with the Heritage Center Museum, on the Capitol

Mall in Bismarck. In need of short-term storage between seasons, I approached Superintendent James Sperry and was pleased with his interest in our research. He was glad to provide storage for sacks of concentrate and some light field equipment. He was happy to do this in exchange for discussions on the paleontology and geology of the area. During one of our long talks, I suggested that the Heritage Center might develop a collection and exhibits of local fossils. This, we now realize, had to wait on construction of the new building near the old building.

During the following 26 years, the Wannagan Creek Expeditions were devoted to establishment of the quarry, followed by intensive and extensive investigation of the Paleocene Fort Union strata in the area. Season by season the Wannagan Creek Expeditions produced some remarkable numbers:

Number of field seasons = 27 (1970-1996)
Number of field days = 1620 (1970-1996)
Number of field crew members = 80 (Appendix III)
Number of cubic yards of matrix excavated = 6,040.6 (quarry site)
Number of field jackets recovered = 1445 +
Number of specimens collected = 8,000 *est.* (exclusive of microfossils)
Number of new taxa discovered = 32 -- ongoing
Number of visitors to site = over 270 (1970-1996)
Over 100 individual crocodiles in evidence, based on skull counts from quarry
Number of GI wall tents lost to the weather = 17 of 19
Number of field note books filled = 30 +
Two million dollars were invested in the Wannagan Creek Expeditions

Some lingering questions:

What was the size of Subtropical Fossil Lake Wannagan?

As mentioned earlier, from an inferred wave base of about one meter below the level of the shoreline, and a maximum wave length of some two meters the resulting fetch was long and indicates a relatively large body of water.

The size of the lake is further indicated by large numbers of bones of large reptiles and large fishes, such as amiids with lengths of 1.2 meters or more. Many turtles also evidently had space (niche separation) as indicated by their numbers and diversity, again indicating a large lake.

What was the duration of Fossil Lake Wannagan?

Termination of the Wannagan Creek biota is marked by an erosional unconformity between the gray shales of level 3 and the massive overlying, unconsolidated deposits of level 4. Catastrophic habitat changes took place here as Fossil Lake Wannagan went extinct. The once flourishing flora and fauna, as is preserved in three beds (levels 1, 2, and 3) has a measured total thickness of about two meters which represents continuous sedimentation. Several generations of some vertebrates, namely crocodiles and turtles, as well as a paleobotanical record that indicates annual cycles among some plants, gives an impression of fairly long duration, as yet undetermined, however. The rate of sediment accumulation could not be determined.

What about the climatic conditions that existed at Fossil Lake Wannagan?

The fossil plant remains found here are the best indicators of the subtropical environment that existed around the lake and its backwaters. Figure 28 is a conception of this locality near the end of the Paleocene, before general cooling began in the Eocene, and extinctions of many archaic mammals took place. It is debatable whether the seasons at Wannagan Creek are best described as spring, summer, autumn, and winter, or simply as wet and dry seasons with pronounced seasonality.

The last few seasons of the quarry operation, between 1991 and 1996, produced some 89 additional field jackets. As excavation activities were reduced during these years, backfilling began in part of the quarry as collecting continued elsewhere in the quarry as well as in surrounding sediments away from the quarry site. During the final season, 1996 activities included backfilling and grading the fill with slopes of the perimeter in accord with USDA requirements.

The longest duration of the three major fossil quarries completed for SMM was the Wannagan Creek expeditions, **1970** through **1996.** During three years numerous other locations where crocodilians occur were also studied for their possible bearing on the interpretations of the Wannagan Creek site. The first quarry, **1960 - 1963,** resulted in recovery of the museum's *Triceratops* from the late Cretaceous Hell Creek Formation in Montana. It was here also that our first champsosaur specimens, that became so essential in my later research, were found. A third major quarry was the Poison Creek dinosaur excavation in Wyoming. It was conducted with schedules that were often concurrent with those of Wannagan Creek between **1977** and **1990.**

The 27 continuous field seasons at Wannagan Creek and the many intervening periods that were devoted to preparation and study of the extensive collections resulted in a significant body of new knowledge about the biota and paleoenvironment of the late Paleocene. With the closure of Wannagan Creek Quarry, the unexcavated expanse of Fossil Lake Wannagan along with the numerous back swamp and paleochannel deposits are bound to add further to the Wannagan Creek assemblage.

ACKNOWLEDGEMENTS

Much of the credit for completion of this lengthy field research is due to the members of the field crews. Many of these individuals also participated in the development of collected materials between field seasons at the museum. Special acknowledgement is made to Tom O'Brien and Robert Spading who were involved throughout the duration of the expeditions. I also thank the Cecil Adams family, U.S. Forest Service personnel, and the N.D. Paleontological Society for their assistance with many aspects of this project. I further thank Becky Huset and Richard D. Benson for reading and improving the manuscript, Tim Erickson for providing all of the work on the figures and Lois Erickson for editing and preparing the manuscript. Many of the Wannagan Creek specimens were developed utilizing "PaleoBond" products through the generosity of William Mason. I am also grateful to the Philip W. Fitzpatrick Research Fund for support of this project in the field as well as in the laboratory.

APPENDIX I

Flora represented in the Wannagan Creek Assemblage. (A Preliminary Analysis)

lismaphyllites grandifolius
Amentotaxdus campelli
Ampelopsia acerifolia
Azolla stanleyii
Canariophyllum ampla
Carpolithes arcticus
Carpolithes sp.
Carya ant quorum
Castabea intermedia
Celtis newberryi
Celtisw peracuminata
Cerdidiphyllum genetrix
Cissus marginata
Cacculus flabella
Cornus hyperborean
Corylus insignis cf. *acutertiaria*
Cypericites sp.
Dictyophyllum anomalism
Dictyophyllum hebronensis
Equisetum
Ficus artocarpoides cf. *Dictyphyllum*
Ficus minutidens cf. *Dictyophyllum*
Ficus planistocata cf. *Dictyophylolum* sp.
Ficus subtract cf. *Dictyophyllum* sp.
Ginkgo adiantoides
Glyptostrosbus europaeus
Glyptostrobus nordenskioldi
Hummamelites inadequacies
Hydrangea antica
Isoetites horrid
usJuglans taurina
Laurophylolumj perseanum
Magnolia berryi
Magnolia magnifolia
Melastomites Montanans
Metasequola coloradensis
Minosdtites caloradensis
Morus Montanansw
Nelumblum tenuifolium
Oreopanads Dakotans
Pensophyllum cordatum
Persia brossiana
Planera microphylla
Platanus nobillis
Platanus reynoldsii
Polareodoxcites plicatus
Porosia varicose
Prunus perita
Pterocarya hispida
Quercus sullyi
Rhamnus Cleburne
Sassafras thermate
Sparganium stygian
Taxodeium olriki
Ulmus rhamnifolia
Viburnum asperum Viburnum cupaneoides
Vitisw olriki
Zamia coloradensis
Zelkova planeroides
Zisphus fibrillosus

APPENDIX II

Fauna represented in the Wannagan Creek Assemblage (A Preliminary Analysis)

Class GASTROPODA
- Order Mesogastropoda
  - Family Hydrobidae
    - *Hydrobia*
  - Family Viviparidae
    - *Viviparus*
  - Family Pleuroceridae
    - *Lioplacodes*

Class PELECYPODA
- Family Unionidae
  - undet. Bivalves

Class INSECTA
- Order Odonata
  - *Gomphaeschna schrankii*
- Order Coleoptera
  - undet. Coleopteran
- Order Lepidoptera
  - undet. Lepidopteran

Class CHONDRICHTHYES
- Order Batoidea
  - *Myliobatis* sp.

Class OSTEICHTHYES
- Order Lepisosteiformes
  - *Lepisosteus* sp.
- Order Amiiformes
  - *Amia fragosa*
- Order Osteoglossiformes
  - Family Osteoglossidae
    - *Joffrichthyes symmetropterus*
  - Family Hiodontidae
    - cf. *Eohiodon*
- Order Salmoniformes
  - Family Esicudae

Esox cf. *E. tieman*

Class AMPHIBIA
- Order Urodela
  - *Piceoerpeton willwoodense*
  - *Scapherpeton* sp.
  - Salamandrid undet.
- Order Anura
  - Undet. Anura

Class REPTILIA
- Order Testudines
  - *Trionyx/Aspideretes*
  - *Plastomenus* sp.
  - *Protochelydra zangerli*
  - undet. polycryptodire
  - undet. emydid
- Order Squamata
  - undet. varanid
  - undet. ophid
- Order Choristodera
  - *Champsosaurus gigas*
  - *Champsosaurus* sp.
- Order Crocodylia
  - *Leidyosuchus (=Borealosuchus) formidabilis*
  - *Wannaganosuchus brachymanus*

Class AVES
- Order Anseriformes
  - *Presbyornis isoni*
- Order Charadriiformes
  - *Dakotornis cooperi*
  - undet. plover-like shorebird

Class MAMMALIA
- Order Multituberculata
  - *Neoplagiaulax hazeni*
  - *Neoplagiaulax* cf. *N. hunteri*
  - *Neoplagiaulax mackennai*
  - *Ptilodus wyomingensis*
  - *Ptilodus* sp.
  - *Catopsalis* sp.
- Order Polyprotodonta
  - *Peradectes* sp.
- Order Insectivora
  - *Leptictis* sp.
  - cf. *Palaeoryctes* sp.
  - *Propalaeosinopa* sp.
  - *Labidolemur soricoides*
- Order Lipotyphla
  - cf. *Leptacodon*
  - *Entomolestes* sp.
- Order Primates
  - *Plesiadapis churchilli*
  - *Plesiadapis* sp.
  - *Ignacius* sp.
  - cf. *Phenacolemur* sp.
- Order Carnivora
  - *Protictis* cf. *P. microlestes*
- Order Condylarthra
  - *Thryptacodon* cf. *T. australis*
  - *Thryptacodon* sp.
  - *Ectocion* sp.
  - *Phenacodus* sp.
- Order Pantodonta
  - *Titanoides* sp.

Trace Fossils
- *Borealosuchipus hanksi*
- Arthropod
  - *Kouphichnium penapodus*

APPENDIX III

WANNAGAN CREEK FIELD CREW MEMBERS LISTED CHRONOLOGICALLY

1970 -- 1996

1970 B.R. Erickson, R. Spading, L Hallgren, S. Hawkins

1971 B.R. Erickson, R. Spading, T. O'Brien, L. Hallgren, R. Kalunchuk, S. Hawkins, G. Weed

1972 B.R. Erickson, R. Spading, T. O'Brien, R. O'Brien, S. Hawkins, P Ganzel, T. McCutcheon, K. Sander, G. Weed, R. Lingk

1973 B.R. Erickson, R. Spading, T. O'Brien, L. Hallgren, P. Ganzel, C. Faraci, T. O'Brien, M. O'Brien

1974 B.R. Erickson, R. Spading, T. O'Brien, L. Hallgren, P. Ganzel, C. Faraci, B. Chuchel, R. Mjos, T. McCutcheon, M. O'Brien, K. Sander

1975 B.R. Erickson, R. Spading, T. O'Brien, L. Hallgren, R. Ganzel, C. Faraci, T. McCutcheon, . B. Chuchel, C.Hudak, T. Guyer, C. Benepe, M. Hawkinson, J. Madsen, B.A. Erickson, A. Kitagawa, R. Mjos, M. O'Brien, D. Chor.

1976 B.R. Erickson, T. O'Brien, P. Ganzel, T. McCutcheon, C. Faraci, C. Hudak, R. Mjos, M. O'Brien, R. Melchior

1977 B.R. Erickson, R. Melchior, R. Mjos, P. Ganzel, C. Hudak, C. Faraci, D. Bourassa, B. Chuchel, T. McCutcheon, G. Wralstad, Wm. Cahill, A Rairamo, G. Hanson

1978 B.R. Erickson, R. Spading, Wm Cahill, T. Erickson, R. Mjos, G. Wralstad, A. Rairamo, P.Ganzel, B. Chuchel, T. O'Brien, T. Sawyer, S. Sawyer, L. Erickson, D. Bourassa, C. Faraci

1979 B.R. Erickson, R. Spading, Wm Cahill, T. Erickson, B.A. Erickson L. Bradley, B. Chuchel, W. Hogenson, R. Mjos, D. Bourassa, M. Williams, T. Stack, S. Bradley, R. Melchior

1980 B.R. Erickson, R. Spading, T. O'Brien, W. Hogenson, R. Loehlain, T. Hanson, L. Pomraning, K. Zentzis, K. Sander, J. Madsen, C. Benepe, C. Hudak, B.A. Erickson, J. Williams L. Gilberton,

Appendix III (cont.)

M. Debace

1981 B.R. Erickson, T. O'Brien, T. Stack, R. Mjos, M. Williams, R. Spading, S. Bradley, D. Bourassa

1982 R. Spading, B.R. Erickson, L. Pomraning, L. Bradley, R. Morrison, L. Hallgren, D. Davis, M. Debace, A. Sabinski, M. Brauer, T. Erickson, A. Land, S. Bradley, D. Bourassa

1983 T. O'Brien, B.R. Erickson, R. Spading, N. Pickett, K. Zentzis, J. Glad, C. Heinz, R. Benson, J. O'Brien, M. Leite

1984 B.R. Erickson, T. O'Brien, R. Poore, M. Brauer

1985 B.R. Erickson, T. O'Brien, R. Spading, R. Benson, M. Brauer, C. Heinz, Wm Dugas, J. O'Brien, S. Nowland, J. Madsen, D. Engberg, C. Benepe, A. Ellis

1986 B.R. Erickson, R. Benson, T. O'Brien, W. Hogenson, D. Engberg, Wm Dugas, G. Bond, A. Sabinski, J. Madsen, D. Davis, C. Benepe, T. Sawyer, T.R. Erickson, K. Hogenson, R. Spading, W. Olson

1987 B.R. Erickson, T. Sawyer, R. Spading

1988 B.R. Erickson, T. Sawyer, R. Spading

1989 B.R. Erickson, T. O'Brien, R. Spading

1990 B.R. Erickson, T. O’Brien, R. Spading, R. Benson, D. Boldt
1991 B.R. Erickson, T. O’Brien, R. Benson, G. Post, D. Boldt, J. Weinberg, J. Campbell, S. Thomas, T. Fink, W. Olson
1992 B.R. Erickson, W. Hogenson, L. Erickson
1993 B.R. Erickson, T. O’Brien, R. Spading, R. Benson, T. Flamino, D. Sorenson, T. Schmidt
1994 B.R. Erickson, T. O’Brien, R. Spading, A. Sanders
1995 B.R. Erickson, T. O’Brien

Appendix III (cont.)

1996 B.R. Erickson, T. O’Brien, R. Spading, J. Jacene, A. Redline, J. Janke

POST QUARRY CREWS 1997 -- 2002

1997 B.R. Erickson, R. Spading, J. Jacene, R. Benson, J. Janke
1998 D, Hanks, R. Wolszon, B.R. Erickson, R. Spading, J. Jacene
1999 D, Hanks, B.R. Erickson, J. Jacene
2000 B.R. Erickson, W. Hogenson
2001 B.R. Erickson, D, Hanks, J. Kramer
2002 D, Hanks, B.R. Erickson

FIGURE 28. Reconstruction of Fossil Lake Wannagan and environs based on the fossil records from the area.

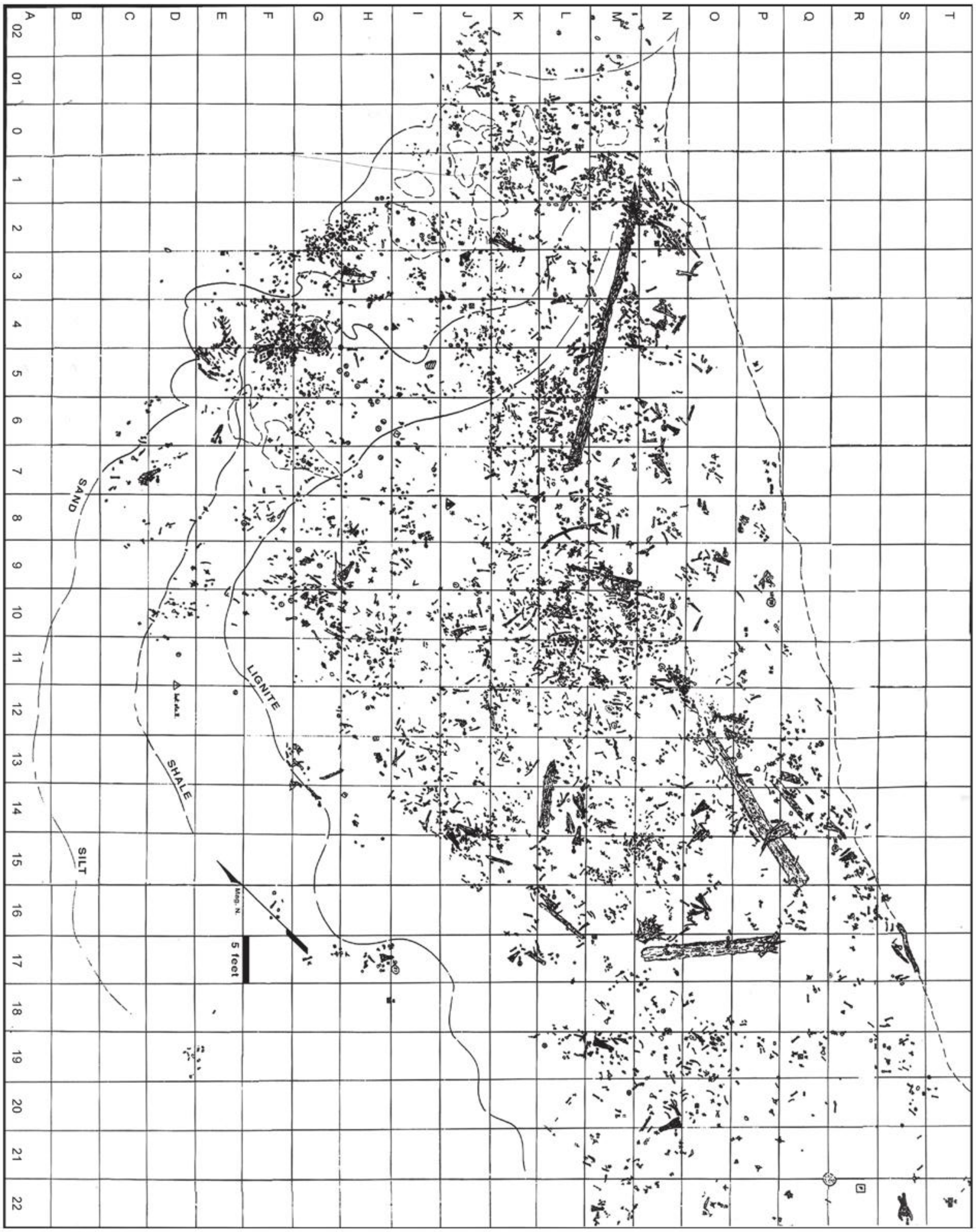


FIGURE 29. Map of Wannagan Creek Quarry, Billings Co., North Dakota. Excavation 1970 – 1996. Sand, silty shale, lignitic shale facies indicated by contour lines.

FIGURE 30. Aerial view of the upper breaks of the Bullion Creek and Sentinel Butte formations, Billings County, North Dakota. Quarry symbol indicates location of Wannagan Creek Quarry. **A**, "New Site" area; **B**, water point at Little Wannagan Creek.

Wannagan Creek Quarry History

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