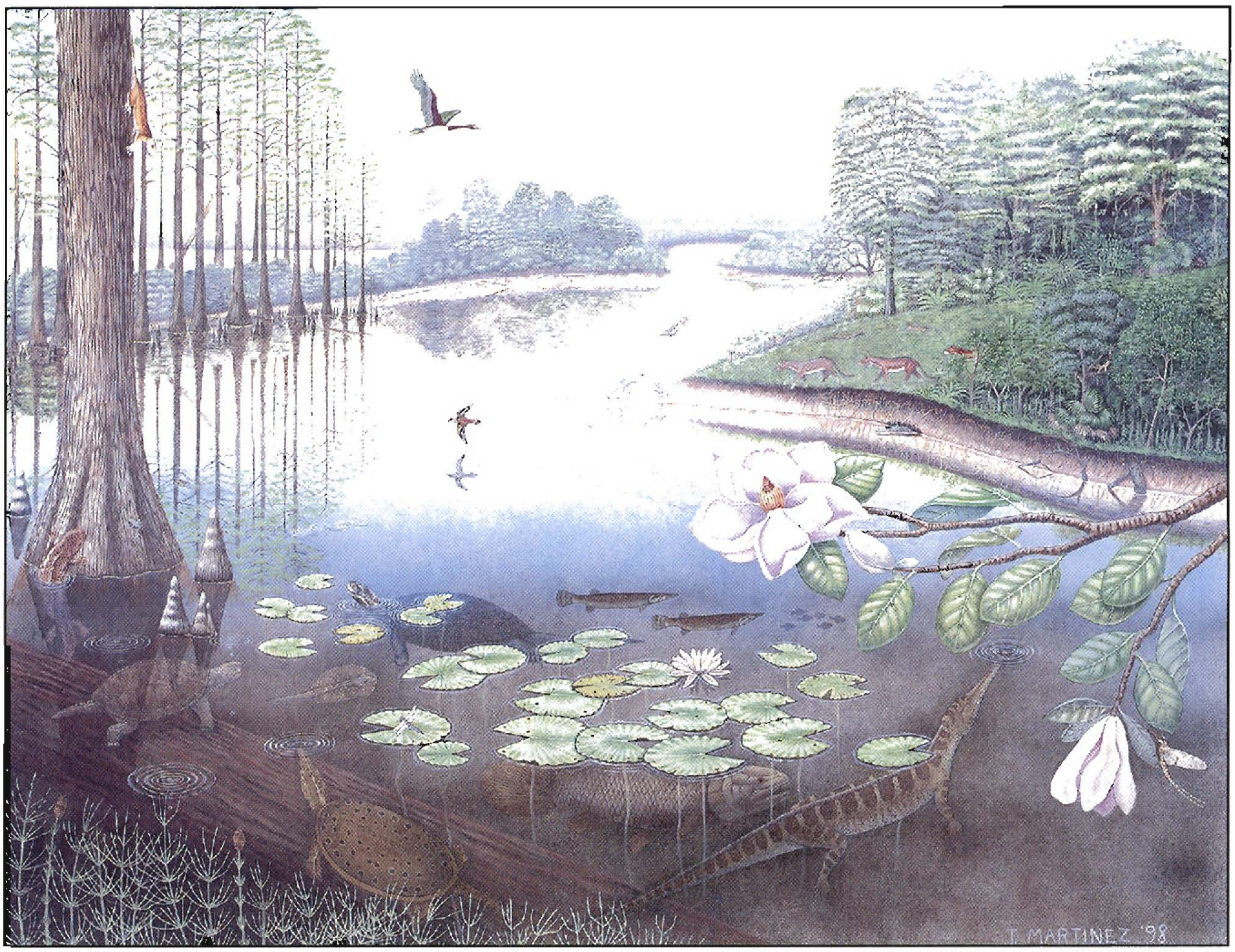
FOSSIL LAKE WANNAGAN
(PALEOCENE: TIFFANIAN)
BILLINGS COUNTY, NORTH DAKOTA

by

Bruce R. Erickson



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John P. Bluemle, State Geologist
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1. *Trionyx/Aspideretes* (soft shell turtle)
2. *Protochelydra zangerli* (snapping turtle)
3. Undetermined turtle
4. *Plastomenus* (soft shell turtle)
5. *Champsosaurus gigas*
6. Palaeophid snake
7. Varanid lizard
8. *Leidyosuchus formidabilis* (crocodile preying on turtle)
9. *Leidyosuchus formidabilis* (crococile near den entrance)
10. Anuran (frog)
11. *Piceoerpeton willwoodense* (giant salamander)
12. *Amia fragosa* (dogfish or mudfish)
13. *Joffrichthyes* (bony fish)
14. *Lepisosteus* (garfish)
15. *Myliobatis* (freshwater ray)
16. *Gomphaeschna schrankii* (dragonfly)
17. Ephemeropteran (may fly)
18. Plover-like shorebird
19. *Presbyornis isoni* (waterfowl)
20. *Dakotornis cooperi* (shore bird)
21. Owl
22. *Plesiadapis* (primate)
23. *Phenacodus* (condylarth)
24. *Protictis* (carnivore)
25. *Ptilodus* (multituberculate)
26. Trocodendron (with bark beetle borings)
27. *Sabal* (palm)
28. *Zizyphus* (cycad)
29. *Platanus* (sycamore)
30. *Ginkgo* (maidenhair tree)
31. *Cercdiphyllum* (katsura tree)
32. *Taxodium* (cypress tree)
33. Cyrpess knees
34. *Vitis olriki* (grape vine)
35. *Metasequoia* (dawn redwood)
36. *Equisetum* (horsetail)
37. *Nelumbium* (waterlily)
38. *Magnolia*

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ABSTRACT

Fossil Lake Wannagan is a new name for a local freshwater lake of undetermined size that existed as part of a floodplain system during the Late Paleocene. It is located in the upper breaks of the badlands of the Little Missouri River in western North Dakota. Fossil Lake Wannagan is recognized from: sediments of fluvial, paludal and lacustrine character; a section of shoreline with well-defined beach cusps; and an exceptionally well-preserved freshwater assemblage of fossils. A sequence of stratified sediments records the brief history of its development and termination by crevasse splay deposition. Limnogeological and paleoenvironmental aspects of this ancient lake are presented along with its age and correlations. The name "Fossil Lake Wannagan" is, herein, introduced for the first time.

KEY WORDS: "Fossil Lake Wannagan"; Paleocene lake/floodbasin; limnogeology and paleoecology; Wannagan Creek Quarry.

ACKNOWLEDGMENTS

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INTRODUCTION

Initial investigation of the fossil deposits in the Wannagan Creek drainage of Billings County, North Dakota, began in mid-1970 after a small sample of crocodilian remains was reported to the author (*Figure 1*). Early examination of the site where the major concentration of bones had been found produced a number of additional specimens and resulted in the decision to further investigate. More intensive efforts during the following year revealed that a rich fossiliferous layer could be accessed by removal of the top of a small butte to a depth of about 10 meters. After two seasons of digging, the existence of a local basin was apparent. This proved to be the margin of a shallow floodbasin, which held a sizable body of fresh water during Bullion Creek time.

Evidence of abrupt lithofacies changes; a mappable shoreline with beach cusps; shallow-water shale and lignite zones; and a bottom marl horizon characterize Wannagan Creek Quarry. These are unquestionably fluvial and lacustrine rather than eolian deposits. Unlike freshwater lakes known elsewhere, such as Paleocene Lake Flagstaff in Utah, which gave rise to the well-known Green River lakes and the intermontane basins they later occupied (Schaeffer and Mangus, 1965), Lake Wannagan began as a swamp or embayment associated with a major river system and its accompanying meandering streams and natural levees. Jacob (1972) describes such a lake/floodbasin as a subenvironment of an alluvial-plain.

Paleontologically, Lake Wannagan and its environs supported a rich and diverse biota comprising an array of all major vertebrate groups, invertebrate taxa, and a large assemblage of aquatic and forest plants (Erickson, 1991). A few ichnofossils are also included in this biota. This report describes the type locality of several new taxa.

Figure 1. Panoramic view of Fossil Lake Wannagan area looking north. Wannagan Creek Quarry (large arrow); contact between the Bullion Creek and Sentinel Butte Formations (long arrow).

LOCATION

Wannagan Creek Quarry was annually operated by the Department of Paleontology of the Science Museum of Minnesota from 1970 to 1996 (*Figure 2*). The quarry occupies the margin of what has been determined to be the remnant of a fossil lake or floodbasin. It is located in the upper breaks of the Little Missouri River in Billings County, North Dakota: Sec.18, T141N, R102W (*Figure 1*). Sixteen readings were taken by one GPS instrument at various positions within the limits of the 40 by 56 square meter excavation site. A mean value of these readings is N47° 02', W103° 39' and is provided here merely for comparison with scaled-map locations as recommended by Brew et al. (1993) as a check on precision or reproducibility of positions determined by low-cost GPS units. Topographically, the quarry is situated on a low wedge-shaped ridge formed by the confluence of two small coulees which trend in a northwest direction. The immediate area is an uneven grassy table of washes and erosion surfaces with re-entrant slopes.

STRATIGRAPHY

Two stratigraphic units are exposed in the area. The Bullion Creek (Tongue River) Formation and the overlying Sentinel Butte Formation are flat-lying with the basal part of the Bullion Creek in the subsurface. The two formations are easily distinguished from one another by the overall buff, yellow and tan color, and numerous interstratified lignitic layers of the Bullion Creek Formation and the general "somber" gray color of the Sentinel Butte Formation. They are separated by a prominent lignite or clinker zone (HT Butte Bed). There is considerable lithological diversity in each formation, but a few layers such as the HT boundary bed and somewhat higher blue strata, locally called the "Blue Beds", are continuous over considerable distances. For broader and more detailed accounts of these strata, see Royse (1967; 1972), Jacob (1972) and Murphy et al. (1993).

The stratigraphic position of the quarry site is in the Bullion Creek Formation 20 meters below the Sentinel Butte contact. Although the quarry is limited in size, measuring approximately 40 by 54 meters, it provides a remarkable variety of lithologies. At the bottom of the sequence, a clay and silt marl defines an initial influx of sediments into a developing backswamp environment. Above this is a lignitic zone a few millimeters thick,

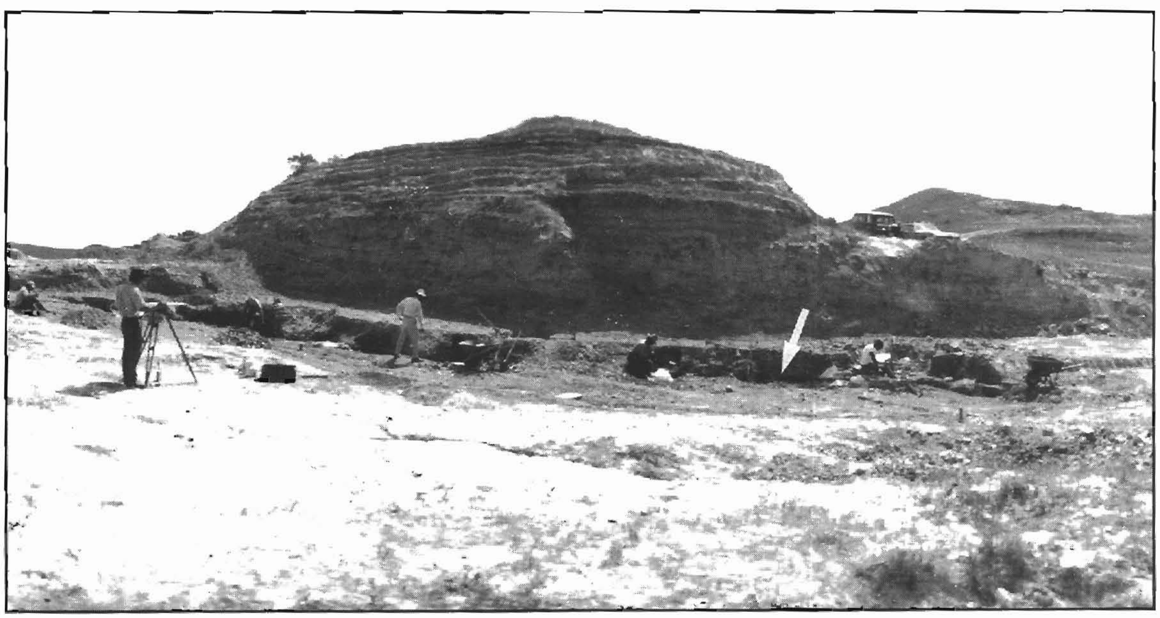

Figure 2. Wannagan Creek Quarry looking southeast toward working face of quarry. Field party excavating above clay and silt layers at the base of fossiliferous zone (arrow).

which increases to over 30 centimeters to the south-southwest. Its interstratified structure of matted plant remains and mudstone indicates a swamp environment. The local dip within the excavation is about 3-4 degrees to the southwest. The regional dip is north toward the center of Williston Basin. The thin lignitic margin follows rather closely the contour of the lenticular shoreline sand, and represents what may be referred to as a wave-base. The lignitic material grades upward into a gray shale some 30-40 centimeters thick. This, in turn, grades upward into a lighter colored shale and clayey sand that is terminated by an erosional unconformity. The total thickness of the sediments of Lake Wannagan, as excavated, is approximately 0.8 meters. A massive overlying cross-bedded crevasse splay sand reaches a thickness of 8 meters. Crevasse splay sand of this thickness indicates proximity to a large stream as the source of the sand that terminated Lake Wannagan.

Sediments of Wannagan Creek Quarry have yielded a number of specimens of the primate *Plesiadapis churchilli* (Kihm, 1993). Biochrons for land mammal ages indicate an age of Tiffanian 4 for *P. churchilli* (Butler et al., 1980). Wannagan Creek Quarry dates to early Tiffanian 4, with an age of about 60 million years (Benson, in press, and references cited therein).

DEPOSITIONAL ENVIRONMENT

Sediments encountered in the excavation of the quarry show a sequence of layers that indicate paludal and fluvial conditions followed by a lacustrine environment. The origin of these sediments was mainly from streams flowing into the basin, as well as from the accumulation of organic debris derived from extensive aquatic plant growth and trees in the basin and on nearby levees. Royse (1970) and Jacob (1972) discuss the overall origin and source of sediments of the Tongue River Formation from highlands to the west.

The basin occupied by Fossil Lake Wannagan was part of a local floodbasin of undetermined size. It existed as part of a much larger floodplain system. Clays and silts were introduced by streams, followed by a thick build-up of organic material that resulted in the development of swampy conditions. Jacob (1972) found no barrier or shoreline sands in the Tongue River and concluded that marshes or swamps probably did not have a lagoonal origin. The lenticular shoreline sands identified in the excavation (Erickson, 1982; 1991) are limited in extent to some 18 meters and may represent splay features. Well-developed sand cusps having asymmetrical form indicate a local embayment with shallow water currents. The presence of these features offers an insight into the depositional setting (Erickson, 1982).

Above the basal marl, a lignitic zone and an overlying gray shale provide the setting for the origin of Fossil Lake Wannagan. The lignitic material indicates settling in relatively quiet shallow water. Plant debris at this level becomes denser away from the shoreline where many identifiable plant taxa are preserved. Among these are various trees and shrubs represented by leaves, fruiting bodies and coalified stems (*Table 1*). Some of these stems are logs 30 centimeters in breadth and over 10 meters long. The shallow water at this time was choked with branches from overhanging trees along the lake margin. Bottom conditions were somewhat mobile, allowing branches as well as some of the long bones to assume the more or less vertical positions in which they were found *in situ*. Subsequent deposition and a continuous buildup of organic debris resulted in eutrophic conditions. It is suspected that accumulation was gradual, occurring over a span of considerable time which represented the period of greatest stability in the duration of Fossil Lake Wannagan. The sediments are uniformly fine-grained and show graded bedding.

Duration and size of the lake are problematical and can be inferred from several bits of evidence. A subtropical setting demonstrated by ample plant fossils suggests only moderate seasonality. No convincing record of varves or any other annual bloom or crop was detected nor is there any cyclicity present in these deposits, as occurs in the Eocene Green River lakes (Selley, 1978). A calculated rate of sedimentation would have questionable reliability.

Shoreline sands, which yielded remains of hatchling crocodiles and provided likely nesting environment (Erickson, 1982), imply an established behavior for the eighty individuals of *Leidyosuchus* (=*Borealosuchus*) that were recovered. These individuals exhibit a size range that includes several unusually large individuals. Three exceptionally large skulls some 12-15 percent larger than average-size specimens are taken as the oldest and most dominant males in this population. Among living species, the largest forms are the oldest males. These individuals have established breeding territories (Cott, 1960). The ratio of three exceptionally large individuals, among the population of some eighty individuals, is not unlike ratios found in living populations (Cott, 1960). The ratio for the fossil crocodile suggests a rather stable habitat. The largest skulls are estimated to represent individuals 35 years of age or more. It is therefore reasonable to presume that these individuals occupied Lake Wannagan for at least this long.

A modern analogue to the Paleocene Fossil Lake Wannagan might be found along the Mississippi River in the states of Mississippi and Tennessee. Here, flood-plain lakes along the meandering river course are often several miles across. The origin of lakes, such as these, is attributed to flooding when the river breaks its banks (Selley, 1978). Further evidence that addresses the question of size of the lake includes the presence of large fishes such as 1-1.5 meter-long specimens of *Amia* and abundant remains of *Lepisosteus*. Each of these predaceous forms would require large expanses of open water with appreciable depth and a good supply of prey species. In the description of the shoreline features discussed above under Stratigraphy, note was made of a lignitic layer margin that was likely wave-base. Depth of the water at this point is judged to have been at least one meter (Sawyer, 1981). This in turn implies a considerable fetch, further suggesting that a large body of water was present.

Sediments laid down during the final stages of lake deposition are light-colored fine sands and clays with relatively few fossils. The fossil specimens that are found in these sediments display signs of considerable oxidation. Jacob (1972) comments on the oxidizing conditions that prevailed in the light-colored beds of the Bullion Creek Formation.

Crevasse splay sands lie unconformably over the uppermost limits of lake deposits. These sands are heavily cross-bedded and reach a thickness of 8 meters. Splay sand in this amount must have had a large stream as its source. Furthermore, the unconformity at the contact is an erosional surface attributed directly to scouring by a large volume of water released through a rupture in the nearby levee system, which produced the sand. This is not unlike recent examples of alluvial sub-facies deposition (Selley, 1978).

BIOTA

A flora of over 100 plant taxa has been recorded from Wannagan Creek (Melchior, 1976; 1977; Melchoir and Hall, 1983) (*Table 1*). Plant distribution is calculated primarily based on relative abundance of specific taxa in the swamp and lake deposits and the known habitat preference of related living species. Large trees such as *Taxodium* (Bald Cypress) as well as a variety of small aquatic plants grew in the waters of the floodbasin. The margins of the lake, including the levees, were flush with *Magnolia*, *Platanus*, *Cercidiphyllum* and many shrubs. Some large trees including *Metasequoia* (Dawn Redwood) were found at a distance from the lake's edge on higher ground (see cover).

Lake Wannagan and its surroundings were a haven for the many species that constitute the Wannagan Creek Fauna (*Table 2*). Most conspicuous of the riparian taxa were the crocodile *Leidyosuchus* (=*Borealosuchus*), the snapping turtle *Protochelydra* and the fish-eating *Champsosaurus* (Erickson, 1982; 1991). Other reptiles include a small alligatorine, other turtles, several lizards, and a palaeophid snake. *Piceoerpeton*, a "Hell-bender"-sized amphibian, and some smaller species are rep-

TABLE 1. WANNAGAN CREEK FLORA

The following list includes all plant fossil taxa from Fossil Lake Wannagan and bordering areas. Amended from Erickson (1991).

Alismaphyllites grandifolius	*Laurophyllum perseanum*
Amentotaxus campelli	*Magnolia berryi*
Ampelopsia acerifolia	*Magnolia magnifolia*
Azolla stanleyii	*Magnolia regalis*
Canariophyllum ampla	*Melastomites montanensis*
Carpolithes arcticus	*Metasequoia occidentalis*
Carpolithes sp.	*Minostites coloradensis*
Carya antiquorum	*Morus montanensis*
Castanea intermedia	*Nelumbium tenuifolium*
Celtis newberryi	*Oreopanax dakotensis*
Celtis peracuminata	*Pensophyllum cordatum*
Cercidiphyllum genetrix	*Persia brossiana*
Cissus marginata	*Planera microphylla*
Cocculus flabella	*Platanus nobilis*
Cornus hyperborea	*Platanus reynoldsii*
Corylus insignis cf. *C. acutertiaria*	*Polareodoxites plicatus*
Cypericites sp.	*Porosia verrucosa*
Dictyophyllum anaomolum	*Prunus perita*
Dictyophyllum hebronensis	*Pterocarya hispida*
Equisetum	*Quercus sullyi*
Ficus artocarpoides cf. *Dictyophyllum*	*Rhamnus cleburni*
Ficus minutidens cf. *Dictyophyllum*	*Sassafras thermate*
Ficus planistocata cf. *Dictyophyllum* sp.	*Sparganium stygium*
Ficus subtruncata cf. *Dictyophyllum* sp.	*Taxodium olriki*
Ginkgo adiantoides	*Ulmus rhamnifolia*
Glyptostrobus europaeus	*Viburnum antiquum*
Glyptostrobus nordenskioldi	*Viburnum asperum*
Hammamelites inaequalis	*Viburnum cupaneoides*
Hydrangea antica	*Vitis olriki*
Isoetites horridus	*Zamia coloradensis*
Juglans taurina	*Zelkova planeroides*
	Zizyphus fibrillosus

TABLE 2. WANNAGAN CREEK FAUNA

Class	Order	Family	
GASTROPODA			
	Mesogastropoda		
		Hydrobidae	*Hydrobia*
		Viviparidae	*Viviparus*
		Pleuroceridae	*Lioplacodes*
PELECYPODA			
		Unionidae	
			undet. bivalves
INSECTA			
	Odonata		*Gomphaeschna schrankii*
	Coleoptera		undet. coleopteran
	Lepidoptera		undet. lepidopteran
CHONDRICHTHYES			
	Batoidea		*Myliobatis* sp.
OSTEICHTHYES			
	Lepisosteiformes		*Lepisosteus* sp.
	Amiiformes		*Amia fragosa*
	Osteoglossiformes		
		Osteoglossidae	*Joffrichthyes symmetropterus*
		Hiodontidae	cf. *Eohiodon*
	Salmoniformes		
		Esocidae	*Esox* cf. *E. tieman*
AMPHIBIA			
	Urodela		*Piceoerpeton willwoodense*
			Scapherpeton sp.
	Anura		undet. anuran
REPTILIA			
	Chelonia		*Trionyx/Aspideretes*
			Plastomenus sp.
			Protochelydra zangerli
			undet. genus
			undet. emydid
	Squamata		undet. varanid
			undet. palaeophid
	Choristodera		*Champsosaurus gigas*
			Champsosaurus sp.
	Crocodylia		*Leidyosuchus* (=*Borealosuchus*) *formidabilis*
			Wannaganosuchus brachymanus
AVES			
	Charadriiformes		*Dakotornis cooperi*
			Presbyornis isoni
			undet. plover-like shorebird
MAMMALIA			
	Multituberculata		*Neoplagiaulax hazeni*
			Neoplagiaulax cf. *N. hunteri*
			Neoplagiaulax mckinnai
			Ptilodus wyomingensis
			Ptilodus sp.
			Catopsalis sp.
	Polyprotodonta		*Peradectes* sp.
	Insectivora		*Leptictis* sp.
			cf. *Palaeoryctes* sp.
			Propalaeosinopa sp.
			Labidolemur soricoides
	Lipotyphla		cf. *Leptacodon*
			Enotomolestes sp.
	Primates		*Plesiadapis churchilli*
			Plesiadapis sp.
			Ignacius sp.
			cf. *Phenacolemur* sp.
	Carnivora		*Protictis* cf. *Microlestes*
	Condylarthra		*Thryptacodon* cf. *T. australis*
			Thryptacodon sp.
			Eotocion sp.
			Phenacodus sp.

resented. *Amia* and *Lepisosteus*, mentioned earlier, along with bony fishes such as *Esox* and *Joffrichthyes*, were found at all levels within the lake. A browsing, sheep-sized mammal, *Phenacodus*, and a badger-sized carnivore, *Protictis*, represent the largest land dwellers collected. Tree-climbers such as the primates *Plesiadapis* and *Phenacolemur*, along with multituberculates and insectivores, occupied the forest canopy and underbrush. Avian evidence of water-loving birds *Presbyornis* and *Dakotornis*, and a plover-like shorebird are also counted in the thanatocoenosis. Kihm and Hartman (1995) described footprints of probable shorebirds, which inhabited a nearby floodplain. Insects were undoubtedly plentiful, but not found in significant numbers perhaps due to the vicissitudes of water currents and severe bioturbation. Ichnofossils in the form of burrows (Melchior and Erickson, 1979) established the presence of additional species.

DISCUSSION

Lake Wannagan is an example of one ecosystem which characterized the western interior of North America during Late Paleocene time. Due to fortuitous circumstances of preservation, a freshwater lakeshore and its biota affords a unique opportunity to study its development and its local fauna.

Certain fossil mammalian species indicate an age of about 60 m.y.b.p. This estimate is derived from *Plesiadapis churchilli*, an "index" taxon of Tiffanian 4 (Sloan, 1987).

Evidence inferring the durability of the lake over a long period of time is: 1) the stability implied by a subtropical environment; 2) a thick marl-bottom bed with overlying accumulations of interstratified lignite and shale; and 3) the large number of individuals of several taxa which had well-established nesting regimens, including old individuals.

The large size of Lake Wannagan can be inferred from: 1) a wave-base at a meter or more below the water's surface; 2) the presence of large predaceous fishes; 3) the large quantity of aquatic and semi-aquatic plants occurring at all levels of the excavation site; 4) a shoreline habitat that was utilized by water-loving birds and water-seeking land dwellers; and 5) comparison with present-day floodbasin lakes.

Areas bordering Lake Wannagan have yielded fewer fossils, and in several cases taxa poorly or not represented in the quarry. Taphonomic differences between the two locations are also remarkable in that the majority of bones in the swamp/lake deposits are disarticulated, presumably due to bioturbation, whereas completely articulated skeletons occur in stratigraphically equivalent, nearby layers. The three factors largely responsible for this are the paucity of crocodiles and more importantly, the existence of quiet backwaters and temporary shallow pools, as well as interfluves beyond the perimeter of the lake. Some of these playas provided unique habitats. The shore was also an estimated gathering place for many species and the abundance of crocodilian coprolites throughout the deposits indicates that it was also a feeding place for the large crocodile (Sawyer, 1981).

In 1996, operations at Wannagan Creek Quarry ended. Final inspection and location of all survey points were made and the entire excavation was back-filled, sloped, subsequently seeded and fertilized as per requirements of the U.S. Forest Service. Plans call for continued investigation in the surrounding area. Surface collecting will continue in an effort to gather further scarce or new specimens, and to revisit earlier evaluations about the paleoenvironment of the area.

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