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| Paleo Research Banner |
| ***PLIOPLATECARPUS* (REPTILIA, MOSASAURIDAE) AND ASSOCIATED VERTEBRATE AND INVERTEBRATE FOSSILS FROM THE PIERRE SHALE (CAMPANIAN), COOPERSTOWN SITE, GRIGGS COUNTY, NORTH DAKOTA**<> |
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| **INTRODUCTION**>Few bedrock outcrops are found in eastern North Dakota because that portion of the state is covered with glacial drift. Exceptions are in areas where the drift is relatively thin and rivers have cut through the veneer of glacial deposits. In these settings marine strata, primarily the Carlile, Niobrara, and Pierre Formations, deposited in the Western Interior Seaway during the Late Cretaceous, are exposed in isolated outcrops. One of these exposures is located 8.5 km southeast of Cooperstown, Griggs County, where erosion of the Sheyenne River has exposed a thick section of the Pierre Shale (Figure 1).

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| Stratigraphic Symbols | **Figure 1 - Geologic section at the Cooperstown site.**Stratigraphic Column |

The Cooperstown site encompasses an area of about two square kilometers in a place referred to locally as "Indian Mounds." The name is derived from the haystack-shaped hills in the valley, which were thought to be Indian burial mounds. These hills, however, are erosional remnants of the once more extensive Pierre Shale. It is here that the most diverse assemblage of vertebrate and invertebrate fossils from the Pierre Shale in North Dakota is found.Pierre Shale outcrops in eastern North Dakota are the furthest northeastern exposures of the Pierre Shale in the United States. They are, therefore, important because they provide a link between exposures of the formation in the type area of South Dakota and outcrops in Canada. The North Dakota Pierre Shale faunas provide biochronologic information about the formation and paleobiogeographic information about the eastern part of the Western Interior Seaway during the Campanian. Even though the eastern North Dakota Pierre Shale sites are important, few studies of the stratigraphy and even fewer studies of the paleontology of the Pierre Shale have been conducted in North Dakota.The occurrence of the Pierre Shale in eastern North Dakota was first reported by [Upham](https://www.dmr.nd.gov/ndfossil/Research/Abstracts/cooperstown_site.asp#Upham)in his monograph on Glacial Lake Agassiz. Early studies of the Pierre Shale in eastern North Dakota by North Dakota Geological Survey geologists primarily addressed the economic potential of the formation for the brick and cement industries. [Kline](https://www.dmr.nd.gov/ndfossil/Research/Abstracts/cooperstown_site.asp#Kline) was first to suggest that at least a portion of the Pierre Shale in North Dakota is equivalent to the Gregory Member of the Pierre Shale as seen at the type area in South Dakota.In the 1960's, the United States Geological Survey conducted several studies of the Pierre Shale. The most important of these studies in eastern North Dakota was by [Gill and Cobban](https://www.dmr.nd.gov/ndfossil/Research/Abstracts/cooperstown_site.asp#GillandCobban). They provided measured sections and described the stratigraphy, paleontology, and biochronology of the Pierre Shale in the Valley City and Pembina Mountain areas. They applied the Manitoba names Pembina and Odanah Members to the oldest and youngest Pierre Shale units and the South Dakota names for the middle units of the formation, the Gregory and DeGrey Members. They also correlated these four members with the type Pierre Shale in south-central South Dakota.**METHODS**Standard geological and paleontological field techniques were employed during this study. Mosasaur and other vertebrate fossils in the DeGrey Member were found by prospecting during six years of field activity. Excavation of the *Plioplatecarpus* partial skeleton was accomplished using plaster jacket extraction techniques. Meter square grids were laid out at the *Plioplatecarpus*excavation site and an excavation map was produced. Most invertebrate fossils from the Gregory Member were recovered by screen washing of matrix through window screen at the site. Small *Squalus* teeth and placoid scales were recovered from the matrix surrounding the *Plioplatecarpus* bones by screen washing matrix through 300 micrometer opening sieves.**STRATIGRAPHY**One of the thickest and best exposed sections of the Pierre Shale in eastern North Dakota occurs at the Cooperstown site where 40 m of the Pierre crops out. The lower 3 m of the section, measured from the level of the Sheyenne River, is the Gregory Member of the Pierre Shale. The Gregory Member consists of light brown to tan, calcareous claystone. Yellow-brown ironstone concretions occur in this member. A diverse assemblage of invertebrate fossils has been recovered from the Gregory. The Gregory Member is overlain by 37 m of the DeGrey Member of the Pierre Shale. The contact between the members is sharp and unconformable. The DeGrey Member is a light to dark gray noncalcareous shale. Thin layers, one to 15 cm thick, of very light gray bentonite occur throughout the DeGrey but are more common in the lower 7 m of the member. Black, iron-manganese carbonate and light gray, phosphatic concretions are common in the lower part of this member. These concretions are often fossiliferous, containing fragments of *Inoceramus.* The upper 18 m of the DeGrey is obscured by vegetation and thin glacial drift containing erratics. Mosasaur and remains of other marine vertebrates are found in the basal 6 m of this member.**PALEONTOLOGY****Gregory Member**A diverse assemblage of invertebrate fossils is found in the [Gregory Member](https://www.dmr.nd.gov/ndfossil/Research/Abstracts/cooperstown_site.asp#Hoganson1). The fossils are mostly steinkerns and are often replaced with limonite. Over 30 invertebrate taxa, including Coelenterata, Bryozoa, Brachiopoda, Bivalvia, Gastropoda, Cephalopoda, Annelida, Crustacea, Asteroidea, and Echinoidea, have been identified. Six ammonite taxa, particularly *Baculites gregoryensis*, provide useful biochronologic information. Foraminifera and ostracodes are common in the Gregory, but have not been examined for this study. Teeth of the sand-tiger shark, *Carcharias*, are rarely found with the invertebrate fossils. The Cooperstown site is the only place in North Dakota where most of these kinds of Pierre fossils have been found although similar faunas have been reported from South Dakota and Wyoming.**DeGrey Member**Mosasaur remains and several taxa of marine fishes were recovered from the basal 6 m of the[DeGrey Member](https://www.dmr.nd.gov/ndfossil/Research/Abstracts/cooperstown_site.asp#Hoganson2). The only invertebrate fossils that have been found in this part of the section are fragments of *Inoceramus.* Several shark taxa are represented by isolated teeth, including the sand-tiger shark, *Carcharias*; the extinct cow sharks, *Squalicorax* and *Pseudocorax*; and the dogfish shark, *Squalus* ([Table 1](https://www.dmr.nd.gov/ndfossil/Research/Abstracts/cooperstown_site.asp#Table1)). Teeth and vertebrae of bony fish, including the salmon-like *Enchodus*, are present. A tarso-metatarsal of the large hesperornithid bird, *Hesperornis,*was also found. The remains of twelve mosasaurs have been found in the lower part of the DeGrey from an area of about 0.5 km. Two kinds of mosasaurs, *Plioplatecarpus* and an unidentified mosasaurine, are present.One collected *Plioplatecarpus* specimen is spectacular and consists of a partial skeleton including essentially the entire skull and lower jaws and a complete, articulated presacral vertebral column. Less than one half of the post-sacral vertebral column is present and the rib cage is approximately one half complete. Right and left coracoids and scapulas are present but most limb elements are missing. This *Plioplatecarpus* specimen represents a previously undescribed taxon based on its huge size (25 % larger than any other known *Plioplatecarpus*), reduced vertebral count, and coracoid and skull characteristics. The specimen will be described in the near future. Scratch marks on some bones and the abundance of *Squalus*teeth and placoid scales associated with the skeleton suggest that the *Plioplatecarpus* carcass was scavenged by dogfish sharks. This skeleton is being prepared for permanent exhibit as a three-dimensional skeletal mount at the North Dakota Heritage Center in Bismarck. The restored skeleton will be 7 m long. The skull alone has a length of one meter.**BIOCHRONOLOGY**The Gregory Member at the Cooperstown site was deposited during the time of deposition of the *Baculites gregoryensis* Western Interior Ammonite Zone as indicated by the abundance of fossils of that taxon found in the member at the site. This implies a Late Campanian age for the member in eastern North Dakota, which is consistent with the age of the member as defined in its type area of south-central South Dakota. No biochronologically diagnostic fossils were recovered from the DeGrey Member at the Cooperstown site. [Gill and Cobban 1966](https://www.dmr.nd.gov/ndfossil/Research/Abstracts/cooperstown_site.asp#GillandCobban2)suggested that the DeGrey Member in eastern North Dakota was deposited during the Late Campanian Ammonite Range Zone of*Didymoceras nebrascensis*.**PALEOECOLOGY AND PALEOBIOGEOGRAPHY**Lithologic similarity, stratigraphic position, and faunal similarity indicate that the Gregory Member at the Cooperstown site is, at least in part, equivalent to the Gregory Member in south-central South Dakota and the Red Bird Silty Member of the Pierre Shale in eastern Wyoming. Gregory Member invertebrate taxa found at the Cooperstown site, such as the gastropod genera *Oligoptycha* and*Margaritella*, also occur in Campanian beds in the U. S. Gulf Coastal Plain. The presence of the brachiopod *Lingula*, the bivalves *Pteria* and oysters, gastropod genera, and other invertebrates in the Cooperstown Gregory Member fauna indicate deposition in shallow, probably subtropical, coastal waters.The hiatus between the Gregory and DeGrey Members at the Cooperstown site may indicate subaerial exposure of the sea floor prior to deposition of the DeGrey although additional study at the site is needed to confirm this. The DeGrey Member is lithologically and faunally similar to the DeGrey Member of the Pierre Shale in south-central South Dakota. The abundant, invertebrate shallow water indicators in the Gregory Member are not present in the DeGrey Member at the Cooperstown site. Water depths were probably deeper at the site during deposition of the DeGrey Member although shallow, warm water conditions are indicated by the cartilaginous fish, mosasaur, and avian fauna. Water depths during deposition of the[Gregory and DeGrey Members](https://www.dmr.nd.gov/ndfossil/Research/Abstracts/cooperstown_site.asp#GillandCobban2) probably never exceeded about 60 m.**CONCLUSIONS**One of the thickest and best exposed sections of the Pierre Shale in eastern North Dakota is found at the Cooperstown site. At this site, the Gregory Member is overlain unconformably by the DeGrey Member. A diverse assemblage of invertebrate fossils is found in the Gregory Member at the site, indicating deposition during the Late Campanian *Baculites gregoryensis*Western Interior Ammonite Zone. The fauna indicates that the Pierre Sea was shallow and warm at that time. The Gregory Member at the Cooperstown site is at least in part equivalent to the Gregory Member in south-central South Dakota and the Red Bird Silty Member of the Pierre Shale in eastern Wyoming. The unconformity between the Gregory and DeGrey Members at the site implies subaerial exposure of the sea floor.Deposition of the DeGrey Member resulted from a readvance of the Pierre Sea in the Cooperstown area. The basal portion of this member contains numerous layers of bentonite and a vertebrate fauna consisting of mosasaur, shark, bony fish, and bird remains. Deposition of the DeGrey Member at the Cooperstown site probably occurred during the Late Campanian in a warm, shallow Pierre Sea. The DeGrey at the Cooperstown site correlates at least in part to the DeGrey Member in south-central South Dakota. The remains of several mosasaurs have been found in the DeGrey at the site. One specimen, a nearly complete 7 m long skeleton, is a new species of *Plioplatecarpus*. The carcass of this mosasaur was scavenged by dogfish sharks.**ACKNOWLEDGMENTS**We gratefully acknowledge the interest and support of the Beverly and Orville Tranby and Tim Soma families who allowed us access to their properties for this study. We, and the citizens of the State of North Dakota, thank Beverly and Orville Tranby, Gloria Thompson, Jacqueline Evenson, and Susan Wilhelm for donating the *Plioplatecarpus* specimen to the state for permanent exhibit at the North Dakota Heritage Center. Gordon Bell, Jim Martin, Bill Cobban, Neil Landman, Rod Feldmann, and J. Mark Erickson examined specimens from the site. We appreciate their help. We also thank the many volunteers who helped excavate the*Plioplatecarpus* specimen, including Gene Loge, Orville Tranby, Scott Tranby, and geology students from St. Lawrence University, Canton, New York**REFERENCES**  Barry, J. G., and Melsted, V. J., 1908, North Dakota Geological Survey 5th Biennial Report, p. 115-211.Gill, J. R., and Cobban, W. 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| **Table 1: List of taxa from the Pierre Shale Cooperstown site.\*=collected from the Gregory Member. +=collected from the DeGrey Member.** |
| **Invertebrates:** |
| Phylum Protozoa |    Phylum Annelida |
|   | Class Sarcodina |   |  Annelida sp. indet.\* |
|   |   | Foraminifera spp. indet.\* |   |   |   |
|   |   Phylum Arthropoda |
| Phylum Coelenterata |   |  Class Crustacea |
|   | Class Anthozoa |   |   | *Dakoticancer* sp.\* |
|   |   | *Micrabacia americana*\* |   |   | *Callianassa* sp.\* |
|   |   | Anthozoa sp. indet.\* |   |   | *Hoploparia* sp.\* |
|   |   |   |   |   | Ostacoda spp. indet.\* |
| Phylum Bryozoa |   |   |   |
|   | Bryozoa sp. indet.\* |   Phylum Enchinoderma |
|   |   |   |   |  Class Asteroidea |
| Phylum Brachiopoda |   |   | *Asteroidea* sp. indet.\* |
|   | Class Inarticulata |   |  Class Echinoidea |
|   |   | *Lingula subspatulata*\* |   |   | *Eurysalenia minima*\* |
|   |   |   |   |   |   |
| Phylum Mollusca | **Vertebrates:** |
|   | Class Bivalvia |   Phylum Chordata |
|   |   | *Inoceramus* sp.+ |   |  Class Chondrichthyes |
|   |   | *Nucula cancellata*?\* |   |   | *Squalicorax pristodontus*+ |
|   |   | *Nuculana* sp.\* |   |   | *Cretolamna appendiculata*+ |
|   |   | *Pteria* sp.\* |   |   | *Carcharias* sp.\*+ |
|   |   | ?*Nemodon* sp.\* |   |   | *Pseudocorax* sp.+ |
|   |   | Ostreidae sp. indet.\* |   |   | *Squalus* sp.+ |
|   |   | Bivalvia spp. indet.\* |   |   | Pristiophoridae sp. indet.+ |
|   |   |   |   |   |   |
|   | Class Gastropoda |   |   Class Osteichthyes |
|   |   | *Margaritella flexistriata*\* |   |   | Enchodus sp.+ |
|   |   | *Trachytriton vinculum*\* |   |   |   |
|   |   | *Atira* sp.\* |   |  Class Reptilia |
|   |   | *Oligoptycha* sp.\* |   |   | Order Chelonia |
|   |   | *Graphidula*? sp.\* |   |   |   | Chelonia sp. indet.+ |
|   |   | Trochidae sp. indet.\* |   |   | Order Squamata |
|   |   | Patellina sp. indet.\* |   |   |   | *Plioplatecarpus* n. sp.+ |
|   |   | Gastropoda spp. indet.\* |   |   |   | Mosasaurinae sp. indet.+ |
|   |   |   |   |   |   |
|   | Class Cephalopoda |   | Class Aves |
|   |   | *Baculites gregoryensis*\* |   |   | *Hesperornis regalis*+ |
|   |   | *Didymoceras cochleatum*\* |   |   |   |
|   |   | *Didymoceras* sp.\* |   |   |   |
|   |   | *Solenoceras mortoni*\* |   |   |   |
|   |   | *Trachyscaphite*s cf. *T. spiniger*\* |   |   |   |

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