Geology of Niobrara State Park, Knox County, Nebraska, and Adjacent Areas, with a Brief History of the Park, Gavins Point Dam, and Lewis and Clark Lake

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Charles A. Flowerday and R.F. Diffendal, Jr., Editors


Educational Circular 13
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September 1997

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Introduction

Location
Niobrara State Park is located in northwestern Knox County, Nebraska, just west of the town of Niobrara and on the west side of the Niobrara River. The present park was opened in the summer of 1987. Mostly north of Nebraska Highway 12, the site is hilly with bluffs overlooking the Missouri and Niobrara rivers. Excellent facilities include paved roads, cabins, an outdoor swimming pool, hiking trails, picnic and camping sites, horseback riding trails, playgrounds, restrooms, a group lodge, and an interpretive shelter. Many vantage points in the park have beautiful views of the lower Niobrara Valley and the middle Missouri Valley. Lovers of native plants and wildlife can see many different species in and near the park. Park grounds are open all year. The park office, about 1.5 miles northwest of the park entrance, is open daily from mid-April to mid-November, and weekdays at other times of the year (figs. 1 and 2).

Purposes
This educational circular describes the prehistory and history of Niobrara State Park, Gavins Point Dam and its reservoir—Lewis and Clark Lake—and several aspects of the geology of the park and nearby or adjoining areas. Sections include information on minerals, fossils, stratigraphy, and geologic history, but the principal focuses of this circular are on the work of and changes in the Niobrara River and on geologic hazards in the area.

Cautions
Caution is advised when visiting the park or any other area. Avoid walking on landslide areas. Stay away from steep hill slopes. Be careful when working on dark shale exposures on hot days because temperatures on these shales reach well above 100 degrees F. Poison ivy, stinging insects, and other such hazards occur. Be careful!

We remind readers that collecting of any kind is prohibited in the park and that permission must be obtained from property owners before going on or collecting from private property.

Acknowledgments
We want to thank James Potter, historian, Nebraska State Historical Society, Lincoln, Nebraska, and Ronald Watt, senior archivist, Church of Jesus Christ of Latter-Day Saints, Salt Lake City, Utah, for their help in securing information on the Mormon visit to the area. The Nebraska Game and Parks Commission and the Nebraska Department of Roads cooperated with several of the authors on work and collections noted in this educational circular. M. Kuzila, B. Hanson, S. Summerside, R. and S. Schleiger, and A. Diffendal reviewed the manuscript and offered suggestions.

Prehistory and History of Native American Occupation of the Niobrara State Park Area and Surrounding Lands

A brief survey of the prehistory of the area surrounding the confluence of the Missouri and Niobrara rivers begins with some sketchy evidence of Native American cultures before white contact. The period during which these cultures thrived is called the Plains Village Period (1000 to 1750 Common Era [C.E.]). A civilization known as the St. Helena phase from the Central Plains tradition (1000-1450 C.E.) was established along the Missouri in northeastern Nebraska during the latter part of this tradition. A few more sites near the area have been found from the Coalescent tradition (about 1450-1750 C.E.). These sites exhibit a lifeway reflecting a combination of the Central Plains tradition, an ancestral Pawnee, corn-growing village culture, and the influence of outside groups. These have been called the Red Bird and Anoka “foci” (focuses) which can include one or more sites.

During the Historic Period, beginning about 1750-1800, one of the most important tribes in the area was the Omaha, who took up a semi-settled lifeway in northwestern Iowa, northeastern Nebraska and southeastern South Dakota. By the 1700s, the Omaha had settled south of Sioux Falls on the Big Sioux River, having learned corn cultivation and earth-lodge construction from the Arikara. The Omaha moved up and down the Missouri Valley and nearby tributaries for the next 150 years and eventually were placed on a reservation in Thurston and Cuming counties.

But the Omaha are probably most important to this area for spawning the Ponca, who split from the Omaha at a time and over issues that are disputed but by 1730 were living near the mouth of the Niobrara. A confirmed historical report puts them on Bazile Creek in 1785. By this time, they were well-enough positioned along the area’s fundamental trade route, the Missouri River, that they would raid trading boats passing up that river, trading stolen goods with upriver tribes such as the Arikara and Dakota. In addition, they would intercept guns headed toward those potential enemies. Of course they also traded overtly with whites coming up the Missouri, as well as with their upstream neighbors.

During the Historic, the Ponca core area and major agricultural base were the bottoms and uplands along the Missouri and near the mouths of the Niobrara River and Ponca and Bazile creeks. The Ponca’s position as middlemen in trade diminished as the fur trade declined. By about 1830, they had abandoned village life and become fully nomadic, following the bison. With the decline of the bison herds and an alliance with the Dakota at an end, the Ponca gave up the

Note: References have been listed by superscript number(s), which refer to citations listed by number in the References Cited section. This system was used to promote greater ease of reading by limiting intrusive lists of citations. Citations added after the initial drafts have been given alphabetical designations within a given number, such as 1a, 1b, etc.
their land by 1858 and retained only a reservation between the Niobrara and Ponca Creek about 20 miles upstream from the mouth of the Niobrara. In another treaty in 1865, the tribe was given its more traditional land from the confluence of the Missouri and the Niobrara, between the rivers, to about 13 miles west of the town of Niobrara; its boundaries then jutted down to between the Niobrara and Ponca Creek for about another 10 miles (fig. 3). In 1868, however, a grave error made in negotiating the treaty establishing the Great Sioux Nation gave the Ponca land to the Sioux. When the government failed to fix the mistake and as they grew tired of Brule Sioux raiding, the Ponca accepted relocation to Indian Territory in present Oklahoma27b.

Many died on the grueling march to Oklahoma, where nearly a quarter of the survivors died of disease and malnutrition during the first two years. In 1879, at the dying request of his son, Standing Bear, a traditional chief, led 29 Poncas on an escape in an attempt to return to their traditional home and to bury the chief’s son there. Arrested on the Omaha reservation, Standing Bear stood trial in a case that set a precedent establishing that Indians have full rights before the law and allowing the Ponca to return to their traditional lands. Forming the Northern Ponca in 1881, they settled on the old reservation, by then, largely abandoned by the Sioux.

However, by 1965, with much of the land out of their hands, the federal government moved to “terminate” the res-
ervation, the last of 109 tribes to be so designated during the 1950s and 1960s (fig. 4). A movement in the 1970s and 1980s to reverse this policy bore fruit for the Ponca when the state of Nebraska recognized the Northern Ponca in 1988; the federal government did so in 1989 after a special provision was inserted barring them from ever seeking restoration of their reservation. Most Northern Ponca still live near the old reservation or in Omaha, Lincoln or Norfolk. Headquartered in new Niobrara, the restored tribe is using its new status to forge an economic development plan and to seek funding for tribal member enterprises.

Another tribe with a significant history in the region is the Yankton Sioux, who had moved into southwestern Minnesota from the woodlands by about 1700. They then moved to southeastern South Dakota due to conflict with other tribes. There they adopted the semi-settled lifeway of their neighbors, the Arikara. By the 1830s, they were observed hunting up the valleys of the Niobrara and the White rivers.

In exchange for giving up about 11 million acres, the Yanktons were offered a 430,000-acre reserve in South Dakota in an 1858 treaty. It bordered the Missouri from the Choteau River about 10 miles upstream from the mouth of the Niobrara to past Lake Andes. During the reservation era, land belonging to the Yankton progressively passed out of Indian hands, particularly through allotment in severalty—separating tribal land into individually owned parcels, which
Fig. 3. Ponca Lands after Treaty of 1865 (after Froehling^{8a,38b}).

Fig. 4. Ponca Landholdings at Termination (after Froehling^{8a, 3a, 22a, 41a}).
History of Niobrara State Park Area and Surrounding Lands Since White Contact

William Clark provided the best early written account of the area that was later to become Niobrara State Park (Niobrara Island)\(^3\). On Tuesday, September 4, 1804, the Lewis and Clark Expedition passed the mouth of the Qui Courre (Niobrara) River. Also known similarly as L'eau qui Court, meaning “running water,” the Niobrara was so called by the French when they adapted to their language the name the Pawnee gave it. Its present name was derived from an Omaha-Ponca designation, “Niobhaka ke,” meaning “spreading water,” for its characteristic spreading of high spring flows over its floodplain\(^2\).

Clark reported the river to be 152 yards wide and 4 feet or less in depth with sand bars at its mouth and bars and islands farther upstream. He said that it resembled the Platte in having these features, but the Niobrara sand was coarser. Clark left his companions and went up the Niobrara about 3 miles to an old Native American village site, rejoining the expedition boat late the same day at Panis Island on the Missouri River, just upstream from the mouth of the Niobrara\(^5\).

Writers disagree on events from 1805 to 1856. Mormons were reported to have moved into the area sometime in the 1840s, but the exact dates of arrival and departure vary, as does the chronicle of events during the Mormon period of settlement. Bouc reported that members of the Ponca Tribe guided Mormons to the area in the winter of 1846 and the Mormons departed in the spring of the following year. The Niobrara Tribune noted the Mormon arrival date as 1847 and their departure the following spring\(^11\). Murphy does not list arrival and departure dates but does note that the settlers stayed for 10 months and planted and harvested crops\(^26\). All agree that the Mormons settled on a piece of land later called Niobrara Island, where much later, the first Niobrara State Park was located. An anonymous author records that a party of 65 Mormon families followed the Platte Valley in the summer of 1846 and contracted to harvest grain somewhere in the Columbus-Genoa area. (Murphy notes about 250 people in the group, but he does not say where he obtained this number\(^2\).) After harvest, a band of Poncas led the group to a campsite near the mouth of the Niobrara. From 14 to 17 people died over the winter\(^4,6,3,1,26\).

Much of the confusion in the accounts above could have been avoided if those writers had looked at a small article by Fry (1922) published in Nebraska History. Fry reported that he interviewed two Mormons who had been part of the party that had overwintered in 1846-47 on the west bank of the Niobrara River, opposite the future town site\(^20\). During the winter, 17 people, including the party leader, Newel(l) Knight, died from pneumonia. (Spelling varies on Newel.) The party left the winter camp in the spring of 1847.

Bennett added further to the story of the Mormon visit\(^1\). He reported that the group of three companies totaled 178 wagons and nearly 400 settlers. On September 8, 1846, they laid out the site for their winter stay and subsequently hayed the area and built a picket fort.

Niobrara Island was about 2.5 miles long and was up to 0.75 miles wide, bounded on the north by the Missouri-Niobrara confluence and on the east and south by the Niobrara\(^6\). Several reports claim that the west side of Niobrara Island was bounded either by a ditch dug for defense against Indian attacks or by the Mormon Canal\(^26,28,31\). The Mormon Canal was reported as a mill race dug by the Mormons\(^31\), but Murphy suggested that this may not have been true\(^26\). Fry noted that survivors he interviewed had told him that the “Mormon canal” was not used for power, but he did not say whether the party had dug the canal\(^20\). Journal records of two of the Mormons, Newel(l) Knight and Joseph Holbrook, include comments on making a millstone and using oxen power to turn the stone, but make no mention of construction of a canal (R.G. Watt, LDS archivist, personal communication, 1997). As Niobrara Island is a vegetated sandbar on the Niobrara Valley floor, probably the Mormon Canal is a natural small branch channel of the river. Whatever the true origin of Niobrara Island, it eventually became part of the Great Sioux Reservation\(^26\). The town of Niobrara was settled in 1856. Some citizens of Niobrara petitioned Congress to set Niobrara Island aside as a town park in 1889 and in due course Congress acted to donate the land to the town\(^26\). Town citizens paid to build a clubhouse on the island and then used it and the park\(^31\). By 1929 town interest in the park was low, and the federal government gave Niobrara permission to transfer the island to the state of Nebraska. The transfer was accomplished by April 1930\(^26\). By 1933 the state had made many improvements on the north half of the island, by that time known as Niobrara Island State Park. These improvements included creating a nine-hole golf course, building picnic areas, moving and repairing the clubhouse, and stocking two lakes with bass and bullhead\(^31\).

By April of 1934, the men of the Civilian Conservation Corps (CCC) camped at Niobrara Island and worked on projects that would continue into 1935\(^26,32,33,34\). The CCC built roads, dug wells, made signs, improved picnic facilities, planted trees, built bridges, landscaped, dug out a lake, made...
baseball diamonds and tennis courts, developed camping facilities, and built cabins. The CCC completed its work and was ordered to move on to Valentine in April of 1935. The park was opened late in 1935 and advertised cabins for rent. Similar advertisements ran in most issues of *Outdoor Nebraska* from late 1935 to the summer of 1944, when a two-page article was published describing Niobrara State Park and reprinted in 1948 and 1952.

In the late 1930s and early 1940s, events took place that would later have a great impact on Niobrara State Park (or Niobrara Island). Major floods in 1942 and 1943 prompted rapid completion of plans to dam the Missouri. Two federal agencies, the U.S. Army Corps of Engineers and the U.S. Bureau of Reclamation, were making plans for the dams. The two, called the Pick Plan, for then Brigadier General Lewis A. Pick, of the Corps, and the Sloan Plan for Glenn Sloan, assistant commissioner of the Bureau, were ultimately merged into the Pick-Sloan Plan. Pick-Sloan was passed by Congress as the Flood Control Act of 1944 on December 22, 1944. Part of the plan was the construction of Gavins Point Dam about 4 miles west of Yankton, South Dakota, by the Corps of Engineers. Considerable debate ensued over the costs and benefits of the various water projects in the Pick-Sloan Plan, but most of them were completed.

The value of Gavins Point Dam lay in the eye of the beholder. This dam was one of several in the Pick Plan for flood and navigation control, provision of uniform flows, minimization of bank erosion, power generation, and recreation on the Missouri River. But the proposal to build Gavins Point Dam was opposed initially by the Bureau of Reclamation, which claimed that it was too expensive for the benefits derived, that it would not be useful in flood control, and that its cost per kilowatt-hour was much greater than the projected cost at other bureau-selected sites. Nonetheless, when the two plans were merged, Gavins Point was included among the projects.

In 1952, construction began on the dam, which was built with locally obtained earth and with chalk rock from the Niobrara Chalk Formation. This earthen dam is 74 feet high, 8,700 feet long, 35 feet wide at the top, and has a maximum base width of 850 feet. There is a concrete powerhouse and spillway at the southern end. Three generators, each originally producing 33,333 kilowatts, were installed in the power house. Power generation began in the fall of 1956 and was upgraded in 1989 to 44,099 kilowatts per generator. Lewis and Clark Lake had an original maximum pool storage capacity of 520,000 acre-feet, but it was listed as 492,000 acre-feet in 1996. The maximum depth also seems to have decreased from a reported 50 feet in 1977 to 45 feet in 1996. The normal summer-recreation operating level in 1977 was 1,208 feet above sea level. The project was completed in 1957 at a reported cost of $50.6 million.

By the mid-1980s, the original park, mostly on Niobrara Island, became increasingly threatened by the Niobrara River. The altitude of the Missouri River at the Niobrara-Missouri confluence is shown as between 1,210 and 1,220 feet above sea level on the 1950 edition of the U.S. Geological Survey 7.5-minute Niobrara, South Dakota-Nebraska, topographic map (fig. 1). Since that time, the water table in the Niobrara area has risen and the lower Niobrara River has changed course and has deposited sediment, thus building up its floodplain and causing channel changes. The Nebraska Game and Parks Commission purchased 1,231 acres of higher land to the west of the old park and built a new Niobrara State Park to replace the old one. Cabins at the new park were opened for rental on June 27, 1987; the new park opened and was dedicated on July 11, 1987. Cabins at the old park were still in use in 1987, but were later abandoned because of high water in the area. Some of the buildings of the original Niobrara Island State Park could still be seen north of Nebraska Highway 12 in 1997 (figs. 1 and 2).

### Geology of Niobrara State Park Area

#### General Stratigraphy

**Cretaceous System**

The distribution of Cretaceous rocks in the park area was first shown on a geologic map in 1845. The hills and valleys around Niobrara State Park are cut into the sedimentary rocks of the Pierre Shale and Niobrara Chalk formations of Late Cretaceous age. These rocks were first described by Meek and Hayden and further described by Hayden (figs. 5 and 6). These rock units were deposited as sediments in a once great shallow sea, known as the Western Interior Seaway (fig. 7), which stretched from the Arctic Ocean to the Gulf of Mexico and from Montana eastward across Nebraska into Iowa and Minnesota.

The oldest sedimentary formation exposed within the park boundaries is the Niobrara Chalk (table 1, modified from Schulte, 1952). This rock forms the nearly vertical bluffs that encompass Lewis and Clark Lake from the mouth of the Niobrara River to Gavins Point Dam near Yankton, South Dakota. The Niobrara Chalk is a dark gray to steel blue color where first exposed, but it soon weathered to a yellowish white when exposed to the atmosphere for a few years. The chalk is composed of innumerable skeletons of the minute oceanic phytoplankton algae called *coccoliths* (plate 1). Coccolith algae lived in great abundance in the oceanic waters of the Western Interior Seaway during the Late Cretaceous, when the Niobrara Chalk was being deposited. Indeed, these coccolith algae were so abundant in those ancient seas that this period of time is named Cretaceous, since *Creta* means chalk. The Niobrara Chalk is the same age as the famous White Cliffs of Dover, also composed of chalk made from the same algae.

In most places along Lewis and Clark Lake, the Niobrara Chalk can be reached only by boat. These vertical cliffs are often unstable and extreme care should be exercised, as rockfalls are always a possibility. In Niobrara State Park, however, there are several locations along the Missouri River trail where a careful walker may examine the chalk in relative safety. The time spent is often rewarded by seeing many fossils of larger creatures. Some of the most common large fossils are the shells of ammonite cephalopods and of the large clam *Inoceramus* and its relatives (plate 2a-c). Unlike many other shellfish, the inoceramid clams managed to tolerate the...
Fig. 6. Geologic map of Niobrara State Park and adjacent area.
soupy, chalky sea floor as the Niobrara Chalk was accumulating. Their large, flat, thin shells acted much the way a snowshoe acts on soft snow, allowing the clams to stay in contact with the sea water, rather than sinking into the soupy morass. The shells of these large clams offered some of the few solid places on the Niobrara sea floor. Many other animals that needed a hard place to attach themselves, such as barnacles and other types of clams, used the inoceramid shells.
Plate 1. a) One of the very well-preserved calcareous nannofossils (Biscutum zulloi) from the Niobrara Chalk Formation at Niobrara State Park. b) Specimen of Boletuvelum candens, a nannofossil normally found only in the upper part of the Niobrara Chalk Formation. This specimen has been reworked into the Crow Creek Member of the Pierre Shale as a result of the impact.
Plate 2. a) A scaphitid ammonite from the middle part of the Niobrara Chalk Formation. The outcrop is located to the east of Niobrara State Park, near the town of Center, Nebraska. Scale bar = 1 inch. b) An inoceramid clam whose upper shell surface has been covered by the smaller clam Pseudoperna congesta. The upper surface of this clam was one of the few firm substrates on the soupy floor of the Western Interior Seaway during deposition of the Niobrara Chalk Formation. Scale bar = 1 inch. c) A large specimen of inoceramid clam from the Pierre Shale Formation near the park. Scale bar = 1 inch.
Thus, many of the inoceramid shells found in the Niobrara Chalk have their surfaces covered with the shells of other sea creatures. The most common such hitchhiker is a small oyster-like clam known as *Pseudoperna congesta* (plate 2b).

In addition to the shelled invertebrates that lived in the Niobrara Sea, there were many animals without shells that inhabited these waters. Although they had no shell or other skeleton to leave behind as fossil remains, evidence of their presence was preserved nevertheless by the burrows that they excavated. These burrows, or *trace fossils* as they are known to geologists, occur as single or branching, cylindrical structures within the rock. They are generally small (less than 2 inches wide) in the Niobrara Chalk, although in other formations they may be appreciably larger. The burrows in the chalk are often lighter in color than the surrounding rock, rendering them readily visible to the naked eye. The burrows tend to occur in distinct layers within the Niobrara. These layers record a period when the water at the sea floor was slightly higher in oxygen than at other times. The higher oxygen content allowed for the colonization of the sea floor by the shell-less invertebrates that produced these burrows.

It is the fossils of vertebrate creatures, however, that have made the Niobrara Chalk world famous as a fossil formation. Among the most common skeletal remains in the Niobrara are bones, teeth, and scales of the giant fish *Xiphactinus*. This huge predator could exceed 20 feet in length. Its body was covered by large, silver-dollar-sized, concentrically ringed round scales. These scales are common in the Niobrara, where they are preserved as dark brown or black, flat circular fossils. The bones of this creature are also common in the Niobrara Chalk. Fossils from other localities in Nebraska and Kansas preserve the entire skeleton of this extinct giant. Its skeleton indicates that it was related to the modern herring and the tarpon. Indeed, it is often called the “bulldog tarpon.” Unlike the modern tarpon, however, the bulldog tarpon of the Late Cretaceous had a set of sharp, spike-like teeth 1-3 inches long, with which it probably impaled its victims.

Lying atop the Niobrara Chalk are the black mudstones, shales, and chalks of the Pierre Shale (table 1). The shale is dark gray to black in color because of the large amount of organic matter and pyrite contained within it. The organic matter came from the remains of the microscopic algae that lived in the surface water of the Western Interior Seaway when the Pierre was deposited. As the bodies of these algae sank to the sea floor, bacteria tried to decompose and recycle the nutrients locked up in the algal bodies. These bacteria used up all of the available oxygen in the water at the sea floor. Other bacteria, living in the sediment, continued to try to decompose the organic matter by making hydrogen sulfide gas (this gas smells like rotten eggs). The pyrite in the Pierre Shale formed as iron from the water mixed with the sulfide given off by the bacteria. This pyrite (also known as *fool’s gold*) often occurs as fist-size irregular chunks known as pyrite nodules. These nodules can be found at several localities in and near Niobrara State Park.

Although the Pierre Shale is composed mostly of black shale and mudstone, it does contain a thin white chalk unit in eastern Nebraska and South Dakota. This unit, the Crow Creek Member of the Pierre Shale, forms a distinctly white band approximately 10 feet thick that is easily visible in the middle part of some landslide exposures along the Missouri River trail. The Crow Creek Member is unusual for at least three reasons. First, the base of the unit consists of a pebbly sandstone. The relatively large pebbles and sand grains in this rock could only have been moved by a vigorous current. No other sands of this kind occur in the Pierre over such a large area. Indeed, all other indications are that the Pierre was deposited in deep, quiet water. Second, many of the sand grains in the basal pebbly sandstone have closely spaced, parallel breaks running through them. This type of deformation happens only when the sand grain is subjected to a very high-pressure impact. Finally, fossils and rock fragments of distinctly different ages occur in the Crow Creek. Many of the pebbly grains in the Crow Creek come from more ancient Paleozoic limestones. A large number of microfossils in the Crow Creek are actually derived from the Niobrara Chalk. This mixing of fossils of different ages is not known from any other Cretaceous rocks in this part of the Western Interior Basin.

What can explain these strange occurrences in the Crow Creek? The answer can be found near the town of Manson, Iowa (fig. 8). There, buried deeply under more recent sedimentary rock, lies the crater formed by the impact of a meteorite\(^1\). Based on the size and shape of the crater, the meteorite was about 1-2 miles in diameter, and struck the Earth at a velocity of about 45,000 miles per hour. The impact excavated a crater that is more than 20 miles across and fractured the earth’s crust to a depth of more than 2 miles. This is the largest impact structure known in the United States. The force of the impact was greater than the combined nuclear arsenal of all nations on Earth today! As the impact occurred, it sent out a hypersonic shock wave that traveled across the surface of the Western Interior Seaway. Broken rock fragments were launched from the impact site, tossing shocked grains tens of miles away into the Crow Creek Sea. The hypersonic shock wave may have triggered a tidal wave, or *tsunami*, that stirred up the sediment of the Crow Creek Sea. This tidal wave would have ripped up older deposits of Niobrara Chalk and Pierre Shale, moving these sediments and their fossils into the basin and mixing them with the Crow Creek fossils.

At the top of the bluff at Niobrara State Park, there is another interval of chalky sediment known as the Mobridge Member. These beds record the last episode of truly marine conditions in the Western Interior Seaway of this area. The Mobridge is known to record marine conditions because of the abundance of marine organisms found in it, including coccolith algae, foraminifers, and large marine reptiles.

The fossils in the Mobridge Member indicate that it was deposited in a sea unlike any that had preceded it in the Western Interior Seaway. Several species of coccolith algae found in the Mobridge Member were previously known only from the ocean basins around Antarctica. In addition, other species typically found in rocks from the Late Cretaceous tropic and temperate zones are absent or very rare in the Mobridge Member. These facts suggest that the Mobridge seawater was relatively cool, and was probably derived directly from the Arctic Ocean to the north.
could slip through the tangle, ambushing their prey. (figs. 1 and 6). The alluvium and landslide debris will be in the park or any adjacent areas shown on figure 6. Sediments discussed in more detail later. Some alluvium older than mostly less than tributaries, colluvium (slope deposits) and landslide debris younger Quaternary System, are present and include alluvium which became a dense seaweed forest, similar to that offshore of California today. The wide bodies of the plesiosaurs could only maneuver through this dense algal forest with great difficulty, whereas the "snake-like" bodies of the mosasaurs seem to have preferred the tropics while other hand, this replacement may have been caused by other rocks of the same age in California. However, they seemed to have abandoned the Western Interior Seaway by Mobridge time. Their place in the ecosystem seems to have been taken over by the mosasaurs, a group of large marine reptiles related to modern snakes.

The replacement of plesiosaurs by mosasaurs may have been a response to cooling sea water temperatures, because plesiosaurs seem to have preferred the tropics while mosasaurs were more common in higher latitudes. On the other hand, this replacement may have been caused by other changes in the seaway. For example, it has been proposed that the plesiosaurs thrived early in the Late Cretaceous, when the waters of the seaway were clear and open. Near the end of the Late Cretaceous, according to this proposal, the seaway became a dense seaweed forest, similar to that offshore of California today. The wide bodies of the plesiosaurs could only maneuver through this dense algal forest with great difficulty, whereas the "snake-like" bodies of the mosasaurs could slip through the tangle, ambushung their prey.

Quaternary System
No rocks of the Tertiary System (fig. 5) have been found in the park or any adjacent areas shown on figure 6. Sediments mostly less than 10,000 years old and belonging to the younger Quaternary System, are present and include alluvium (river deposits) of the Niobrara and Missouri rivers and their tributaries, colluvium (slope deposits) and landslide debris (figs. 1 and 6). The alluvium and landslide debris will be discussed in more detail later. Some alluvium older than 10,000 years in age occurs as valley fills and high terrace remnants along Nebraska Highway 14 on the east side of the Niobrara River southwest of Niobrara, Nebraska.

Vertebrate Fossils and Minerals

Vertebrate Fossils
The first vertebrate fossil described from North America west of the Allegheny Mountains was discovered in 1804 by Lewis and Clark “in a cavern a few miles distant from the Missouri [River]” above Council Bluffs. This specimen, mistaken for a reptile by Harlan in 1824 and given the name Saurocephalus (reptile-headed), is actually a predatory fish. The exact collecting locality is uncertain. However, since these fish are known only from Upper Cretaceous rocks (notably in western Kansas and New Jersey), it follows that the specimen must have come from northeastern Nebraska or western Iowa, where marine rocks of this age outcrop. No additional specimens were discovered in this area for more than 180 years until amateur paleontologist Ben Vrana found a complete skull in the Niobrara Formation near the Gavins Point Dam. This important specimen was donated to the University of Nebraska State Museum and is prominently displayed in the State Museum’s Mesozoic Gallery in Morrill Hall on the University of Nebraska-Lincoln campus (plate 3a).

Few vertebrate fossils have been found in the type area of the Niobrara Chalk Formation in and around the new Niobrara State Park. This is primarily due to the limited, near-vertical local exposures, in contrast to the nearly continuous badland outcrops in west-central Kansas where the world-famous Smoky Hill Chalk Member has produced thousands of articulated (arranged as when alive) skeletons of marine vertebrates. A fossil collector can be quite successful in Nebraska by carefully inspecting slump blocks and cliff faces along the Missouri River and its tributaries and looking for hard, dark gray to black bone, which contrasts well with the yellow- to light-gray chalk medium. Specimens discovered in slump blocks are often in several fragments. These can be reassembled and jacketed with protective layers of plaster and burlap (see below).

The shallow sea that covered Nebraska during the Late Cretaceous teemed with vertebrate life. The most common fossil discoveries are the remains of teleosts (bony fishes). There are many varieties ranging in size from small prey-fish several inches long to the huge, voracious Xiphactinus, which grew to 16 feet and consumed prey 6-7 feet long. Isolated jaws (plate 3b), vertebrae (plate 3d), and scales (plate 3c) are usually found, but partial to complete skeletons (plate 3e), which require a great deal of patience and skill to properly prepare, are occasionally discovered. Shark teeth are abundant at some localities and may be identified by their shape and size. Sharp, pointed, sometimes serrated teeth belong to predatory meat-eating varieties (plate 3f, g), while low, rounded, striated "pavement teeth" indicate a preference for molluscs (plate 3h).
Plate 3. Typical Mesozoic marine vertebrate fossils: a) Saurocephalus, bony fish, Niobrara Formation, side view of skull, X 0.33. b) Bony-fish, Niobrara Formation, jaw and bone fragments in chalk, X 1.5. c) ?Xiphactinus, Niobrara Formation, fish scale, X 1.75. d) Xiphactinus, Niobrara Formation, fish vertebra, X 0.7. e) Complete skeleton of Xiphactinus, Niobrara Formation, X 0.03. f) Cretorexhina, Niobrara Formation, shark teeth, X 1. g) Squalicorax, Niobrara Formation, shark tooth, X 0.7. h) Ptychodus, Niobrara Formation, shark tooth, X 0.6. i) Bony-fish, Pierre Formation, partial skeleton with encrusting gypsum, X 1.75. j) Mosasaur tooth, Niobrara Formation, X 1. k) Mosasaur vertebra, Niobrara Formation, X 0.7.
The most spectacular vertebrate fossils are the remains of giant marine reptiles—mosasaurs and plesiosaurs. Again, isolated elements (teeth, vertebrae, paddle bones) are more commonly encountered (plate 3j, k) while complete skeletons are extremely rare. Other backboned animals that might be found in these deposits (pterosaurs, toothed birds, and giant sea turtles) are also very rare in Nebraska. Bird and pterosaur bones are hollow, and, therefore, usually crushed flat, resembling more common fish bones.

The Niobrara State Park Mosasaur

In 1986 construction of a state recreation road within the new park exposed the Mobridge Member of the Pierre Formation in several roadcuts. The following year, while planting trees along one of the new cuts, Nebraska Game and Parks Commission horticulturists Jon Morgenson and Steve Brey made a thrilling discovery. Several large petrified bones were protruding from the chalk rock while weathered bone and tooth fragments lay scattered on the slope below. Morgenson, an avid amateur paleontologist, did the proper thing by reburying the bones that remained in place and taking the fragments to the NU State Museum for identification. The fragments were from the jaws of a large mosasaur (or giant sea lizard)! Permission to remove them was obtained from park Superintendent Steve Kemper, and a small crew of volunteers and State Museum staff set to work excavating the remaining bones. It didn’t take long to remove the soft rock surrounding a magnificent skull and partial skeleton of the huge *Mosasaurus missouriensis*, so far Nebraska’s largest known and most ferocious Late Cretaceous resident.

Special excavation techniques were required to successfully remove the forequarter of a 33-foot long mosasaur (plate 4). The first step was to uncover the entire extent of the “bone-bed,” in this case a 7 x 7 feet jumble of skull, paddle, vertebrae, and ribs. This large area was then subdivided, at appropriate gaps between bones, into five manageable blocks. Each block was left on a sturdy pedestal; all exposed bone was covered with a tissue paper separator; and strips of burlap soaked in plaster were applied to form a hard, protective field jacket. The large blocks were reinforced with 2 x 4’s to prevent cracking during transportation to the laboratory for preparation. An important final step before removal was to number and map the size and orientation of each field jacket for future scientific studies.

Unlike most vertebrate remains found in the Pierre Shale, which are damaged by gypsum crystal growth (plate 3i), the Niobrara State Park mosasaur is beautifully preserved in three dimensions. Such delicate structures as the ring of bones inside the eyeball were found in place. For this reason, the specimen was painstakingly prepared for exhibit in the Mesozoic Gallery of the NU State Museum. Care was taken to maintain the position of each bone as it was found. The scattered, jumbled appearance of the skeleton indicates that scavengers, such as small sharks and bony fish, disarticulated (tore apart) the carcass before burial. On the lower jaw, a row of large puncture wounds showing no evidence of healing suggests that this animal may have perished in combat with another mosasaur of comparable size. The steps involved in taking a large vertebrate fossil from discovery to display are shown in plate 4.

Although Nebraska is world-famous for Cenozoic vertebrate remains from 35 million to 10,000 years in age, no sediments or fossils of this age are preserved within Niobrara State Park. Those interested in Cenozoic fossils are encouraged to visit Ashfall Fossil Beds State Historical Park, about 30 miles southwest of Niobrara, where paleontologists are excavating complete skeletons of rhinoceroses, three-toed horses, camels, and other 10-million-year-old animals.

The complete remains of fossil vertebrates in the sedimentary rocks of Nebraska are rare and of great scientific importance. Anyone discovering a skeleton that shows signs of being complete is urged to notify the Division of Vertebrate Paleontology, University of Nebraska State Museum, Lincoln, NE 68588-0514, so that the staff may supervise its collection, preparation, and study. The discoverer will receive full credit and the satisfaction of making a significant contribution to our knowledge of prehistoric life.

Minerals

Several minerals occur in the Niobrara Chalk and/or Pierre Shale. Crystals of the selenite variety of gypsum, hydrated calcium sulfate (CaSO₄•2H₂O), are very common in some parts of the Pierre. Light reflections from crystal faces on the shale surface in natural exposures and roadcuts look like broken glass from a distance. These crystals are beautiful but soft and are easily scratched. Pyrite and marcasite crystals may be found in both formations. These iron disulfide (FeS₂) minerals decompose in air and form iron oxides. Selenite, pyrite, marcasite, and other minerals are described and their distributions across Nebraska shown by Pabian.

Work of and Changes in the Niobrara River

Sedimentation in the River Channel and Floodplain

At Niobrara State Park, the Niobrara River occupies a broad valley in between bedrock bluffs. Outcrops of the Niobrara Chalk and Pierre Shale formations of Cretaceous age can be observed along the western valley margin within the park (front cover and fig. 6). The river channel ranges from 200 to 1,800 feet wide and consists of a network of channels, sand bars, and vegetated islands (fig. 9-11). The active river channel is flanked by a floodplain, extending to the valley walls, that is characterized by wetlands and areas of dense vegetation and agricultural use (fig. 9). The lower reaches of the river, including the Niobrara State Park area, are characterized by perennial flow and exhibit a classic braided channel network typified by branching and reuniting shallow channels separated from each other by branch islands or channel bars.

The Niobrara River is a sand-bed braided river because the predominant river bed material is a relatively uniform medium-grained sand. The sand is eroded by the Niobrara River and its tributaries from Quaternary terrace and valley fill deposits and sand-rich parts of the Long Pine Formation and
Plate 4. The Niobrara State Park Mosasaur: from discovery to display. a) Nebraska Game and Parks horticulturists Jon Morgenson (left) and Steve Brey discovered the skeleton in a roadcut within the park. b) Front of the skull as it appeared in the ground soon after excavation began. c) Mosasaur skeletal remains; elements recovered are shaded. d) Volunteer Jennifer Tschirren applies a tissue-paper separator prior to plastering. e) Steve Kemper (second from left) and crew help load the large jacketed blocks. f) Final preparation prior to installation in the State Museum’s Mesozoic Gallery. g) Mosasaur attacking Xiphactinus, from Mark Marcuson’s mural in the Mesozoic Gallery.
Ogallala Group of Tertiary age upstream from the Niobrara State Park area. In addition to being a source of sediment, these deposits supply water to the Niobrara River drainage basin by discharge from the High Plains aquifer. The river flows along the northern edge of the Sand Hills and also receives water and sediment from tributary streams that drain that region. Within the Niobrara River and its various tributary channels, sand is transported downstream as actively migrating dunes and bars. The dunes and bars in the Niobrara River are also common in other braided rivers such as the Platte River in southern Nebraska.

Sedimentation (that is, sediment deposition) in an active river channel occurs when relatively high water flows begin to diminish. Because a high water flow is capable of eroding and transporting more sediment than a lower flow, sediment deposition must occur in response to a decrease in the water flow. At relatively high water flows, the entire channel of the Niobrara River can be submerged with no sand bars visible above the water surface. As water levels decrease, bar complexes emerge, and the flow of the river is divided into a number of smaller channels that continuously shift their position (fig. 11). This is the typical braided channel network.

The sandy sediment moving through the channel network can accumulate on the floodplain adjacent to an active river channel through the processes of crevassing and avulsion (fig. 12a,b). These processes occur when the water in an active river channel is diverted to the floodplain by a flood that cannot be contained within the river channel or via a break in a levee. Crevassing is a temporary situation where a flow of water and sediment exit an active river channel and encroach onto the floodplain. However, an active river channel resumes its previous course once the water flow decreases and ends the crevassing event. The same process resulting in a permanent change in the course of an active river channel is an avulsion. Avulsion is an important process in delivering sediment to the low-lying floodplain areas of a river valley. Through the processes of crevassing and avulsion, the Niobrara River is able to supply sediment to all areas of its valley and fill the valley with sediment over time.

At Niobrara State Park, the Niobrara River flows into the Missouri River. The interaction of these two rivers has caused sediment deposition in both of the rivers in the vicinity of the park. Dams on the Missouri River, both upstream and downstream of the Niobrara River confluence (Fort Randall and Gavins Point Dams), have reduced peak water discharges and created a backwater lake (Lewis and Clark Lake). As a result, river levels have risen and rapid sediment build-up (aggradation) has occurred. Up to 7.5 feet of sediment was deposited along the lower 13 miles of the Niobrara River from 1952 to 1996. This long term trend of sediment build-up is ongoing and will continue in the future as a consequence of the regulation of the Missouri River.

Since completion of the reservoir system the lobes of sediment that protrude into the Missouri River from the mouth of the Niobrara River have coalesced into a delta (fig. 13).
Fig. 12. a) Aerial view (above) and b) annotated photo (right) of the old park site, just north of Nebraska Highway 12, looking south. This area is being flooded by waters from the main channel of the Niobrara River (upper left) and the Mormon Canal (upper right). The width of the Mormon Canal at the highway bridge is approximately 75 feet.

Prior to regulation of the Missouri River, the sediment that accumulated at the confluence of the two rivers would be swept away on occasion and moved farther downstream by floodwaters. By eliminating floods on this part of the Missouri River, the sediment accumulation has stabilized as a delta. The growth of the “Niobrara delta” has been monitored and studied by the Corps of Engineers.23,38

The Changing Face of the River

Changes in the Niobrara River occur on a seasonal basis, as well as over longer time spans. One can evaluate these changes by studying historical records and maps, photographs and hydrologic records from the U.S. Geological Survey, as well as topographic surveys and the river deposits themselves. Views of the lower Niobrara River before and after completion of the Missouri River reservoir system are shown in figures 14 and 15. In 1938, no delta is present at the confluence of the Niobrara and Missouri rivers, and the Niobrara River appears relatively straight and of uniform width between Highway 12 and the river mouth (fig. 14). By 1975, the Niobrara delta has formed and the river channel is much more variable in width and pattern (fig. 15) in comparison to the earlier view. Roads of the old park site are well defined on the 1975 image.

Seasonal changes in the lower Niobrara River are related to changes in water discharge of both the Niobrara and Missouri rivers. Increasing water discharges causes river levels to rise. An increase in the level of the Missouri River shifts the location of maximum sedimentation in the lower Niobrara River valley farther upstream. Decreased Missouri River levels allow Niobrara River sediment to extend farther into the Missouri River channel and add to the delta. The strength of the Niobrara’s water flow determines the amount of sediment deposition. Looking at records of the water flow and level of the Niobrara and Missouri rivers, respectively, one can appreciate the constant change of sedimentation patterns in the Niobrara State Park area (fig. 16a, b).

The flow of the Missouri River is towards the left (east) in the photograph. Niobrara State Park is located on the bluffs in the upper right of the photograph. The Niobrara River is approximately 900 feet wide at the railroad bridge.

Ice formation during the winter months also plays an important part in the seasonal changes observed in the Niobrara River. Water in shallow channels containing weak water flows is prone to freezing, and only the deepest part of the river channel can maintain water flow during the winter. However, episodes of freezing and thawing will cause variations in the water flow. The presence of ice in the river channel enhances the erosive power of the water flow, which may carve a deeper channel in the river bed during the winter months than during the remainder of the year. When the ice begins to break-up in the early spring, ice jams occur in the river channel and may disrupt or impede the river’s flow. In March 1995, an ice jam caused a break in the levee on the west side of the Niobrara River just upstream of the Highway 12 bridge. This levee break evolved over the past two years into the avulsion illustrated in fig. 12.

Shifting of the active river channel is causing pronounced changes in the lower Niobrara River valley. In 1996, much of the sandy river bed became exposed downstream of the Highway 12 bridge to near the old railroad bridge (fig. 2). Vegetation began to establish itself on this sandy surface soon afterward. Areas around the old park site that were densely
Fig. 14. Aerial photograph of the Niobrara, Nebraska, area on June 30, 1938. The mouth of the Niobrara River is at the railroad crossing, and no delta is present. Floodplain areas immediately adjacent to both the Niobrara and Missouri rivers are agricultural fields. Note the road network of Niobrara, Nebraska, for scale.

vegetated in 1995 were covered with sand in early 1996 and appeared relatively barren (fig. 17a, b). The avulsion of the river channel caused most of the Niobrara River's flow to enter the Mormon Canal, which could not hold that volume of water. The Nebraska Department of Roads plans to construct a new bridge over the Mormon Canal and to widen the Niobrara River channel to deal with the changing river. In July 1997, contractors had established a pit in the Pierre Shale (fig. 1) and were dumping shale debris along Nebraska Highway 12 between the Mormon Canal and the main channel bridges. However, because the river and its bed load constitute a dynamic system that changes constantly, major shifts of the channel and banks should be expected in the future.--Eds.]

Another aspect of change in the Niobrara River is that the river appears very different at different locations throughout Nebraska. Results of recent research indicate significant differences in channel form, depositional and erosional processes, and in the sequence of surface deposits between the river at Niobrara State Park and just 30 miles upstream near Lynch, Nebraska. The Niobrara River just upstream of the avulsion at Niobrara State Park is characterized by multiple, shallow channels; numerous small bars; medium-
grained, sand-size sediment; and a main channel that is elevated relative to the adjacent floodplain. Near Lynch the river is characterized by fewer, deeper channels; less numerous, larger bars; coarser-grained sand-size sediment; and a floodplain that is elevated relative to the main channel.

The River Through Time
Historical records indicate that the Niobrara River has changed through time. An indication of this change is found at the old park site where abandoned cabins are now being buried (fig. 18). These recent observations of the river channel shifting position, resulting in the burial of dense vegetation on the floodplain, can be used to interpret the river's depositional history. By collecting cores of the river and floodplain deposits, river sands and buried vegetation can be identified in the subsurface, which lends clues to the past locations of the active river channel and adjacent floodplains.

Cores from the active river channel are composed predominantly of sandy sediment. This suggests that the active river channel prior to the most recent avulsion had maintained a constant location for a considerable period of time. Near the base of some cores, an interval of clay-rich
Fig. 16. a) Average monthly water discharge of the Niobrara River for 1990-1994 as recorded at the USGS gauging station near Verdel, Nebraska (above); b) level (or stage) of Missouri River at USGS gauging stations upstream, at Greenwood, South Dakota, and downstream, at Springfield, South Dakota (upper right), from the Niobrara River confluence (elevation in feet).

(Fig. 16b) Sediment is present (fig. 19). This clay material is not usually deposited in the water flows typical of the active river channel. Clayey sediment could either settle out of quiet waters on floodplains or be concentrated into horizons by soil-forming processes. Based on knowledge of channel shifts through time, this clay-rich interval in the channel deposits suggests that, in the past, floodplain areas or islands occupied what is now the location of the active river channel.

Cores from the floodplain areas show alternating layers of sand, clay, and organic material (fig. 20). The organic material consists of plant debris in various states of decomposition. The presence of clay and organic-rich intervals together in the floodplain cores is indicative of buried soil horizons. Multiple buried soil horizons in individual cores suggest that prolonged periods of exposure and soil formation characterize the locations and time spans represented by the various floodplain cores. Except for the most recent episode, the sand deposits that separate the buried soils in the floodplain cores are the result of crevassing events. The timing of these events in the past is not known. Aerial photographs of the lower Niobrara River have been used to identify the timing of the most recent crevasse splay deposition. The upper sand interval in the floodplain cores represents the most recent crevassing event.

Fig. 17. a) Cabins in the old park site during the summer of 1995 (above). Note the dense vegetation around cabin 2. b) The same general area around cabin 2 during the summer of 1996 (below). Note the lack of vegetation and the recent sand deposits that now blanket this area. Person indicates scale.

Fig. 18. Interior of a cabin at the old park site. The cabin is filled with sand from the Niobrara River.
Natural Geologic Hazards in the Area

Floods

Floods on both the Missouri and Niobrara rivers have affected the Niobrara State Park area throughout recorded history. In fact, the town of Niobrara, Nebraska, has been moved three times as the result of floods and rising river levels. Flooding in late March and early April of 1881 led to abandonment of the original townsite along the Missouri River. Floods in 1899 and 1927 also caused significant property damage and required buildings to again be moved. According to newspaper accounts, floodwaters associated with these major events did not recede for up to three weeks\textsuperscript{30}. The previous location of the town, along the southern bank of the Missouri River, is shown in the 1938 and 1975 aerial photographs (figs. 14 and 15).

Historically, Missouri River floods occurred twice each year: in early spring (March-April), due to runoff from snowmelt in the upper Great Plains, and in late spring to early summer, due to runoff from snowmelt in the Rocky Mountains\textsuperscript{23}. The volume of water discharge is often greater in the late spring, but the river level is often higher in the early spring. Ice in the Missouri River assumes an important role in the early spring floods. As the ice sheets begin to break up, the river channel can become clogged with ice debris and water flow can be restricted. These “ice jams” create temporary dams, behind which the river rises to unstable levels. Catastrophic flooding can result from failure of the ice jams when combined with rapid melting and high runoff. Reducing the yearly flood hazard along the Missouri River was a principal goal behind construction of the Gavins Point, Fort Randall, and other Missouri River dams.

The largest flood of record on the Missouri River occurred in 1952, just prior to completion of the reservoir system. Water covered the entire width of the Missouri River valley in places from “bluff to bluff.” The river crested at 16.4 feet above normal, surpassing previous record flood levels in 1943 and 1950 by 2.8 feet and 5 feet, respectively\textsuperscript{30}. The peak discharge for that flood event is estimated at approximately 500,000 cubic feet per second (cfs)\textsuperscript{38}. The typical discharge of the Missouri River, in its current state, ranges from 20,000 to 40,000 cfs, which is controlled by the Corps of Engineers at the various dams. The strength of the 1952 flood was sufficient to remove sediment that had accumulated in the Missouri River channel at the mouth of the Niobrara River. The absence of this type of flooding since completion of the reservoir system has allowed sediment accumulations to evolve into the delta that is present today (fig. 13).

Floods have also occurred along the Niobrara River, but at smaller magnitudes than the Missouri River. Those floods are not as severe because the average discharge on the Niobrara River is about one-tenth that of the Missouri River. Significant floods on the Niobrara River occurred in 1960, 1962, and 1964 with peak discharges of 25,000 to 40,000 cfs\textsuperscript{38}. The largest flood of record on the Niobrara River in 1960 destroyed a part of the Nebraska Highway 12 bridge that crosses the river, just adjacent to the old park site. As with the 1952 flood of the Missouri River, Niobrara State Park was isolated by the 1960 flood of the smaller Niobrara River.
These floods illustrated the vulnerability of the old park site, which was situated on the floodplain of the Niobrara River.

From this brief review of the history of the Niobrara and Missouri rivers, it is clear that the low-lying floodplains in the Niobrara State Park area are prone to flooding (fig. 21). This process inherent to all river systems has always occurred in the past and can be expected to occur in the future. After several moves, Niobrara State Park and the town of Niobrara, Nebraska, now both reside on bluffs above the floodplain, out of reach of these two rivers.

Landslides

Nebraska is not generally recognized by the public as a landslide-prone state; however, in a recent study as many as 250 were recorded within the state. More than 40 were found along roadways in Knox County. Eight landslides were recorded and classified within the boundaries of Niobrara State Park (fig. 1).

Landslides are the downward and outward movement of earth materials. In general three conditions are required before landslides can occur. First, geologic formations (the rocks themselves) must have a history of landsliding. Second, the land surface usually must be sloping. And third, excessive amounts of water (either human-induced or in the form of precipitation) must be present.

All of these conditions exist naturally at the park. The Pierre Shale, found throughout the park, has an extensive history of landsliding in this area of Nebraska (fig. 6). This formation also has a tendency to slide on fairly low slopes, and some of the landslides in the park can be found in the low slope areas on the higher uplands far away from the valleys. The second naturally occurring condition involves many areas in the park that have steep and unstable slopes. These can be observed along both the eastern side adjacent to the Niobrara River and the northern part along the Missouri River. That only leaves the third condition required for landslides to occur: excessive amounts of water.

Water helps cause landslides for two reasons. When it enters the underlying soils and rocks, it causes an increase in the pore-pressures (the build-up of pressure in soil due to liquids), and it also naturally adds weight to the soil mass.

Types of Landslides

Four types of landslides from Varnes’s classification (1978), one of the more well-accepted classification systems, occur in the area (fig. 22). Three of these types are found within the park boundaries: rock falls, rock slumps, and complex slides. Rock falls are free-falling rocks from a steep bank or cliff, from an undercut stream bank, or from an eroding valley wall (fig. 23). Examples of rock falls can be found on the park’s eastern edge in the area along the steep cliffs adjacent to the Niobrara River, where pieces of the Niobrara Chalk Formation and overlying materials fall directly into the river.

Rock slumps are masses of bedrock that move downward in a rotational failure plane (fig. 24). Examples of rock slumps...
Soil

Niobrara Chalk

Fig. 23. Diagram of typical rock fall.

can be seen along the park’s northern boundary adjacent to the Missouri River. They occur along the top of the bluffs, which have slumped downward towards the bottom of the valleys, and also in the uplands, where slopes have become unstable. In both instances they develop in the Pierre Shale Formation.

Complex slides are combinations of two or more types of landslides (fig. 25). Complex slides in the park, a combination of rock slumps and rock flows, occur where the Pierre Shale in the upper section of the bluffs fails as rock slumps and then flows over the underlying Niobrara Chalk Formation, picking up pieces of the Niobrara and finally coming to rest at the base of the park’s northern boundary along the Missouri River bluffs. These are large slides that start at the top of the bluffs and end up at the bottom, in some instances covering part or all of the walking trail.

In most instances landslides are rather slow moving, except for rock falls, which occur almost instantaneously and sometimes with very little warning. For the most part, landslides within the park could be characterized as nuisances that slowly creep over trails, slowly undermine or cave-in along roads, or in some instances, cause some damage to existing buildings due to settling or moving of foundations, walls, patios, paved walks and drives.

Landslides Outside the Park

The northeast corner of Nebraska is a hotspot for Nebraska landslides. In Knox County more than 40 landslides were documented in a study that was limited only to landslides that had an impact on county, state and federal roads\(^{18}\). Many more in Knox County were not examined or classified. The largest landslides affecting a Nebraska highway can be seen from the high picnic areas in Niobrara State Park. Approximately 1.5 miles southeast of the park entrance on state Highway 14 are two large interacting landslides that face west. The landslides occur in an area where, over a long period of time, the Niobrara River has cut into a fairly large hill. In the early 1900s the Chicago and Northwestern Railroad built a line from Verdigre, Nebraska, to Niobrara. The railroad was located along the base of the large hills, and landslides were a problem at this site. A low dike between the railroad and the river was built to protect the rail line from the river and landslides. The dike consisted of rip-rap and other large pieces of rocks and boulders. The railroad was later abandoned for economic reasons; however, traces of the old line can still be found in isolated areas.

The Nebraska Department of Roads rebuilt Nebraska Highway 14 from Niobrara to Verdigre in 1985. In an attempt to lower the grade (cut down the steep hill) they cut into the

Fig. 24. Diagram of typical rock slump.

Fig. 25. Typical complex slide.
existing hillside, and the area began to slide almost immediately. The roadway was moved about 20 feet east in an attempt to by-pass the new landslide. Within a year, two slides developed on the new road about 1,000 feet apart. The largest of the two interacting landslides, closest to the top of the hill, measures over 1,000 feet wide; the other is nearly 600 feet wide. The landsliding continued, and in 1994 the highway was relocated approximately 500 feet east of its former location. The new road is not involved at the present time; however, the landslide along the old road is still actively moving, especially during excessive precipitation. Older Quaternary deposits (silt, sand and gravel) overlie Pierre Shale of Cretaceous age beneath this hillside. Almost all of the landslides in Knox County are directly related to the Pierre Shale, the exceptions being some of the rock falls that occur in the Niobrara Chalk Formation.

Other landslides can be viewed close to the park (fig. 1). Two are about 500 feet west of the park entrance on Nebraska Highway 12, about 30 feet up the hill along both sides of the highway. A little more than half a mile west of the park entrance in a small valley crossed by the highway, another landslide has destroyed part of the eastbound shoulder and part of the road. The landslide is located just below the south side of the highway, and part of the road is rotating into the small and shallow valley.

Further west on Nebraska Highway 12, only about 0.7 and 0.8 miles from the park entrance, are two landslides that were last active during 1986 when the area experienced a very wet fall and spring. These, along with all the other slides in the area, will again become active during the next wet period.

Many landslides occur along the Medicine Creek valley just to the west of the park. Some of these are very old and may be hard to find; others are very easy to locate. Most of the landscape in the area (underlain by the Pierre Shale) has been shaped by the landslides into a specific landform or configuration that is easily recognized. Across the Missouri River in South Dakota, the Pierre Shale is a major problem for the South Dakota Department of Highways.4,17,40, Now that you know what to look for, see how many landslides you can locate in this part of Nebraska during your visit.

Earthquakes and Earthquake Faults

No earthquakes have been recorded in the vicinity of Niobrara State Park, but a minor quake did occur in Knox County on February 6, 1996.4, The quake was centered near Creighton, Nebraska, and measured 3.6 on the Richter Scale.4, Burchett reported minor structural damage in Bloomfield, Brunswick, Creighton, and Coleridge, Nebraska.4 In addition to two recorded from Knox County, there have been quakes noted in Cedar, Dixon, Holt, and Pierce counties since 1867. Given these facts, there is no reason why a quake could not occur in the park area that might be felt and do some damage to structures.

There is a probable earthquake fault exposed in the north roadcut just west of the park (figs. 1, 6, 26). Rock strata of the Pierre Shale on both sides of the fault are inclined, but the strata on the east side are more deformed (fig. 26). The fault appears to be a normal or tension fault with the west side uplifted relative to the east side. Such faults are the most common kinds in Nebraska. We do not know when the rocks along the fault plane moved. Movement happened after the disrupted beds of the Pierre Shale were deposited but could have occurred at any time from then until prior to 1867.

Eversoll (personal communication) has noted that this could be a landslide, rather than a fault. At this point we do not know for certain if the rocks are faulted or if, instead, they have moved along a local landslide slip plane. Tilting of strata on both sides of the slip plane and deformation on the downdropped side do not look like the effects of landsliding described earlier by Eversoll. We would have to do extensive drilling or seismic work across the area to see if the offset extends deep beneath the earth, indicating faulting, or was restricted to surface rocks alone. No plans have been developed to do this work so the question of the origin of the feature will remain subject to debate.

Conclusion

The history and geology of Niobrara State Park and vicinity offers a fascinating story that has not come to an end. Wonderful fossils have been found here, and more remain to be discovered. Seasonal and annual variations in the flow of the Niobrara River, as well as intermittent floods, landslides and earthquakes are important factors in the continuing geologic changes in the area. Unintended consequences of building Gavins Point Dam and creating Lewis and Clark Lake downstream from the mouth of the Niobrara River will persist far into the future.

References Cited

2. Blodgett, R.H. and Stanley, K.O., 1980, Stratification, bedforms and discharge relations of the Platte braided river

*Fig. 26. Deformed Pierre Shale, probably cut by a fault at the north roadcut west of Niobrara State Park entrance.
system, Nebraska: Journal of Sedimentary Petrology, v. 50, no. 1, p. 139-148.
3a. Boyd County Registrar of Deeds, no date, 1. Deed Books,
2. Numerical Index, in Register of Deeds: Boyd County Courthouse, Butte, Nebraska, Boyd County.
3b. Brown, G., 1994, preserving vertebrate fossils: notes from the laboratory: Museum Notes, University of Nebraska State Museum, No. 87, 4 p.
22a. Knox County Registrar of Deeds, no date, 1. Deed Books,
2. Numerical Index, in Register of Deeds: Knox County Courthouse, Center, Nebraska, Knox County.
27. Nebraska Game and Parks Commission, undated, Niobrara State Park brochure.
31. Niobrara Tribune, 1933 (13 April), Niobrara Island State Park, "Where the sky is blue and the earth is wide and there's lots of fish by the riverside": Niobrara Tribune, v. 43, p. 1 ff.
**Table 1. Measured geologic section by Schulte (1952) of Cretaceous rocks exposed near Niobrara State Park.**

Section 2 (Modified) of Schulte (1952)
Description of succession of beds beginning at top of hill in NW 1/4 of sec. 11, T. 32 N., R. 7 W., and extending down intermittent stream (or highway) to intersection of county road and former railroad tracks in SW 1/4 of sec. 1. Youngest formation at top.

<table>
<thead>
<tr>
<th>FORMATION &amp; MEMBER NAMES</th>
<th>DESCRIPTIONS</th>
<th>THICKNESS IN FEET</th>
<th>PRESENT (P) OR ABSENT (A) IN PARK</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pierre Shale Formation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Elk Butte Member</td>
<td>Shale, dark gray; small, flat, layered ironstone concretions</td>
<td>67</td>
<td>P</td>
</tr>
<tr>
<td>Mobridge Member</td>
<td>Chalk, impure; weathers to various shades of yellow and gray; grey unweathered; highly calcareous, few bentonite (volcanic ash weathered to clay) seams</td>
<td>96</td>
<td>P</td>
</tr>
<tr>
<td>Virgin Creek Member</td>
<td>Shale, gray; numerous thin bentonite seams; slumps readily</td>
<td>23</td>
<td>P</td>
</tr>
<tr>
<td>Verendrye Member</td>
<td>Verendrye zone Shale, dark gray, numerous layers of flat, iron-manganese concretions</td>
<td>16</td>
<td>P</td>
</tr>
<tr>
<td>DeGrey Member</td>
<td>Shale, gray, scattered round black, manganese-iron concretions; several bentonite seams</td>
<td>20</td>
<td>P</td>
</tr>
<tr>
<td>Crow Creek Member</td>
<td>Chalk, yellow calcareous, indurated with conchoidal fracture</td>
<td>1.3</td>
<td>P</td>
</tr>
<tr>
<td>Gregory Member</td>
<td>Chalk, impure, not indurated, white sand mixed in the lower part</td>
<td>2.1</td>
<td>P</td>
</tr>
<tr>
<td>Sharon Springs Member</td>
<td>Shale, dark gray, fissile, bituminous; 2, 6&quot; bentonite seams in lower part, yellow shale chips</td>
<td>6.6</td>
<td>P</td>
</tr>
<tr>
<td>Niobrara Chalk Formation</td>
<td>Chalk, weathers to orange, gray unweathered, forms ledges with seams of bentonite, and gypsum</td>
<td>52</td>
<td>P</td>
</tr>
</tbody>
</table>

**Glossary**

**alluvium** - clay, silt, sand, gravel, or similar unconsolidated material deposited by a stream or other body of running water, as a sorted or semi-sorted sediment in the bed of the stream or on its floodplain or delta, as a cone or fan at the base of a slope.

**ammonite** - any ammonoid cephalopod belonging to the order Ammonitida, characterized by a thick, ornamented shell with sutures (seams) having finely divided lobes and saddles. Range: Jurassic to Cretaceous.

**avulsion** - a sudden separation of land by flood or an abrupt change in the course of a stream, as by a stream breaking through a meander or natural levee or by a change in current when a stream deserts its old channel for a new one.

**Cenozoic** - an era of geologic time, from the beginning of the Tertiary period to the present, beginning about 65 million years ago; characterized by the evolution and abundance of mammals, advanced mollusks, and birds and by plants that have seeds.

**cephalopod** - any marine mollusk belonging to the class Cephalopoda, characterized by a definite head, with the mouth surrounded by part of the foot that is modified into a lobe with tentacles or arm-like appendages with hooklets or suckers or both. The external shell, if present, as in nautiloids, is univalve and resembles a hollow cone; it may be straight, curved, or coiled and is divided into chambers; the shell is internal in present-day cephalopods such as octopuses, squids, and cuttlefishes and their fossil ancestors, such as the belemnites. Nautiloids and ammonoids are extinct and generally valuable as index fossils. Range: Cambrian to present.

**coccolith** - a general term applied to various microscopic calcium-rich structures or button-like plates having various shapes and averaging about 3 microns in diameter, constituting the outer skeletal remains of a coccolithophore. Coccoliths are found in chalk and in deep-sea oozes of the temperate and tropical oceans and were probably not common before the Jurassic.
colluvium - a general term applied to any loose, mixed, and incoherent mass of soil material and/or rock fragments deposited by rainwash, sheetwash, or slow continuous downslope creep, usually collecting at the base of gentle slopes or hillsides.

Cretaceous - the last period of the Mesozoic era (after the Jurassic and before the Tertiary period of the Cenozoic era), between 135 and 65 million years ago; also, the corresponding system of rocks.

crevasse splay - a wide break or crack in the bank of a river or canal.

disarticulated - related to body parts amputated or separated at the joints.

foraminifer - any protozoan belonging to the subclass Sarcodina, order Foraminifera, characterized by the presence of an external shell of one or many chambers composed of secreted calcite or of composite particles. Most foraminifers are marine but freshwater forms exist. Range: Cambrian to the present.

High Plains (Ogallala) aquifer - a massive aquifer under the central and south-central Great Plains composed mostly of sand and gravel, sand, silt, clay and sandstone and siltstone. It reaches from South Dakota to Texas and is most extensive and at its greatest saturated thickness in Nebraska.

inoceramid - related to Inoceramus, a genus of large bivalve mollusks (suborder Mytilacea) especially characteristic of the Cretaceous.

marcasite - a popular term used in the gemstone trade to designate any of several minerals with a metallic luster (especially crystallized pyrite, as used in jewelry) and also polished steel and white metal.

mosasaur - a genus (the type of the family Mosasauridae) of large, extinct, aquatic, fish-eating lizards related to the recent monitors but having limbs modified into swimming paddles.

Paleozoic - an era of geologic time, from the end of the Precambrian to the beginning of the Mesozoic, about 570 to about 225 million years ago.

phytoplankton - the plant forms of plankton; for example, diatoms, which are unicellular aquatic plants related to algae.

plesiosaur - a genus of marine reptiles (suborder Plesiosauroidea) of the Mesozoic of Europe and North America having a very long neck, a small head and limbs developed as paddles for swimming.

pterosaur - an order of Archosauria comprising flying reptiles flourishing from the Jurassic to the Late Cretaceous ages and including the pterodactyls and related forms.

pyrite - a common, pale-bronze or brass-yellow mineral: FeS2; similar to marcasite and often has small amounts of other metals; shines brightly and has been mistaken for gold, which is softer and heavier; also called “fool’s gold.”

Quaternary - the second period of the Cenozoic era, following the Tertiary, beginning 1.6 million years ago and extending to the present; also, the corresponding system of rocks; consists of two unequal epochs: the Pleistocene, up to about 10,000 years ago, and the Holocene, since that time.

rip-rap - a foundation or sustaining wall of stones thrown together without order, as in deep water, on a soft bottom, or on an embankment slope to prevent erosion.

seismic - pertaining to an earthquake or Earth vibration, including those artificially induced.

selenite - the clear, colorless variety of gypsum, occurring (especially in clays) in distinct, transparent crystals or in large crystalline masses that easily break into broad, thin layers.

stratigraphy - the science of rock strata, concerned with succession and ages of strata, with their form, distribution, composition, fossil content, geophysical and geochemical properties and with their environments of origin.

stratum (singular) / strata (plural) - a tabular or sheet-like body or layer of sedimentary rock, visually separated from layers above and below; a bed; defined as a stratigraphic unit that may be composed of a number of beds, as a layer greater than 1 centimeter thick making up a part of a bed, and as a general term that includes both “bed” and “lamination”; usually used in its plural form, strata.

tarpon - a marine fish closely related to the ten-pounder. It is common in the Gulf of Mexico off the coast of Florida, has an elongated body with large, silver scales, and reaches about 6 feet and 200 pounds; a noted sport fish.

Tertiary - the first period of the Cenozoic era (after the Cretaceous of the Mesozoic era and before the Quaternary), between 65 and 1.6 million years ago; divided into five epochs: the Paleocene, Eocene, Oligocene, Miocene, and Pliocene.

tsunami - a wave produced by any brief, large-scale disturbance of the ocean floor, principally by a shallow earthquake or earth movement, subsidence, or volcanic eruption; characterized by great speeds (up to 950 kilometers/hour), long wavelengths (up to 200 kilometers), long periods (generally 10-60 minutes), and low observable amplitude on the open sea, although it may rise to heights of 30 meters or more and cause much damage on an exposed coast.
Geologic Bedrock Map of Nebraska

Explaination:
- Tertiary:
  - Ogallala
  - Arikaree
  - White River
  - Fox Hills
  - Pierre
- Cretaceous:
  - Niobrara
  - Carlile
  - Greenhorn—Graneros
  - Dakota
- Jurassic
- Permian
- Pennsylvanian
- Mississippian
- Devonian
- Silurian
- Ordovician
- Cambrian
- Precambrian

Geologic Cross Section Along Southern Nebraska Border

Note: Unconsolidated sediments of Recent and Pleistocene age cover the bedrock throughout much of the State and are not shown.