12-25-2003

Lewis and Clark and the Geology of Nebraska and Parts of Adjacent States

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and Parts of Adjacent States

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Relief map of Missouri River sites
by L. M. Howard

Educational Circular No. 18

December 2003

Conservation and Survey Division/School of Natural Resources
Institute of Agriculture and Natural Resources/College of Arts and Sciences
University of Nebraska–Lincoln

University of Nebraska–Lincoln

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Acknowledgments

We would like to thank Mark Burbach, Ron and Susie Schlieger, and Jozsef Szilagyi for their suggestions for improving the manuscript; and Gary E. Moulton for his help throughout.

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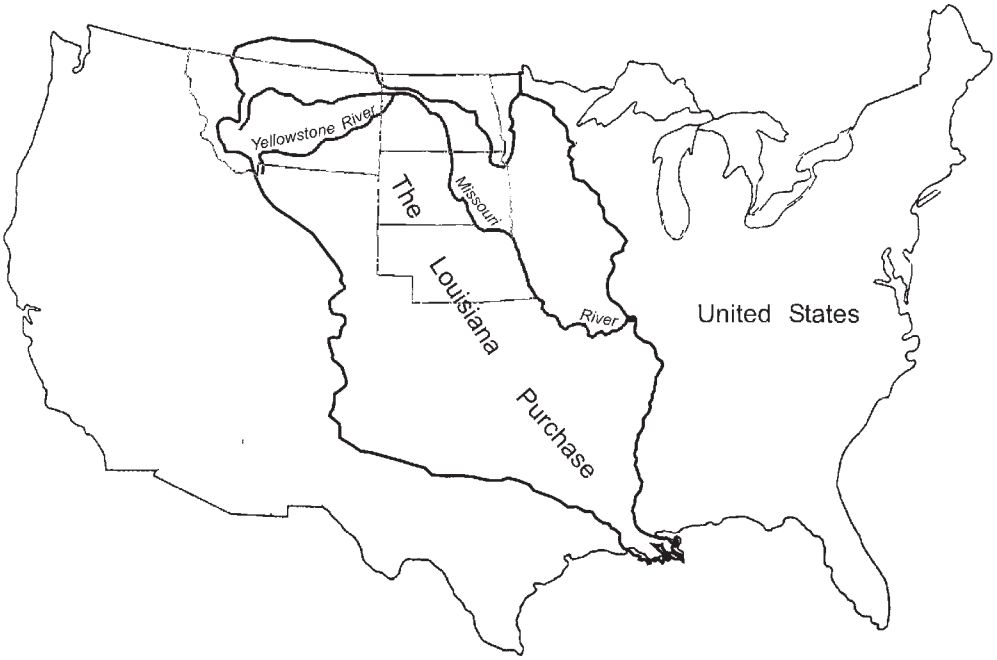
General Introduction

Meriwether Lewis and William Clark undertook their journey with the Corps of Discovery in 1804-1806 in order to explore the area that the United States had purchased from France in 1803. Then known as Louisiana, this region included almost everything west of the Mississippi to the continental divide (illustrated below).

In order to find the best route across the continent, President Thomas Jefferson charged Lewis to follow the Missouri River to its headwaters and then locate rivers flowing down the west side of the Rocky Mountains to the Columbia River and into the Pacific Ocean. Jefferson's written instructions further specified that the members of the expedition collect and describe plants and animals new to science; enter the latitude and longitude of the rivers, mountains, and other features; and note the land's potential for farming, as well as the climate, timber, and wildlife. They were also to record the occurrences of volcanic features and minerals of all kinds, but especially metals, limestone, coal, and saline and mineral waters. Their journals, notebooks, and maps indicate that the explorers took this charge seriously because they collected a great deal of information on these topics.

Meriwether Lewis by Charles Willson Peale, from life, 1807; William Clark by Charles Willson Peale, from life, 1807-1808; courtesy of Independence National Historical Park, National Park Service



The Louisiana Purchase of 1803 doubled the area of the United States.

"The Face of the Countrey....
The Countrey bordering on the Missourie....from the Plate to the Fort Mandan the Countrey is Generally open Plains, intersperced with Groves of Timber, which is to be found on the Rivers & Smaller Streams Generally–
winter, 1804-1805
[summary report sent to President Thomas Jefferson from the winter camp at Fort Mandan, North Dakota]

Lewis and Clark were astute observers of the land across which they traveled. In most cases, however, they did not know what had caused its appearance. At that time, few, if any, would have because the discipline of geology was in its infancy. James Hutton, the father of modern geology, had published his *Theory of the Earth With Proofs and Illustrations* in 1795, but few people were aware of the work nine years later.[14] The concepts of geologic time and of absolute age dating of rocks were only beginning to be developed in Europe. The first geologic map, by William Smith in England, was not published until 1815. The ideas of continental glaciation and of the widespread flooding of the continents by oceans had not yet been proposed.

From then until now, research and study have led to new knowledge and broader understanding. The Earth is more than 4.5 billion years old, with rocks at least as old as 3.8 billion years preserved in some places. From mapping rock formations, we know that some of them are widespread, covering major parts of some continents, islands, and the sea floor. Sea level has risen and fallen many times, sometimes covering almost all of the land areas of the globe. In Nebraska, many of the sedimentary rock formations exposed at the surface are sandstone, siltstone, shale, and limestone that were originally deposited as soft sediments on coastal plains, along beaches, or off shore in shallow seas that once covered the state. Later these sediments hardened into rock. These deposits are Pennsylvanian, Permian, and Cretaceous in age. Geologists have recognized cycles of the rise and fall of seas many times over what is now Nebraska during Pennsylvanian and Permian times; but they have not given this ocean a formal name. Other geologists, studying the Cretaceous rocks, have called the sea where they were deposited the Cretaceous Western Interior Seaway. This body of water covered central North America from the present Gulf of Mexico to the present Arctic Ocean.

More recently, over the last 2.5 million years, North America was subjected from time to time to major cold periods or Ice Ages. The southern edges of the ice sheets that initially formed in Canada reached as far south as northeastern Kansas and northern Missouri. These ice sheets disrupted river courses many times and changed the face of the land. During warming periods when the ice melted away, huge wind storms eroded silt and sand and formed the deposits beneath the Loess Hills along both sides of the Missouri and other valleys and in the Sand Hills farther west.

Lewis and Clark were not aware of the geologic events described above; they did, however, understand some aspects of geology. From the notations in their journals, it is clear that they could identify some minerals and rocks. They recognized certain fossils. They were also aware of natural hazards such as landslides, floods, and volcanic activity. Among the books that they took with them for reference was Richard Kirwan's *Elements of Mineralogy*, first published in London, England, in 1784 with a second expanded edition in 1794-1796.[16]

Although Lewis and Clark frequently described geologic features, they seldom speculated on the processes that might have produced them. The few exceptions concern the effects of flowing water. They noted landslides and banks being undercut, as well as shifting sand bars and old river channels and channel cut-offs. They also commented on water's role in rounding pebbles and in shaping rocks.

Many of the geologic features described by William Clark along both sides of the Missouri River from what is now southeastern Nebraska north to where the river fully enters South Dakota can be seen today on public land or from roadsides, at or near the places he noted.

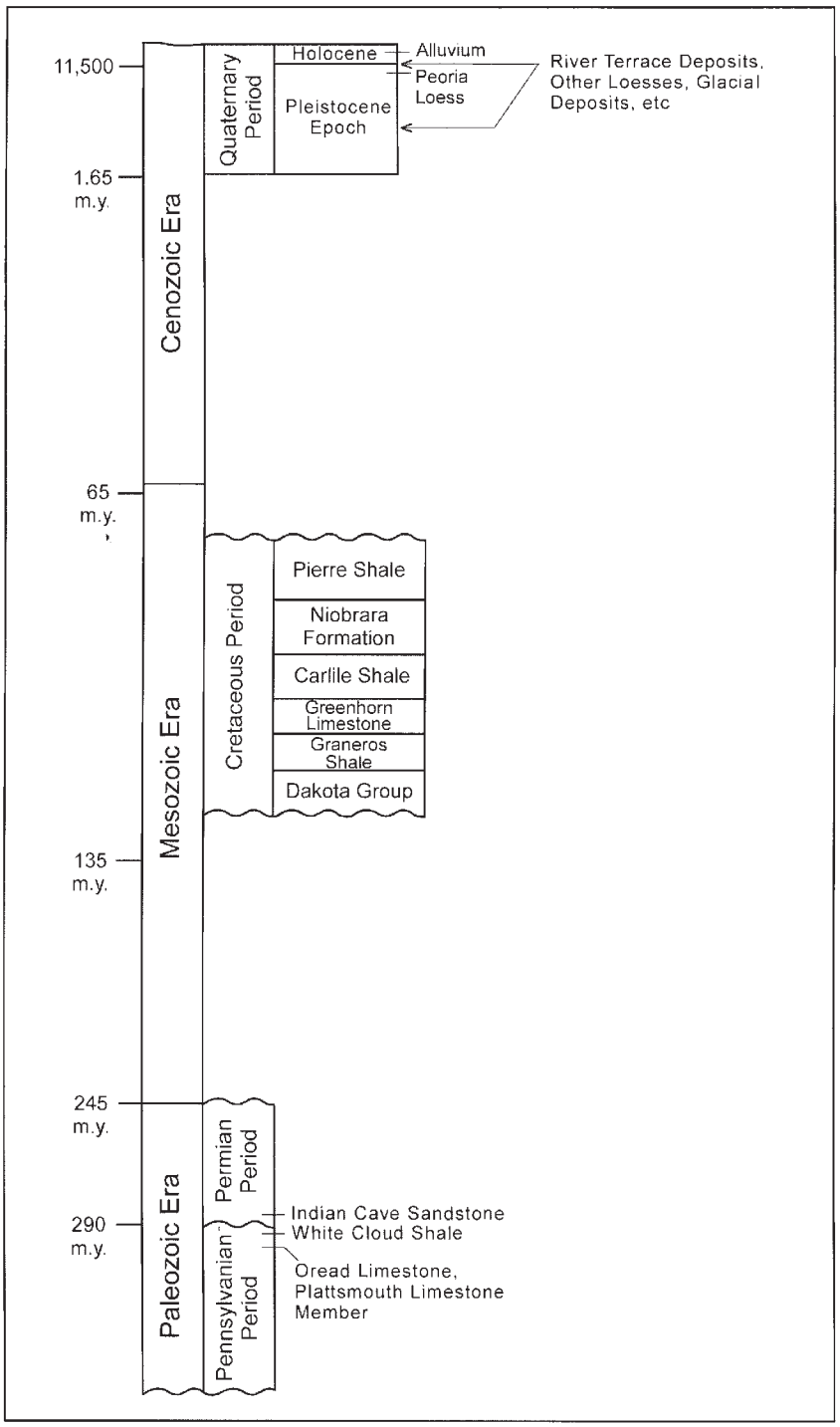
Ores Minirals Salts & Salt Salines

I know of no Body of ore.... The Bluffs of the Missouri above R. Jacque abounds in minerals of various Kinds, Such as Cobalt, Piritus, Alum, Coperas, & a variety of other mineral Salt is Collected in various parts of the Missourie Country...."

winter, 1804-1805

[summary report sent to President Thomas Jefferson from the winter camp at Fort Mandan, North Dakota]

For each of the following sites, a quotation from the journals is accompanied by a geological interpretation of what was seen then and can still be seen today. A location for viewing and a picture of the site taken in 2002-2003 is included, together with aerial views of four of the sites. The name of the relevant U.S. Geological Survey topographic map is given in brackets for each site, for example: [Falls City].



Geologic time scale with the names of the formations encountered by Lewis and Clark. m.y. – millions of years ago.

The Words of Lewis and Clark

Because spelling, punctuation, and capitalization had not yet been standardized, the writings of Lewis and Clark contain many different forms and abbreviations of the same word. An unfamiliar term can often be recognized by reading it aloud.

When traveling on rivers, the explorers used the nautical terms larboard *and* starboard *to indicate direction. Facing in the direction of travel, larboard (now called* port*) or larboard side (l.s. or L.S.) means left; starboard or starboard side (s.s. or S.S.) means right.*

Quotations come from the journals of William Clark. There are no journals by Meriwether Lewis covering this part of the expedition's travels.

Treeless plains (site 1)

Looking to the northwest from St. Deroin Cemetery in Indian Cave State Park, Nemaha County, Nebraska.

For several days after passing what is now the Kansas-Nebraska border, Clark commented upon the absence of trees on the uplands away from rivers and creeks to the west. Since then, residents have reduced the incidence of prairie fires and have planted trees, particularly around homes and buildings and in shelterbelts. Volunteer trees seeded by winds, birds, and other animals have added to the tree cover in southeastern Nebraska. Because much of the rest of the upland west of the Missouri Valley is being used for production agriculture, there are very few places where the plains can be seen as Clark described them in 1804. Nonetheless, there are some areas where grasses cover the uplands, and trees are confined mostly to the valleys of streams tributary to the Missouri. [1, 10, 13]
[Falls City]

Site 1.

"The High Land approaches near the river on the L.S. and well timbered next to the river, back of those hills the Plains Commence."
July 10, 1804

"I walked on Shore....after assending and passing thro a narrow Strip of wood Land, Came Suddenly into an open and bound less Prarie, I Say bound less because I could not See the extent of the plain in any Derection, the timber appeared to be confined to the River Creeks & Small branches...."
July 19, 1804

Peoria Loess, Upper Pleistocene Series; bluff (site 2)

A roadcut in loess with vertical fractures on the north side of U.S. Highway 159, 1.2 miles west of the Rulo, Nebraska, exit of U.S. Interstate Highway 29, Holt County, Missouri.

Thick late Pleistocene wind-deposited yellow silts and very fine sand, called loess (pronounced *luhss*), blanket the bluffs and parts of the valley floor along the Missouri River in Nebraska, northernmost Missouri, Iowa, and southeastern South Dakota. Geologists call the youngest of the thick deposits the *Peoria Loess*, named for exposures first studied in the Peoria, Illinois, area. The silts making up most of the loess were deposited on the floodplain of the developing Missouri Valley by runoff waters from glacial Lake Agassiz, a late Pleistocene lake in eastern South Dakota, North Dakota, western Minnesota, and southern Manitoba, Canada. During subsequent dry periods from about 20,500 to 10,000 years before present, the silts were eroded from the floodplain by winds and deposited on the adjacent valley sides and uplands. This loess thins to the east and to the west away from the valley, strong evidence supporting this idea of erosion and deposition. Beneath the Peoria Loess are older loesses, glacial tills, and bedrock formations that are usually buried.[23] [Falls City]

Site 2.

"...we came to & Camped for the night. at a point on the S.S. opposit a yellow Clay Clift."

July 10, 1804

Sandstone in the White Cloud Shale, Upper Pennsylvanian System; bluff (site 3)

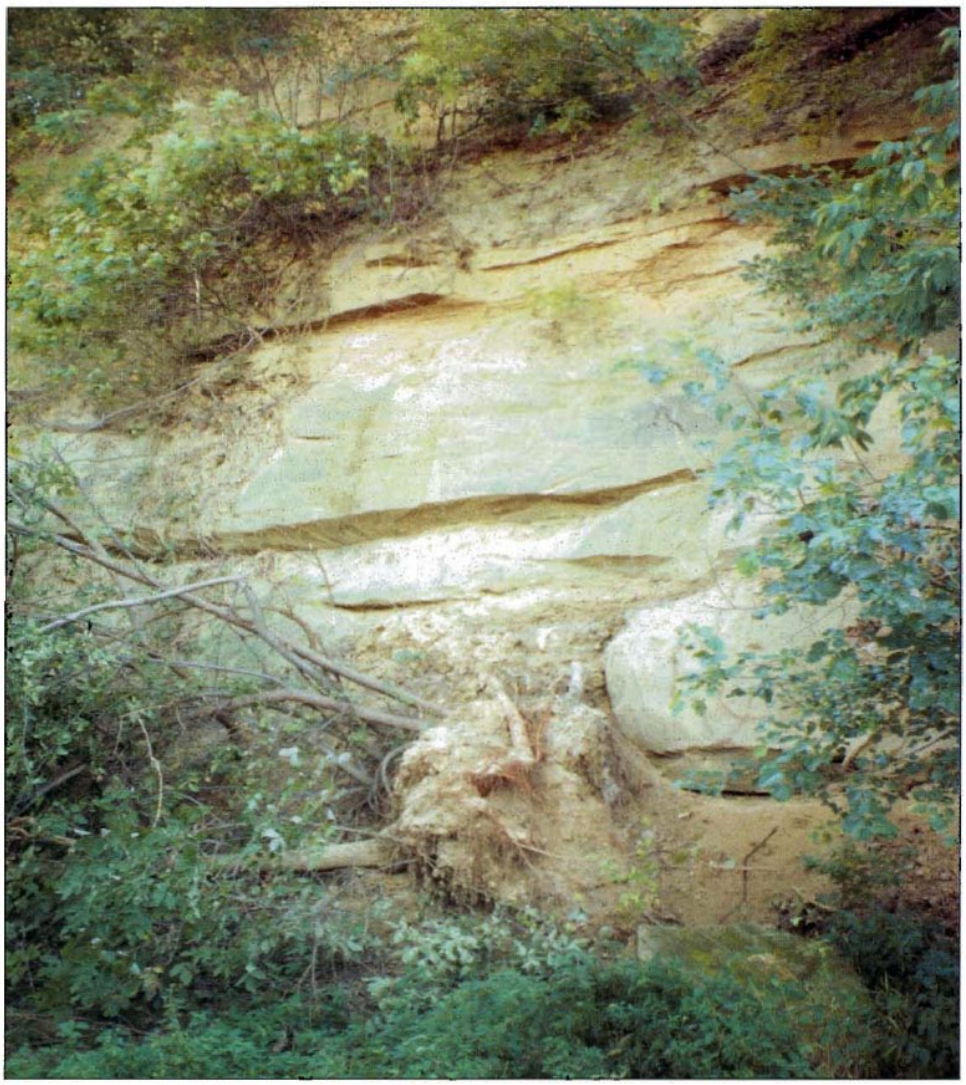
The sandstone bluff on the south bank of the Big Nemaha River, about 0.25 mile above its mouth, looking southeast from Nebraska Highway 7 at the bridge, about 3.7 miles south of Rulo, Richardson County, Nebraska, on the Iowa Indian Reservation.

The Big Nemaha River has eroded the bluffs on its south side near its confluence with the Missouri River, exposing beds of sandstone. The sandstone is a part of the White Cloud Shale, which is about 80 feet thick in this area. The sandstone is in the lower part of a group of formations that is the geologically youngest Pennsylvanian group in Nebraska, Kansas, and Missouri. Sandstone and coal beds occur within the shale. All of these rocks were deposited by rivers as sediments on a coastal plain in Late Pennsylvanian times and later hardened into sedimentary rocks. The sandstone beds are cross bedded, which indicates that they are the sites of ancient river channels.[19, 20] [Falls City]

Site 3.

"...on a Sandstone Bluff about 1/4 of a mile from its [Big Nemaha River] *mouth on the Lower Side I observed Some Indian marks, went to the rock which jucted over the water and marked my name & the day of the month & year"*
July 12, 1804

Landslide (site 4)



A landslide along the Steamboat Trace Trail about 0.5 mile east-southeast of Peru, Nemaha County, Nebraska.

The Missouri River in Nebraska, which is largely controlled today by structures such as levees, no longer actively erodes its bluffs in most of the places where it comes in contact with them. Because the river was uncontrolled in 1804, where its channel ran against the bluff, it undercut the rocks, causing landslides. Cuts made into the bluff along the trail on the former tracks of the Missouri-Pacific Railroad are still subject to erosion and landslides. The Indian Cave Sandstone, deposited in Early Permian times, is exposed for several miles along part of the abandoned railroad right-of-way. Nearly vertical joints in groups roughly perpendicular to one another are zones of weakness in this rock. Landslides develop in the sandstone along these joints.[2-5] [Falls City]

Site 4.

"...about 20 acres of the hill has latterly Sliped into the river above a clift of Sand Stone for about two miles...."
July 16, 1804

The Loess Hills
(site 5)

An exposure of loess at the Star School Hill Prairie Conservation Area, U.S. Highway 275, 1.5 miles south of the Iowa-Missouri border, Atchison County, Missouri.

In 1804, the bluffs on the Missouri and Iowa side of the Missouri River valley were treeless and often devoid of vegetation on their tops. Because the bluffs today are mostly tree covered, bald hills can be seen in only a very few places. The bluffs are directly underlain mostly by yellow Peoria Loess.[23]
[Nebraska City]

Site 5.

"...an extensive Prarie on the S.S. This Prarie I call Ball pated Prarie, *from a range of Ball Hills parrelel to the river & at from 3 to 6 miles distant from it, and extends as far up & Down as I Can See,"*
July 16, 1804

Plattsmouth Limestone Member, Oread Formation, Upper Pennsylvanian System; fossiliferous limestone (site 6)

Limestone exposed in a railroad cut along the tracks at the Shilling State Wildlife Area, just north of Plattsmouth, Cass County, Nebraska.

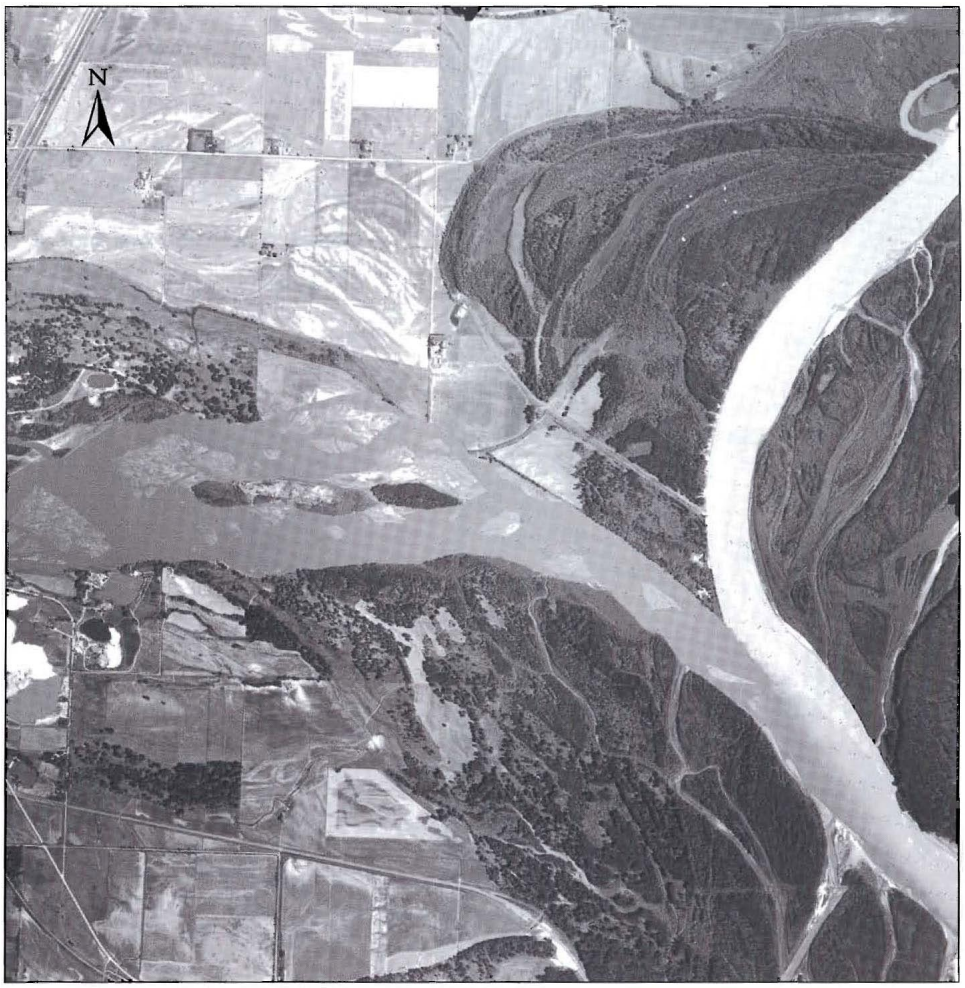
In 1804, the Missouri flowed against the bluffs in the vicinity of what is now Plattsmouth, Nebraska. The river eroded the bedrock beneath the bluffs in this area exposing limestones and shales of the Pennsylvanian Oread Formation and younger beds. These limestone and shale beds were originally deposited as lime muds, clays and silts in an ocean that formerly covered all of the American Midcontinent. The ocean teemed with animal and plant life. After the organisms died, their skeletal debris accumulated on the ocean floor and became part of the sediment that later hardened into rock.[3, 5, 7] [Omaha]

Site 6.

"Some high lands covered with timber L.S in this hill is limestone & Seminted rock of Shels &c."

July 21, 1804

The mouth of the Platte River (site 7)



a) An aerial photograph of the mouth of the Platte River. The Missouri River, to the right, is a lighter color, indicating that it is carrying more suspended sediment than the Platte, to the left. Below the rivers' confluence, sand bars from the Platte continue for a distance downstream on the west side of the Missouri (photo courtesy of the U.S. Natural Resources Conservation Service, 1949).

The Platte has carved its valley down into Pennsylvanian-age bedrock at and upstream from its mouth. Its valley is much narrower than the Missouri's. The Platte is a braided river, having many channels intertwined with bars, that carries a great deal of sand and some gravel in its bed load. In contrast, the Missouri meanders carry far more silt and clay. The aerial photograph reflects this difference in the gray tones of the two rivers.

The aerial view also shows the smooth banks of the Missouri, which is controlled by human structures. Neither river is as active today as in 1804-1806. The Missouri's banks are stabilized from its mouth to Sioux City, Iowa; and it is tamed by dams upstream from there. The volume of water in the Platte has been reduced by extensive irrigation all along its course through Nebraska.[3, 22] [Omaha]

Site 7.

"This Great river being much more rapid than the Missourie forces its current against the opposit Shore, The Current of This river Comes with great Velocity roleing its Sands into the Missouri, filling up its Bend & Compelling it to incroach on the S [North] Shore we found great dificuelty in passing around the Sand at the mouth of this River Capt Lewis and My Self with 6 men in a perogue went up this Great river Plate about 1 miles, found the Current verry rapid roleing over Sands, passing through different Channels none of them more than five or Six feet deep, about 600 yards Wide at the mouth "

July 21, 1804

b) Sand bars near the mouth of the Platte River from the U.S. Highway 75 bridge, north of Plattsmouth, Cass County, Nebraska.

Site 7.

[on the return journey] *"passed the enterance of the great river Platt which is at this time low the water nearly clear the Current turbelant as usial; the Sand bars which Choked up the Missouri and Confined the {river} to a narrow Snagey Chanel are wastd a way and nothing remains but a fiew Small remains of the bear {bar} which is covered with drift wood...."*

September 9, 1806

River terrace and terrace fill (site 8)

a) Looking west at the terrace fill from the Missouri River floodplain below Fort Atkinson State Historical Park, near Fort Calhoun, Washington County, Nebraska.

On the west side of the Missouri Valley, north of Omaha to Tekamah, Nebraska, there are remnants of old floodplain deposits of the Missouri when its channel was at a higher altitude than it is today. These remnants, called river or fluvial terrace fill, are flat topped (arrow above), much like the very flat surface of the floodplain today. The surface of this terrace fill is about 60 feet above the present valley floor. After this former floodplain fill had been deposited, geologic conditions changed. The Missouri then cut down through the terrace sediments and deepened its valley. Through time, the deepened river eroded laterally across its valley, eliminating most of the former floodplain deposits, except for a few remnants. The town of Fort Calhoun, Nebraska, is built largely on the surface of a remnant of this terrace fill. To the southeast of the town is the former site of the U.S. Army's Fort Atkinson, on top of the remnant. Near here, Lewis and Clark met with representatives of the Oto and the Missouri Indians at the "Council Bluff," a name which was later adopted by the town adjacent to Omaha across the Missouri River in Iowa.[18] [Fremont]

Site 8.

"...further back at the Distance of about a mile the Countrey rises about 80 or 90 feet higher, and is one Continual Plain as fur as Can be Seen, from the Bluff *on the 2d rise imediately above our Camp the most butifull prospect of the River up & Down and the Countrey opsd. prosented it Self which I ever beheld...."*

July 30, 1804

b) The flat-topped terrace with some of the restored buildings of historic Fort Atkinson.

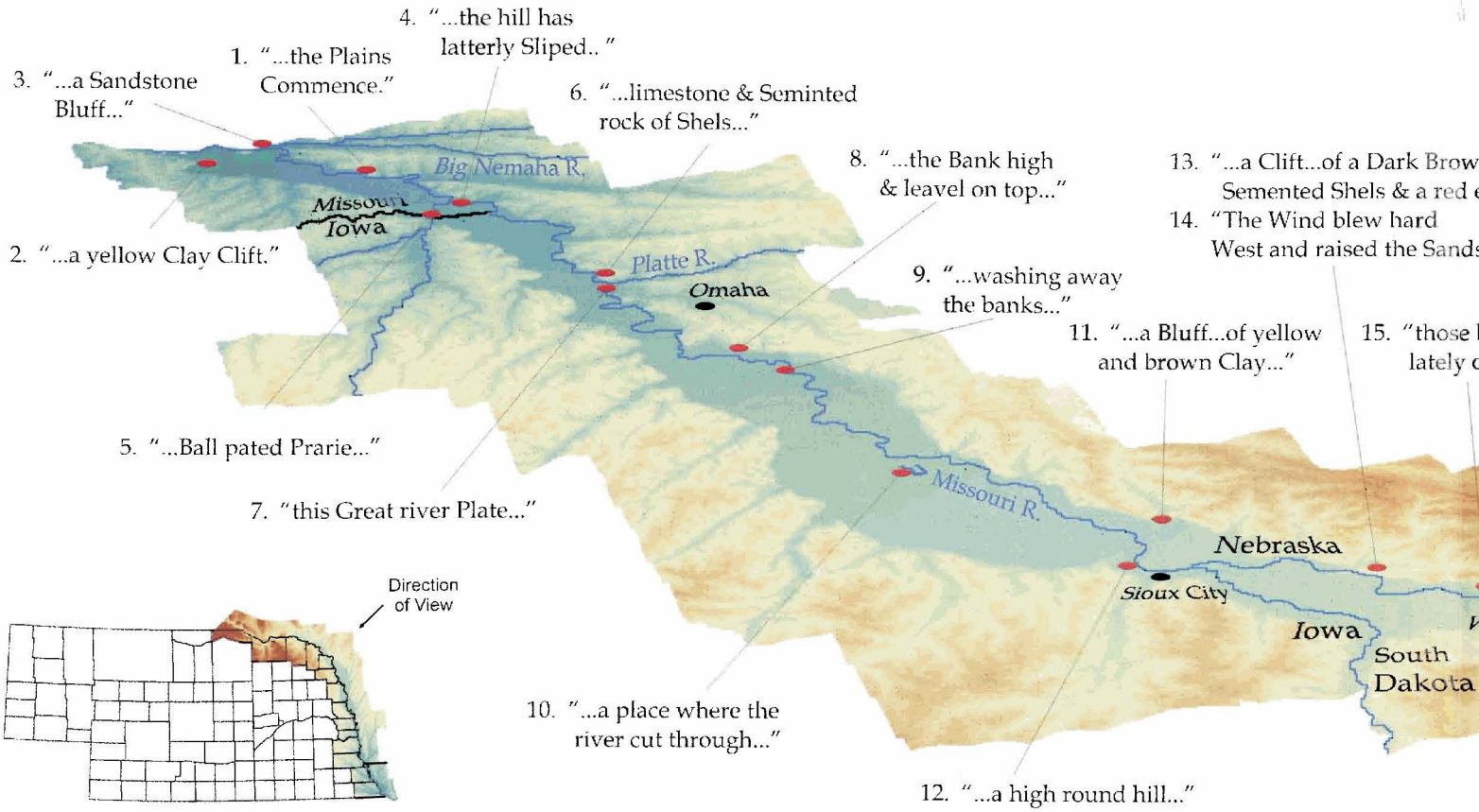
c) An aerial photograph of the town of Fort Calhoun, Nebraska, and the terrace that was the site of Lewis and Clark's Council Bluff. The edge of the terrace (arrow) is marked by the first prominent tree line east of the town (photo courtesy of the U.S. Natural Resources Conservation Service, 1965).

Site 8.

"The Situation of this place which we Call Council Bluff *which is handsom elle-vated a Spot well Calculated for a Tradeing establishment, the Bank high & leavel on top well Calculated for a fort to Command the Countrey and river...."*

August 3, 1804

Lewis and Clark and the Geology of Nebraska

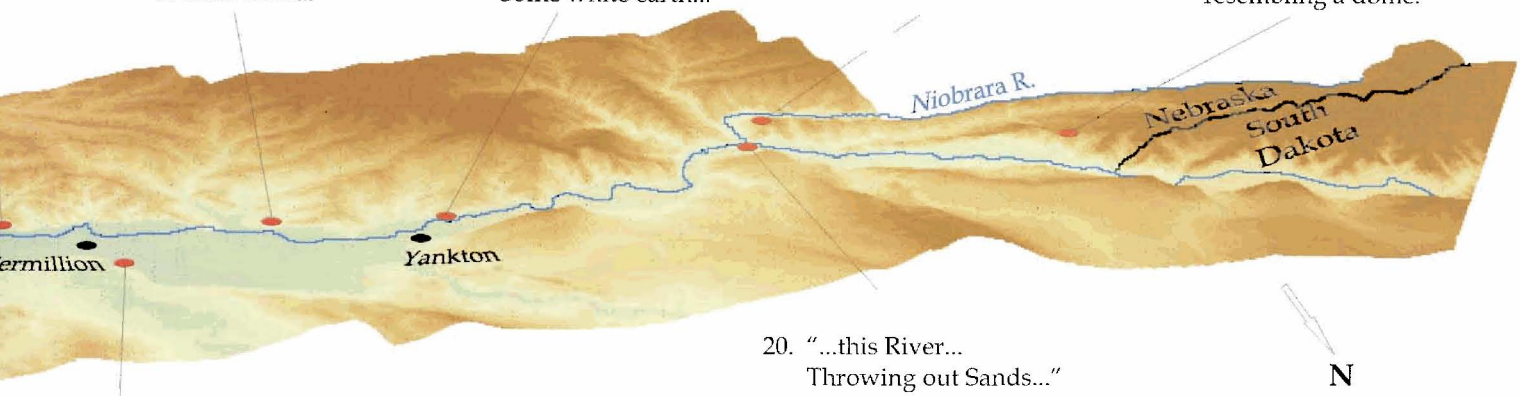


Relief map of Missouri River sites by L. M. Howard

n Colr...,
earth."

..."

luffs...
n fire..."



16. "...to visit a High Hill..."

Bank cutting and landslides (site 9)

A cut bank on the Iowa side of the Missouri River under the U.S. Highway 30 bridge just east of Blair, Washington County, Nebraska.

The Missouri was much more active in 1804 than it is today. The river cut away the sediments of the floodplain on the outsides of its meander curves, undercutting the sediment and causing landslides. This is still happening in some places along the river today, in spite of the efforts of humans to stop the process. [Blair]

Site 9.

"...the bends of the river to day is washing away the banks, haveing nothing to oppose the turbelance of the [river] when Confined by large hard Sand Points, forceing this Current against the bends the Soil of the entire bottom between the high land, being the mud or Ooze of the river of Some former period mixed with Sand & Clay easely melts and Slips, or washies into the river the mud mixes with the water & the Sand collects on the points"

August 5, 1804

Cut off meander and oxbow lake (site 10)

An aerial photograph of Blue Lake at Lewis and Clark State Park, about 1.2 miles west of U.S. Interstate Highway 29 at the Onawa exit, Monona County, Iowa. (photo courtesy of the U.S. Natural Resources Conservation Service).

There are many meander cut offs and oxbow lakes along the Missouri River from southeastern Nebraska north to the vicinity of Vermillion, South Dakota. In 1804, Clark described an oxbow just west of what is now Onawa, Iowa. The river had eroded through a neck in a meander and left a former channel segment behind. The two ends of this abandoned segment filled in with sediment, forming a shallow lake in the shape of an oxbow. Part of this cut-off meander is still a lake today. [Sioux City South]

Site 10.

"This place is called Coupe a Jarcke [Jacque's cut] a place where the river cut through and shortend the River Sevl. mls."

August 10, 1804

Dakota Group, Cretaceous System; bluff (site 11)

An exposure of sandstone in the Dakota Group, just west of the high school football field, Homer, Dakota County, Nebraska.

The Dakota consists of sandstones and some chert pebble conglomerates deposited in river channels, as well as siltstones and claystones deposited in channels and adjacent floodplains. Some of the siltstones and claystones have red, weathered zones that are relicts of soils which formed on exposed sediments.[6] The colors of exposed rocks are reds, yellows, and browns, reflecting the presence of iron oxide (rust) in the rocks. Sandstone beds are frequently cross-bedded, typical of the bedding in sand bars. Fossils include pollen, impressions of tree stems and leaves, and some clams. In south-central Nebraska, dinosaur footprints have been found in the Dakota. Because bluffs in this area are often heavily wooded, good rock exposures are rarely natural. The Dakota Group was deposited at the start of the second major cycle of the rise and fall of the Cretaceous Western Interior Seaway, the Greenhorn Cycle.[15, 26, 27] [Sioux City South]

Site 11.

"...the Commencement of a Bluff which is about 4 miles extending on the river, of yellow and brown Clay in Some parts in it near the river a Soft Sand Stone is inbeded on the top (which is from 20 to 150 feet above the water....)"

August 12, 1804

Peoria Loess, Upper Pleistocene Series; bluff (site 12)

The view of the Missouri River valley from the top of Floyd's Bluff, underlain by Peoria Loess at the Sergeant Floyd Monument, Sioux City, Iowa.

Sergeant Charles Floyd, the only member of the expedition to die during the journey, succumbed to what was probably appendicitis. Underlying the bluff where Floyd was buried is Peoria Loess. This is a widespread deposit composed of silt and very fine sand that blankets river terraces, valley sides, and uplands along the Missouri River in Nebraska, northernmost Missouri, Iowa, and southeastern South Dakota. Approximately 20,500 to 10,000 years ago, this sediment called *loess* was lifted from river valleys by winds and deposited on the land when the winds slackened.

This unit was named from an area first studied near Peoria, Illinois. The thickest deposits, more than 180 feet, are found in central Nebraska. Peoria Loess is light tan to yellow in color and has small calcium-carbonate concretions. Fossils include pollen, land snail shells, and mammal bones, including those from mammoths. Loess frequently has vertical or nearly vertical joints. Layering or stratification is usually not obvious. Loess is thicker along the Missouri River and thins away from the valley in all directions.[23] [Sioux City South]

Site 12.

"we Buried him [Sgt. Charles Floyd] *to the top of a high round hill over looking the river & Countrey for a great distance"*

August 20, 1804

Greenhorn Limestone underlain by Graneros Shale, Upper Cretaceous System; bluff (site 13)

a) Prominent ledges in the Greenhorn Limestone underlain by the Graneros Shale. Below the Graneros, rocks of the upper Dakota Group are hidden by trees, at the boat ramp in Ponca State Park, north of Ponca, Dixon County, Nebraska.

These limestones and shales weather brown to yellowish brown with red iron oxide formed from the decomposition of iron-sulfide minerals such as pyrite and marcasite. Unweathered rocks are gray to very light gray in color. The limestone beds, which are harder than the shales, form ledges that protrude from bluff slopes. Fossils include skeletal plates from coccoliths, shells of foraminifera, shells of clams, scales and bones from fish, teeth of sharks, and bones of marine reptiles called *plesiosaurs*. In some places in the Greenhorn Limestone, the rock is composed of fossil clam shells held together by a fine-grained matrix of cemented lime mud.[17, 21] Bentonitic clays formed from weathered volcanic ash occur in the Graneros Shale, proof of volcanic activity in the developing mountains of the western United States. The Graneros and Greenhorn were deposited during the second major cycle of the Cretaceous Western Interior Seaway, the Greenhorn Cycle.[15] [Sioux City North]

b) Fossil clam shells on a bedding surface in the Greenhorn Limestone.

Site 13.

"...a Clift of Allom Stone of a Dark Brown Colr. Containing also in crusted in the Crevices & Shelves of the rock great qts. of Cabalt, Semented Shels & a red earth."
August 22, 1804

Blowing sand and silt from an exposed sand bar (site 14)

Wind-deposited sand that has been re-worked from sand bars, at the tent camping area in Ponca State Park, north of Ponca, Dixon County, Nebraska.

During floods, the Missouri River transports and deposits a considerable amount of sand on bars in and along the river channel and on its floodplain. Recently deposited sand may be picked up and transported by winds if vegetation has not yet covered it, or if the vegetative cover has died off in a dry period. [Sioux City North]

Site 14.

"The Wind blew hard West and raised the Sands off the bar in Such Clouds that we Could Scercely See this Sand being fine and verry light Stuck to every thing it touched, and in the Plain for a half a mile the distance I was out every Spire of Grass was covered with the Sand or Dust"

August 23, 1804

Carlile Shale, Upper Cretaceous System; bluffs (site 15)

The Carlile Shale at Ionia Volcano. *The short, narrow, dark-colored bed in the center is probably lignite coal. Today the Missouri's channel, seen in the upper right of the photograph, is far from this bluff. The overlook is located on private land that has generally been open to visitors, north from Nebraska Highway 12 at a Nebraska State Historical Marker in Newcastle, Dixon County, Nebraska.*

The *Ionia Volcano*, as it has come to be called since Lewis and Clark visited the site, is a bluff and landslide area in the Carlile Shale.[4] According to Clark's map, in 1804 the Missouri River flowed against this bluff, thus eroding it. Thin lignite coal beds occur here in the Carlile Shale, as does marcasite, the iron-sulfide mineral that is unstable when exposed to air, and selenite, the colorless form of gypsum. Decomposition of marcasite yields heat and a sulfur smell; lignites also may spontaneously combust, producing heat. Either or both of these processes could have caused the heat that Clark reported. The "Cabalt" or "Cristolised Substance" was probably selenite. The Carlile Shale is the upper part of the second major cycle of the Cretaceous Western Interior Seaway, the Greenhorn Cycle.[15] [Sioux City North]

Site 15.

"those bluffs has been lately on fire and is yet verry Hott, Great appearance of Coal, & imence quantities of Cabalt in Side of that part of the Bluff which Sliped in,...."

August 24, 1804

Erosional remnant (site 16)

The Niobrara Formation at Spirit Mound *with glacial erratics (arrow) exposed in the field in the foreground on South Dakota Highway 19, six miles north of Vermillion, Clay County, South Dakota.*

During the Ice Ages, continental ice sheets moved into southeastern South Dakota eroding the bedrock in places. At this hill, now known as *Spirit Mound*, the ice did not wear the rock down to a flat surface, but instead left behind an erosional remnant of chalk from the Niobrara Formation. The hill is surrounded on all sides by lower and flatter land covered by glacial deposits including some erratic boulders.[8, 11, 24, 25] [Sioux City North]

Site 16.

"Capt Lewis and my Self Concluded to visit a High Hill Situated in an emence Plain three Leagues N. 20° W. from the mouth of White Stone [now Vermillion] *river, this hill appear to be of a Conic form and by all the different Nations in this quater is Supposed to be a place of Deavels..."*

August 24, 1804

"this hill is about 70 foot high in an emince Prarie or leavel plain from the top I could not observe any woods except in the Missourie Points...."

August 25, 1804

Niobrara Formation over Carlile Shale, Upper Cretaceous System; bluffs (site 17)

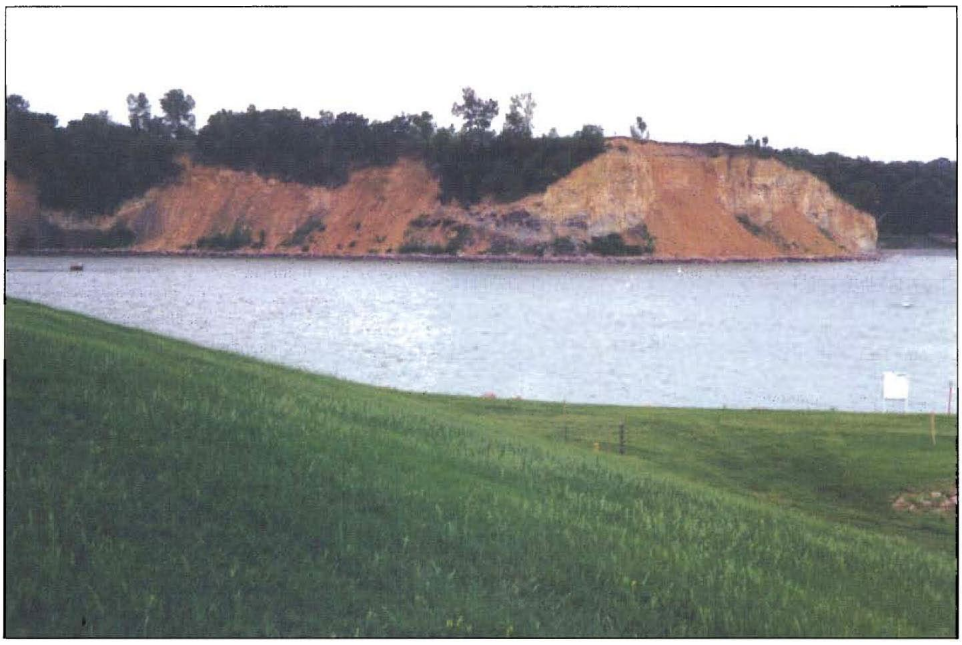
The Niobrara Formation over the Carlile Shale in bluffs along the valley, near St. Helena, Cedar County, Nebraska.

The Niobrara chalks are white to cream and light yellow colored. The Carlile is dark gray or bluish gray in this area.[4] [Yankton]

Site 17.

"passed a Clift of White & Blue or Dark earth of 2 miles in extent on the L.S....."
August 26, 1804

Niobrara Formation, Upper Cretaceous System; bluffs (site 18)



A bluff in the Niobrara Formation at the southern end of Gavins Point Dam at Calumet Bluff, west of Yankton, South Dakota.

The Niobrara Formation is widely exposed both downstream and upstream of Gavins Point Dam.[4] When weathered, this chalk is light gray to white or yellowish-cream colored. Some surface exposures have a red color due to the presence of iron-oxide minerals in the rocks. The chalk is darker gray in unweathered exposures. Fossils make up most of the rock. Most are microscopic coccolith debris and foraminiferal shells. Larger fossils include shells of clams and oysters, and bones, scales and teeth of fishes. The best exposures of the chalk are on the Nebraska side of the Missouri River valley in the vicinity of the former site of the Calumet Bluff, where Lewis and Clark met with the Yankton Sioux. Much of the bluff was removed during dam construction. The Niobrara is the lower formation in the third major cycle of the Cretaceous Western Interior Seaway, the Niobrara Cycle.[15] [Yankton]

Site 18.

"...passed a Bluff containing Some white earth on the L.S..... we proceeded on about 3 Miles higher and Camped below the Calumet Bluff in a Plain on the L.S....."

August 28, 1804

Lower part of Pierre Shale, Upper Cretaceous System; bluff (site 19)

The Pierre Shale in a roadcut on the north side of Nebraska Highway 12, just west of the entrance to Niobrara State Park, Knox County, Nebraska.

Bluffs of "blue clay" were noted by Lewis and Clark at several places along the Missouri Valley.[9, 12] The lower Pierre Shale is predominantly dark gray to black with a bluish undertone in parts. It is a marine deposit that contains fossil clams, ammonites, and other invertebrates, shark teeth and the bones of fishes and of the swimming reptiles, mosasaurs (sea-going swimming lizards) and plesiosaurs. The formation is sulfate-rich and often yields a sulfur smell at exposures. The Pierre is unstable on hill sides and often develops landslides where it is at or near the land surface. The lower Pierre Shale is in the third major cycle of the Cretaceous Western Interior Seaway, the Niobrara Cycle.[15] [Yankton]

Site 19.

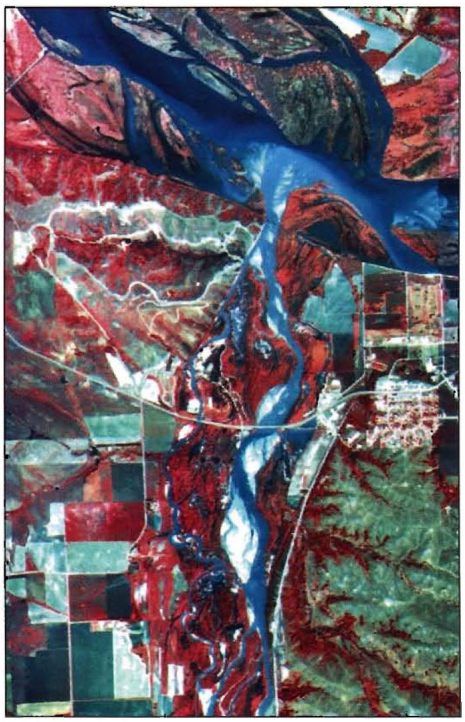
"...the high land jut the river forming a Bluff of Bluish Clay."

September 4, 1804

Sand bars at the mouth of the Niobrara River (site 20)

a) A view of sand bars near the mouth of the Niobrara River from the former railroad bridge in Niobrara State Park, Knox County, Nebraska.

Clark compared the Niobrara River to the Platte. Both have many bars, but, as he noted, the Niobrara's sands are coarser. This difference is due to the Niobrara's eroding the coarser gravels and sands of the ancestral Platte River that once flowed across this area and then moved to the south before the Niobrara Valley began to form. From time to time, the Niobrara floods and changes the position of its main channel. Today, the river is building a delta into the headwaters of Lewis and Clark Lake, the reservoir behind Gavins Point Dam (upper right-center of figure b at site 20). The large load of sand carried by the Niobrara is also contributing to the growth of the many large sand bars in the reservoir downstream of its confluence with the Missouri.[12] [Atkinson]



b) A satellite image of the mouth of the Niobrara River, 1988 (photo courtesy of CALMIT, University of Nebraska-Lincoln).

Site 20.

"...passed the mouth of the River Que Courre *(rapid R)* [now Niobrara] *on the L.S. ...this River is 152 yards wide at the mouth & 4 feet Deep Throwing out Sands like the Platt (only Corser) forming bars in its mouth....this river widens above its mouth and is devided by Sand and Islands, the Current verry rapid, not navagable for even Canoos without Great dificulty owing to its Sands; the color like that of the Plat is light"*

September 4, 1804

Erosional remnant (site 21)

Chalk beds in the Pierre Shale at Old Baldy *in eastern Boyd County, Nebraska, to the west of a county road from Nebraska Highway 12 to the Missouri River valley, just before the Missouri turns north and fully enters South Dakota.*

The dome-shaped hill that has been known as *Old Baldy* or *The Tower* draws attention for its unusual light color. Chalks in the Upper Cretaceous Pierre Shale weather light yellow to white when exposed to the air, as do those in the Niobrara and Greenhorn formations. Vegetation does not grow readily on this Pierre chalk member. This hill is an erosional remnant that has not yet been leveled by streams.[9] [Atkinson]

Site 21.

"we landed...near the foot of a round mounting which I saw yesterday resembling a dome. Capt Lewis & my Self walked up, to the top which forms a Cone and is about 70 feet higher than the high lands around it, the Bass is about 300 foot in descending this Cupola, discovered a Village of Small animals that burrow in the grown [prairie dogs]...."

September 7, 1804

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APPENDIX A

FOR FURTHER READING

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Vol. 8: *June 10-September 26, 1806.*

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APPENDIX B

U.S. GEOLOGICAL SURVEY TOPOGRAPHIC MAPS

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41095-E1-TM-100

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Sioux City North (IA-SD-NE)
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Yankton (SD-NE)
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GLOSSARY

alluvial fan - a low, outspread, relatively flat to gently sloping mass of loose rock material, shaped like an open fan or segment of a flattish cone, deposited by a stream at a place where it issues from a narrow valley onto a plain.

ammonite - an extinct shell-bearing cephalod mollusk related to the octopus, squid and chambered nautilus.

bed load - the larger or heavier particles (boulders, pebbles, gravel) moved by a river or stream along its bottom.

bed - a layer of sediments or sedimentary rock bounded above and below by more or less well-defined surfaces.

bentonitic clay - a soft, plastic, light-colored substance composed of clay-size particles produced from the chemical alteration of volcanic material, usually ash.

bluff - a high bank with a broad, steep cliff face overlooking a plain or a body of water.

braided - branching and rejoining repeatedly to form an intricate pattern or network of small interlacing stream channels.

chalk - a fine-textured, usually white-to-light-gray or buff limestone of marine origin, consisting almost entirely of calcite formed by the shallow-water accumulation of shells from microscopic organisms.

chert - a hard, dense sedimentary rock composed primarily of interlocking crystals of the mineral quartz, often containing traces of other minerals that give it color. It occurs primarily as concretions in limestones.

clay - a plastic material consisting mainly of particles less than 0.074 mm (0.0029 inch) in diameter.

coccolith - microscopic external skeletal debris secreted by cells of marine floating algae of the class Chrysophyceae.

concretion - a hard, compact mass or aggregate of mineral matter, nearly spherical; formed by precipitation from water around a center such as a leaf, shell, etc.

conglomerate - a coarse-grained sedimentary rock composed of rounded fragments cemented together.

cross-bed - a bed inclined at an angle to the primary angle, often horizontal, of other beds above or below it. Rivers and streams often deposit cross-bedded sediments in their channels.

cutoff - the new and relatively short channel formed when a stream cuts through a narrow strip of land called a *neck*, and thereby shortens the length of its channel.

delta - the low, nearly flat, alluvial tract of land at or near the mouth of a river, commonly in a triangular or fan shape, resulting from the accumulation of sediment supplied by the river.

deposit - (noun) earth material of any type that has accumulated by some natural process including water, ice, wind, volcanoes, or other agents; (verb) to lay down by natural processes.

erratic - a rock fragment carried by glacial ice, deposited at some distance from the rock outcrop from which it was derived, and generally but not necessarily resting on bedrock or sediment of different composition.

floodplain - the strip of relatively smooth land adjacent to a river channel, formed by the present river and covered with water when the river overflows its banks.

fluvial - of or pertaining to a river or stream.

foraminifera - protozoa (single-celled animals) that secrete a shell of one or more chambers

formation - a body of rock that is usually tabular and has certain unifying characteristics that can be used to separate it from other formations. It is mappable at the Earth's surface or traceable in the subsurface.

glacial till - see *till*

gravel - an unconsolidated, natural accumulation of typically rounded rock fragments greater than 2mm (0.08 inch) in diameter.

iron sulfide - a mineral compound in which sulfur is linked with iron.

joint - a fracture or crack in a rock.

lignite - a brownish-black coal intermediate between peat and subbituminous in the transformation of plant debris into coal.

limestone - a sedimentary rock consisting primarily of calcium carbonate generally formed from the skeletal debris of sea-dwelling organisms.

loess - a widespread, homogeneous, usually not layered, silt and very fine sand deposit that blankets the land. Loess readily breaks into its constituent particles and often contains calcium carbonate. It is generally light yellow or yellowish brown. Loess is generally thought to be wind-blown dust. Pronounced *luhss*.

meander - one of a series of freely developing sinuous curves in a stream.

mosasaur - an ocean-dwelling lizard, up to 30 feet long, that lived during the Cretaceous Period.

oxbow - the abandoned bow- or horseshoe-shaped channel of a former meander left after the meander has been cut off.

pebble - rock or mineral fragments having a diameter between 4 and 64 mm (1/6 and 2.5 inches).

plesiosaur - a marine reptile of the Mesozoic Era having a very long neck, small head, and limbs shaped like paddles for swimming.

sand - rock or mineral fragments having a diameter between 1/16th and 2 mm (0.0025 and 0.08 inch).

sand bar - a low ridge of sand that borders the shore and is built to the water surface by currents in a river or wave action in a lake or sea.

sandstone - a medium-grained sedimentary rock composed of sand-size fragments held together by a cementing material.

sedimentary - pertaining to solid material that originates from weathering of rocks and minerals, accumulation of organic debris, precipitation of solids from solutions, or combinations of these.

selenite - the clear, colorless variety of gypsum (calcium sulfate) occurring in transparent crystals.

shale - a laminated (layered) rock composed of more than 2/3 clay-sized particles.

silt - sedimentary particles having a diameter in the range of 1/256th to 1/16th mm (0.00016 to 0.0025 inch).

siltstone - a sedimentary rock composed of silt-sized particles. It generally contains hard, thin layers.

skeletal plate - any hard part of the skeleton of an organism in a flat or tabular shape.

terrace - a former floodplain. Any long, narrow, gently inclined surface bounded along one edge by a steeper descending slope and along the other by a steeper ascending slope.

till - glacial deposits, predominantly unsorted and unlayered.

topography - the general configuration of a land surface or any part of the Earth's surface; the features revealed by the contour lines of a map.

weather - to undergo change such as discoloration, softening, crumbling, or pitting of rock or mineral surfaces, brought about by exposure to the atmosphere and its agents.